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Short communication

Using the Environmental Kuznets Curve to evaluate energy policy: Some practical considerations

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HIGHLIGHTS

- Many practical issues need to be considered when estimating the EKC.
- Concerns expressed by some about use of polynomial functions are misplaced.
- Confidence bands on EKC turning points should be provided.
- Differences in short and long-run elasticities are not indicative of EKC shape.
- Reduced-form estimates should be interpreted cautiously by policymakers.

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ABSTRACT

The Environmental Kuznets Curve (EKC) is a widely applied empirical model that is used to assess the effect of country's increased income on its emissions (such as CO_2). Typical estimation is of a reduced form model relating per capita emissions to per capita GDP (and sometimes to energy consumption) with an eye toward determining whether a country's per capita emissions increase or decrease with per capita GDP. In this article, we consider a number of practical issues in estimating and using the EKC for energy policy analysis. Proper estimation procedures should be used if the empirical work is to provide valid estimates of the EKC's shape. In addition, policymakers should proceed with caution when crafting policy on the basis of reduced form estimates of the EKC because the reduced form model provides limited insight into the policy implications of the relationship between income, energy consumption and emissions.

1. Introduction

The Environmental Kuznets Curve (EKC) was initially developed by Grossman and Krueger (1991). At its most basic level, the EKC posits an inverted U-shape in the relationship between per capita emissions (such as CO_2) and per capita GDP (or per capita income) as shown in Fig. 1. At relatively low levels of per capita GDP, per capita emissions increase with per capita GDP but eventually at a declining rate. After per capita emissions reach a maximum, they decline as per capita GDP continues to grow.

No formal theory was used to develop the EKC, but Grossman and Krueger explain that the increasing industrialization associated with initial economic growth would yield increasing per capita emissions as per capita income increased. Eventually, the growth in per capita income and the shift away from heavy industry would lead to a negative relationship between per capita emissions and per capita income.[1] Later authors, such as Suri and

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[1] Carson (2010) reviews theoretical models that were later developed in support of the EKC.

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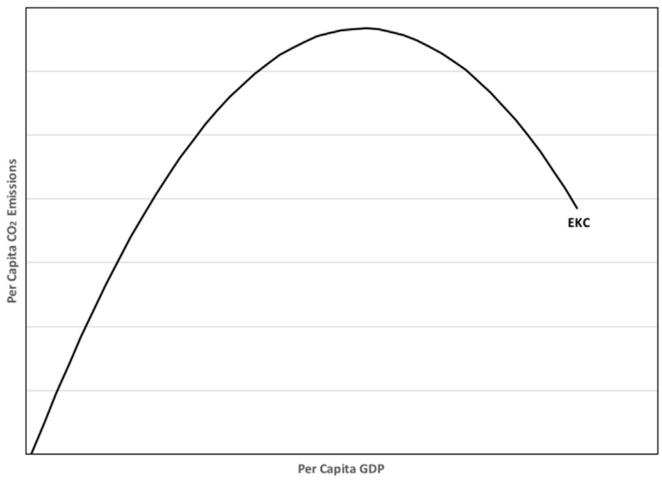

Fig. 1. A basic Environmental Kuznets Curve.

Chapman (1998), Roca and Alcántara (2001), and Soytas et al. (2007) added energy consumption to the model and used the EKC to make recommendations for energy policy. Following Narayan and Narayan (2010), a number of authors have shifted toward dynamic estimation of the EKC.

In the present work, we examine the policy implications of various approaches to estimating the EKC. We address several concerns including the policy interpretation of estimating a reduced form model, the use of highly correlated explanatory variables in the estimation of the EKC, and the lack of confidence bands in estimating the turning point of the EKC. We also examine the use and interpretation of dynamic models for estimation of the EKC.

The remainder of this paper is organized as follows: Section 2 discusses basic estimation and interpretation of the EKC. Section 3 examines concerns about basic estimation of the EKC. Section 4 examines dynamic estimation and interpretation of the EKC. Section 5 provides the conclusions and policy implications as a guide for policymakers and their advisors.

