The Oil Drum: Net Energy

Discussions about Energy and Our Future

Using Thermodynamics to (Re)Examine Environmental Kuznets Curves

Posted by David Murphy on May 11, 2009 - 10:01am in The Oil Drum: Net Energy
Topic: Environment/Sustainability
Tags: ekc, environmental economics, environmental kuznets curve, eroi guy, first law, original, thermodynamics [list all tags]

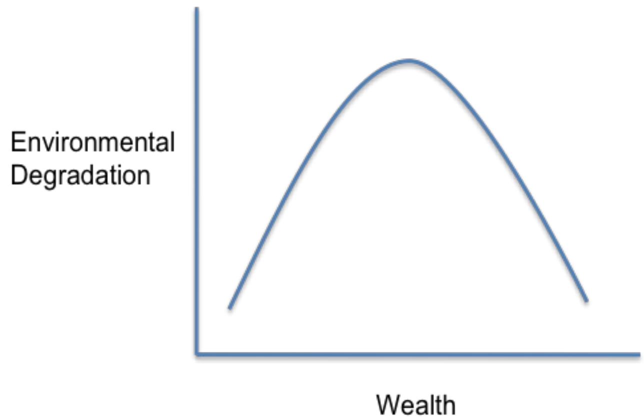

Figure 1. Conceptual diagram of the EKC.

The Environmental Kuznets Curve (henceforth EKC) was developed from a paper written by Simon Kuznets in 1955 titled *Economic Growth and Income Inequality*. His theory explained that the relationship between economic growth and income inequality forms an inverted U-shape graph with income inequality on the y-axis and economic growth (e.g. GDP/capita) on the x-axis. EKCs extend Kuznets' original theory by stating that pollution increases as economies grow from agrarian to industrial, but as the population becomes wealthier a turning point is passed after which the amount of pollution decreases as income grows, forming an inverted U-shape (Figure 1). As such, EKC theory has been cited as a justification to prioritize economic development over environmental stewardship (Beckerman, 1992), and just last week the science reporter for the New York Times, John Tierney, wrote an article claiming exactly the same thing: *"The richer everyone gets, the greener the planet will be in the long run."*

However, after 20 years of research and over 100 peer-reviewed papers, academia has yet to come to a consensus over the exact mechanism driving EKCs. Much of the disagreement over EKCs stem from shaky empirical support. To be sure, numerous studies used empirical tests and found the existence of EKCs, but many of these same studies disagree in two important ways: 1) estimates of the turning point of the inverted U-shape for pollutants vary widely and 2) the EKC relationship describes the trends for some pollutants only, not all. I propose that the lack of consensus surrounding EKCs stem from the fact that EKC theory, as it has been studied, ignores the laws of thermodynamics.

Review of the First Law of Thermodynamics

The first law of thermodynamics states that energy cannot be created nor destroyed. When coal is burned, for example, all of its energy is transformed to some other form, such as electricity, sulfur dioxide or nitrogen oxide to name just three. There are a myriad of other examples. The important point is that energy is conserved in every transformation. A basic understanding of the first law is important because it means that transforming pollution from one form to another is not the same as eliminating pollution. That is, extracting pollutants from flue gases transforms the pollutant, but does not eliminate it. To illustrate this point empirically, I have reexamined two of the most commonly cited examples supporting EKCs: deforestation and sulfur dioxide.

Deforestation

Cropper and Griffiths (1994) tested for an EKC relationship between income and deforestation in 64 developing countries around the globe and found that the incomes of many of the African and Latin American countries were still below the turning point; meaning that those countries were not yet rich enough to stop deforestation. However, in a similar study Panayotou (1995) analyzed deforestation in 41 tropical nations and found that the turning point for deforestation was around $1,300 per capita (2003 dollars), which is much lower than the turning point estimates for many air pollutants. Panayotou explains that deforestation should have a lower turning point than most industrial air pollutants as most tropical deforestation occurs to clear land for farming, which occurs before industrialization in the “normal” evolution of an economy. The list of papers examining EKC and deforestation seems ever expanding, and for a detailed discussion see Yandle et al., (2004).

Global per capita GDP, however, is roughly 4 times the turning point level cited by Panayotou (1995), and has been since 1990, yet the forest area around the globe has declined over that entire time period (Figure 2). According to the findings of Panayotou (1995), forest area around the globe should be increasing, as the global income is greater than the turning point in the EKC. Thus simple attempts to validate the findings of Panayotou fail, moreover, they are contradictory.

