Interpreting Estimated Environmental Kuznets Curves for Greenhouse Gases

by

Charles D. Kolstad¹
Bren School of Environmental Science & Management and Department of Economics,
University of California, Santa Barbara

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Abstract

This paper examines the question of how to interpret a relationship between income and carbon emissions in a country (the environmental Kuznets curve – EKC -- for carbon). A very simple and graphical structural model of an EKC is developed and the problems of applying the concept to carbon are discussed. A major issue is the weak link between demand to avoid damage from climate change and regulations limiting greenhouse gas emissions at the country level. The paper goes on to interpret three recent papers in this Journal in the context of this structural model.

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I. INTRODUCTION

The March 2005 issue of this journal was devoted to the *Socioeconomic Drivers of Greenhouse Gas Emissions*. As the issue was framed (Leifman and Heil, 2005), it was primarily concerned with Environmental Kuznets Curves (EKC) for greenhouse gas emissions. The EKC literature suggests that there is a relationship between the per capita income in a country and the per capita or gross emissions in the country, often rising as income initially increases, then peaking and falling as a country becomes richer (see Grossman and Krueger, 1995; Selden and Song, 1994).

A fundamental question that has pervaded the literature on EKC’s regards the interpretation of estimated EKC’s. Are they simply correlations with no predictive power or do they represent some fundamental relationship? These concerns are even stronger in the case of carbon emissions, since regulation of these emissions has been rare worldwide. Put somewhat differently, “What in fact do we learn from a carbon EKC? Are these just idiosyncratic correlations with no predictive power?”

In this paper we present a general and highly simplified structural explanation for the shape of an EKC and we do this descriptively and graphically. We then ask what one would expect an EKC to look like for a largely unregulated pollutant – greenhouse gases. Additionally, we provide specific comments on several papers published in the March 2005 issue of this Journal: Fonkych and Lempert (2005), Lopez and Galiano (2005), and Aldy (2005). We close with suggestions for future research.

II. A STRUCTURAL ORIGIN OF THE EKC

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2 This quote is a paraphrase of a question asked at the WRI September 2005 Symposium by Prof. Grainger Morgan of CMU.
To some, the EKC is simply a reduced form concept – for whatever reason there is a correlation (or not) between per capita income in a society and levels of pollution. To a certain extent, early work on the EKC adopted this approach. But one can also view the EKC through a structural lens (e.g., Kolstad, 2000; McConnell, 1997; Lieb, 2002; Andreoni and Levinson, 2001).

For a structural explanation of the EKC, consider the problem in two steps. First, given the income and other characteristics of a country, what determines the level of environmental quality? Then perform a comparative statics exercise, raising income and inferring how the equilibrium level of environmental quality changes. The shortcomings in this sort of simple analysis of the forces shaping an EKC should be recognized – clearly there are more forces at work in determining levels of pollution in a country than those we discuss here. The point of this simple analysis is to gain insights into the general nature of the EKC.

More precisely, start with the supply and demand for a pollutant, the same paradigm we would use to understand the provision of an ordinary market commodity, holding income and other exogenous factors constant. Although supply and demand for pollution seems like an odd concept, they are most easily interpreted as supply and demand for pollution reductions, with a sign reversal. Willingness to pay for an extra unit of pollution is the negative of willingness-to-pay to have one less unit of pollution – pollution reduction. Similarly, the supply of pollution can be most easily viewed through the lens of the marginal cost of emission reductions: the marginal cost of providing one more unit of pollution is the negative of the marginal cost of reducing one more unit of pollution.
With this explanation, the supply curve for a pollutant is straightforward: as an imaginary emissions tax is raised from zero to some positive number, gross emissions of the pollutant in question will decline. This results in a supply curve, although it will be downward sloping in the marginal cost of emissions control. At an individual level, demand for a pollutant is simply a marginal willingness-to-pay vs emissions schedule. However, an aggregate demand schedule not only involves aggregating individual demands but also including the connection between individual demand and environmental regulation, via the political system. In some political systems, this connection will be strong; in others, not so strong. The net effect is a curve relating emissions to the marginal willingness-to-pay for emissions reductions, as in Figure 1. The intersection of supply and demand yields the level of emissions (Fig. 1).