2. Basic estimation and interpretation

The EKC was originally estimated with U.S. time-series data, but it was not conceived with a time dimension. That is, the relationship between emissions and income evolves only as a function of income. As such, the relationship between emissions, income, and energy consumption for a particular country or region can be written in general terms as

$$E_t = E(Y_t, \boldsymbol{X}_t) \quad (1)$$

where E_t is per capita CO_2 emissions at time t, Y_t is per capita GDP at time t, and $\boldsymbol{X}_t$ is a vector of additional observable factors, such as energy consumption, that can lead to environmental degradation.[2] The functional form should be specified to allow for per capita emissions to rise with per GDP ($\partial E_t/\partial Y_t > 0$), reach a maximum ($\partial E_t/\partial Y_t = 0$), and then fall as per capita GDP rises ($\partial E_t/\partial Y_t < 0$). For the remainder of this communication, we follow the recent literature and assume per capita measures for both emissions and GDP (Stern, 2014).

For purposes of estimation, Grossman and Krueger (1991) use a simple cubic function to allow for a changing relationship between per capita emissions and per capita income as income rises. Other early models use simple quadratic functions. Surveys by Dinda (2003), Stern (2004), and Carson (2010) indicate that many later empirical studies using time-series or panel data adopt, as the standard model, a polynomial approximation of a logarithmic curve:

$$\ln E_{ct} = \alpha_c + \gamma_t + \beta_1 \ln Y_{ct} + \beta_2(\ln Y_{ct})^2 + \boldsymbol{\delta X}_{ct} + e_{ct}; \quad c = 1, 2, \ldots, C; \; t = 1, 2, \ldots, T \quad (2)$$

where the first two terms, α_c and γ_t, are constants that vary across countries and time, respectively, β_1 and β_2 are the parameters showing the relationship between per capita GDP and per capita emissions, and δ is a vector of parameters showing the influence of the additional observable factors.[3] The turning point for per capita GDP, where per capita emissions are at a maximum, is $\tau = e^{-\frac{\beta_1}{2\beta_2}}$.

3. Concerns with basic estimation of the EKC

A number of concerns have been raised with basic estimation of the EKC. Among these concerns are that the EKC relationship is specified as a reduced form model; quadratic estimation of the polynomial approximation involves the use of variables that are likely to be highly correlated; many authors fail to assess and provide confidence bands on the EKC's turning point; and the variables may not have been tested for stationarity and cointegration. We consider each of these issues in turn.

3.1. Policy interpretation of a reduced form model

As typically estimated, the EKC is a reduced form model. That is, the *causal* channels through which output affects emissions are not explicitly represented in the model. For instance, the effect of growing per capita income on an individual's willingness to accept pollution is not explicitly represented and estimated when the model is a reduced form.

Although reduced form models can be attractive in examining basic relationships between variables, they can be consistent with a number of different underlying theories. Because differing underlying theories about the EKC could lead to substantially different policy recommendations, the reduced form model can be used to provide empirical support for a number of conflicting policies without distinguishing among them. In short, reduced form estimation provides information about the EKC's shape, but it does not tell us why the EKC has such a shape, and it provides only ad hoc guidance to policy.

In addition, in what has become known as the "Lucas Critique," Lucas (1976) pointed out that it can be naïve to predict the outcome of a change in economic policy on the basis of econometric estimation alone.[4] Because the decision rules of economic agents can vary with changes in policy, a change in policy can yield results that are substantially different than an estimated model shows. The problem is more likely to occur with reduced form models in which the policy levers or agents' behaviors are not well specified (as is typical for the EKC) or if the policy interventions are

[2] For example, one can possibly think of the $\boldsymbol{X}_t$ vector consisting of per capita consumption of various energy sources $S_{1t}, S_{2t}, \ldots S_{jt}$, where S_{jt} is energy source j at time t.

[3] In the original Grossman and Krueger (1991) paper, the authors use a levels specification relating environmental indicators per capita and income per capita. We follow Stern (2004), who explains that allowing environmental indicators to become zero or negative is inappropriate since economic activity leads to resource utilization, and via the laws of thermodynamics, resource utilization assuredly leads to the production of waste. Thus, a non-zero restriction is warranted and is applied via the logarithmic specification.

[4] The Lucas Critique is most commonly applied to macroeconomic policy, but the concept also applies to microeconomic policy.