The intersection of supply and demand however is only one point. To generate an EKC for a single country, one must do the thought experiment of raising or lowering per capita GDP and imagine/estimate what happens to supply and demand and thus the equilibrium level of pollution. This is illustrated in Figure 2 which shows how both supply (AB) and demand (CD) for pollution might shift from an increase in per capita income. Supply shifts up to A’B’ because it is more costly to provide the same amount of pollution when incomes and industrial activity are higher. Alternatively, the structure of the economy may change as people become richer, resulting in different costs of abatement. Similarly, demand shifts up to C’D’ because higher incomes generate higher willingnesses-to-pay for environmental quality. As can be inferred from the figure, the equilibrium level of pollution can either decline or increase, depending on the magnitude of the individual shifts in supply and demand. A large shift in supply (ie, significantly
higher marginal costs) will result in higher pollution levels. A stronger increase in
demand will result in decreased pollution levels. Thus when marginal costs increase
more rapidly than consumer demand, pollution levels increase. When demand increases
more than supply, then pollution decreases.

Using this model, we can conduct a thought experiment regarding how pollution
levels should change as a poor country gets richer and richer, ending up as a rich country.
Initially, demand for environmental quality is low and probably doesn’t change very
much as incomes increase modestly. Furthermore, the political system is probably not
likely to immediately reflect popular sentiment in government regulatory policy. Thus
the net effective aggregate marginal willingness to pay for pollution reductions is low and
this remains unchanged as for a reasonable range of low incomes. When a country is
much richer, political institutions are likely more democratic and thus regulations better
reflect the sentiment of the population (Deacon, 2005). Furthermore, the marginal
willingness to pay for emissions reductions is probably higher within the population.

On the supply side, as a poor country becomes richer, industry is expanding and is
probably heavy – of the pollution-intensive sort. Thus the marginal cost of providing a
given level of pollution (cost of controlling emissions – not damages) is significant and
rises quickly as incomes increase. As the country becomes rich, the structure of the
economy changes, perhaps moving from heavy industry into light industry and services.
Thus the marginal cost of providing a given level of pollution may even decrease. Thus
there is a natural tendency for the supply of pollution to go down as incomes increase
(though this will not be picked up in a cross-sectional analysis).
The net effect is that for low income levels, equilibrium pollution levels rise with income, mostly due to the supply side. For higher incomes, both the demand side is stronger and the supply side weaker. The net effect is that equilibrium pollution levels may decline with increases in income for richer countries. This pattern is in fact what is often observed with empirically estimated EKC’s.

There is one important complicating factor that we have not treated and that relates to the dynamic nature of the EKC. Our thought experiment is basically static. Yet incomes rise over time and certain dimensions of a problem cannot be held constant over time. In particular, technology changes over time. Typically the cost of emissions reductions will decline with time and the rate of decline will be higher if there are significant efforts in the world to reduce emissions. Having said this, most EKC’s are estimated on cross-sectional data where implicitly technology is fixed.

The important point in the development above is that policy is endogenous. Demand can shift because people want less pollution. But demand also may shift or not, depending on how well the political process connects consumer preferences to environmental regulations. Without that connection, demand will stay flat and not move and thus emissions will only increase. Or more specifically, the observed EKC will actually only trace out the intersection of the supply curve with the horizontal axis, reflecting the maximum amount of pollution with no demand side involved – interesting but not something to use for policy prescriptions.

III. THE EKC FOR CARBON
Carbon dioxide (the primary greenhouse gas) follows this same general framework, having a demand side and a supply side. There is a cost of reducing carbon emissions and that cost changes as the structure of the economy changes. For economies that rely on heavy industry, the marginal cost of reductions may be significant. For economies that have a significant service sector, the costs of reduction may be more modest. In low income countries, individuals may be directly responsible for very little in the way of emissions but in richer countries, individuals are emission producers, responsible for significant emissions, primarily through automobile use, electricity consumption and oil and gas for heating.

There is also a demand for reductions in greenhouse gases, manifest through the demand for reduction in the deleterious effects of climate change. Poorer countries have a lower willingness-to-pay to avoid these effects, in large part because their incomes are low and must be dedicated to food and other necessities of life. The effects of climate change may be significant but for someone earning $100 per year, the monetary willingness-to-pay to avoid climate change is bounded by $100 per year and is likely much lower. In higher income countries, the willingness-to-pay is higher but ironically, much of life is more insulated from the climate. In fact, people in temperate climates have been seeking out warming climates for some time. Nevertheless, there is a willingness-to-pay to avoid climate change.

But the big difference is in the connection between individual willingnesses-to-pay for reduction and regulations to implement that demand. This link is much weaker than for more localized pollutants and results in a net demand for reductions that is very diluted. As a global pollutant, there is a very imperfect connection between regulatory
actions in a country and benefits to the citizens of the country. Thus even in a fully functioning democracy, there is a weak incentive to translate demand for lower global greenhouse emissions into regulations on domestic industry. Significant control of domestic industry will typically have a very modest effect on global emissions. This can be seen in the difficulty in implementing international agreements on greenhouse gas emissions. The Kyoto Protocol is the primary international agreement and it is far from an effective mechanism for controlling global emissions.

A second aspect of carbon emissions that weakens the link between willingness-to-pay for reductions and regulations to implement that desire is the long time delay involved in the connection between emissions and damages. It is the citizenry of the world in 2100 that may wish very strongly that we do something now about greenhouse gas emissions. But even in the most democratic countries of the world, future voters carry very little weight in present decisions – unfortunate but true.

A third aspect of carbon emissions is that they are often highly correlated with emissions of other pollutants associated with energy combustion. Thus the demand for cleaner fuel to reduce particulate and sulfur emissions may result in some shift from coal to oil or natural gas, and in the process significantly reducing emissions of carbon (coal has more carbon per unit of energy than oil and natural gas is lower than either).

The bottom line is that demand for reductions that will be revealed by data is very low – similar to the horizontal axis in Figure 1. The result is that as per capita income in a country changes, the equilibrium level of emissions will trace out roughly the intersection of the supply curve with the horizontal axis, as in Figure 3. In any event, observed carbon emissions as a function of per capita income reveal little information
about the underlying forces driving them, and what information that is revealed must be interpreted with care.

IV THREE STUDIES OF CARBON EKC’S

Given the discussion above, we turn to the question of interpreting empirical results on EKC’s for carbon.

Fonkych and Lempert (2005) examine a set of scenarios of future emissions of greenhouse gases generated by the UN’s Intergovernmental Panel on Climate Change (IPCC). This is an interesting approach to the EKC since it looks at “future” emissions, at least as generated and predicted by the IPCC. The authors are careful to couch their analysis in terms of what conclusions can be drawn. Unfortunately, it is not clear what value there is to examining IPCC forecasts. If the IPCC has assumed some sort of EKC in generating the forecasts, then hopefully that can be recovered. If not, what can be concluded? The authors of this paper are careful to point out the limits of inference from their study, indicating that their analysis should not be used to predict but to examine the characteristics of the IPCC forecasts.

Aldy (2005) conducts an interesting analysis of different states of the US – per capita incomes differ across states, as do greenhouse gas emissions. Among other things, he finds a real turning point around 1970-75. Most likely, this is due to the rise in the price of energy starting in 1972-3 and the introduction of the Clean Air Act Amendments of 1970, which were the first major national emissions control regulations for stationary sources in the US. Since there have been virtually no regulation of carbon emissions historically, it is unclear how we should interpret this. Perhaps the clearest use of the
paper is as the author states – to infer the compositional changes in the US economy over time.

Lopez and Galinato (2005) examine deforestation with the aim of developing an EKC for forest area in a country. This is an important question and analysis. Forest area is of course related to climate change since forests are such an important sink. However, deforestation is not the same as climate change (though the authors of the paper make no claim to the contrary). One should not interpret results on an EKC on forests as saying anything about an EKC for greenhouse gases. In fact, in poorer countries deforestation is dominated by issues of property rights and corruption (see Barbier and Burgess, 2001). Thus, one would expect any EKC to pick up how this institutional failure is affected by income. How this translates to climate change is more ambiguous.

V. IMPLICATIONS FOR FUTURE RESEARCH

One of the major issues that calls into question empirical attempts to derive an EKC for carbon is the disconnect between consumer demand and regulation of emissions. However, the Kyoto Protocol provides an opportunity to address this deficiency. In particular, the Aldy (2005) paper suggests that a similar exercise could be carried out for the states of the EU as the EU moves into the Kyoto commitment period. The EU has implemented a carbon trading system that effectively generates a demand for carbon reductions. An examination of how the intersection between supply and demand varies over countries of the EU may yield important insights on how different income countries respond to calls to reduce carbon emissions. One will still face the problem of
interpreting any statistical relationship that may emerge. In fact, one will still be left with the question of how to interpret any correlation between per capita income and emissions.
REFERENCES


Figure 1: Equilibrium emissions resulting from a country’s net demand (CD) and supply (AB) for emissions.
Figure 2: Effect of a Shift in Demand/Supply for Pollutant Emissions on Equilibrium Level of Pollution
Figure 3: Effect of a Shift in Supply for Carbon Emissions on Equilibrium Level of Emissions