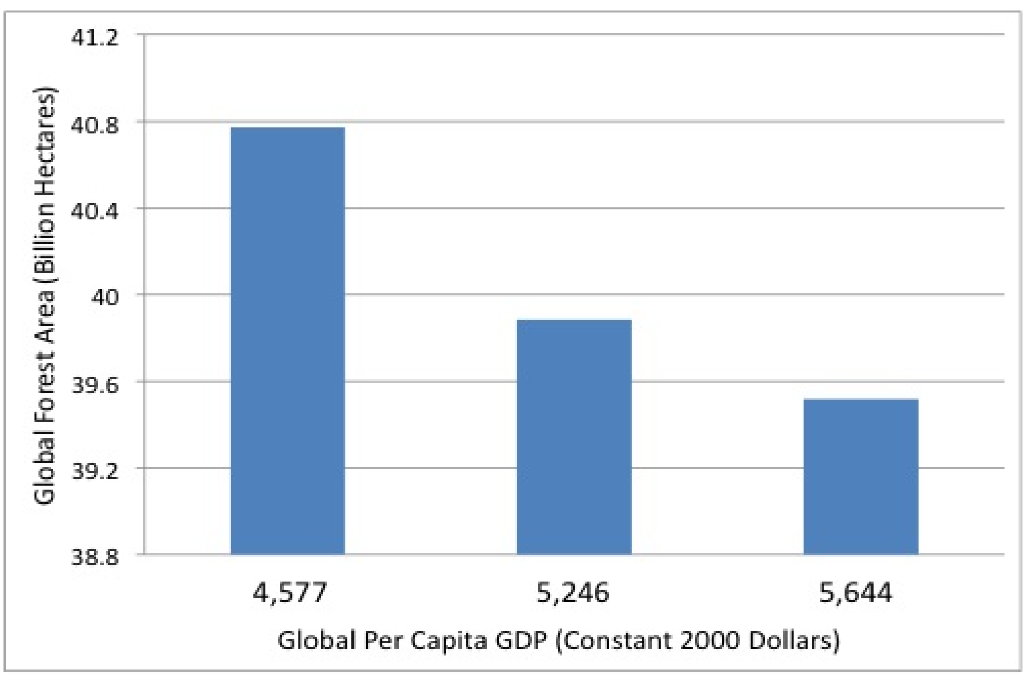

Figure 2. Global forest area as a function of global per capita GDP in the year 2000.

Sulfur-Dioxide

Burning coal releases the embodied chemical energy within the coal and in doing so creates electricity and numerous pollutants. After the Clean Air Act was enacted, coal burning power plants (among others) installed scrubbers so that these pollutants could be removed from the flue gases, and hence decrease air pollution. As a result, many EKC studies found strong correlations between high income and low sulfur dioxide emissions (Grossman and Kruegar, 1991; Selden and Song, 1994; Cole et al., 2001).

Each of these studies excluded, however, the fact that these high-income areas had decreased sulfur emissions at the expense of increased ground pollutants in the form of Coal Combustion Waste (CCW). CCW is the amalgamated end product of many flue gas pollutants, including sulfur dioxide. In this example, the CCWs are shipped back to the coalmine or stacked outside the coal power plant. Data on CCW is hard to find, but the little that I could find indicates that more landfills and surface impoundments, i.e. the facilities that store CCW, are coming on-line as U.S. income grows (Figures 3). In other words, increasing income is correlated negatively with sulfur dioxide emissions, but correlated positively with the production of CCW. So in accordance with the first law of thermodynamics, scrubbing sulfur pollutants out of a flue gas doesn't eliminate the pollutant, rather it simply transforms the pollutant.

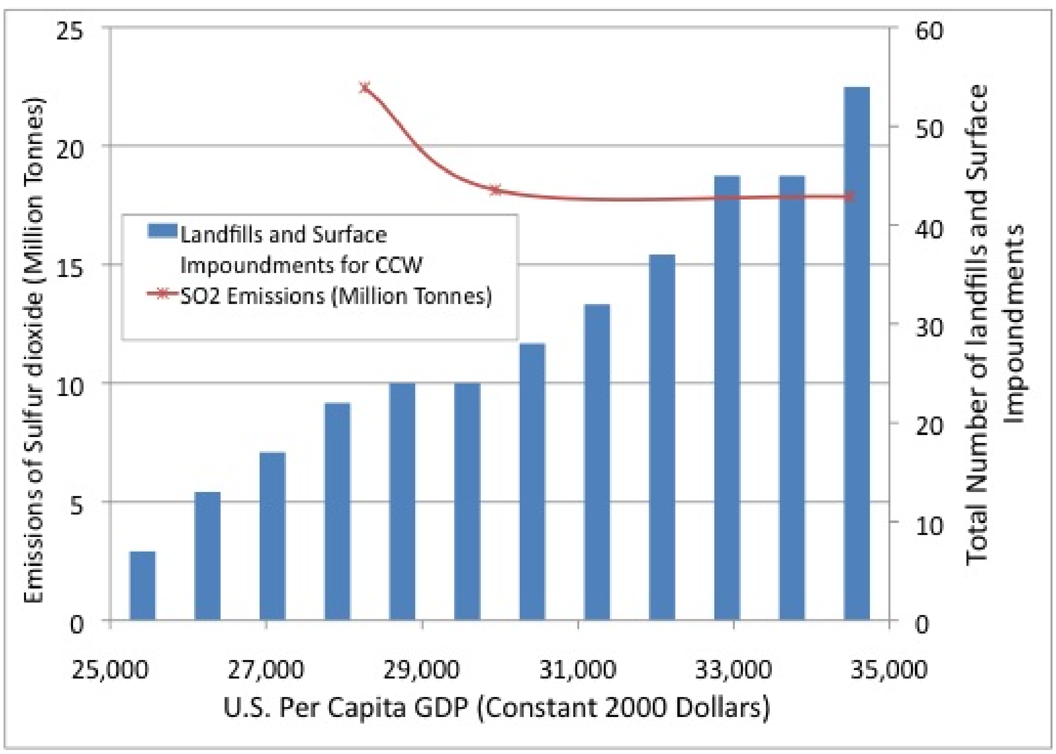

Figure 3. Emissions of sulfur dioxide and total number of landfills and surface impoundments as a function of U.S. per capita GDP (constant 2000 dollars).

Conclusion

Yandle et al. (2004) state "By the mid-1990's, investigations of the EKC relationships had generated enough consistent findings to give assurance for many pollutants, richer is definitely cleaner." Yet EKCs do not have wide empirical support, and since simple attempts to validate the empirical support for EKCs fail, I question the utility of EKCs as a unifying paradigm for environmental and economic policy. As I have shown in the examples of deforestation and sulfur dioxide, simply changing or extrapolating the system boundaries to incorporate thermodynamics calls into question the EKC relationship. To be sure, it is true that sulfur dioxide emissions have decreased within the U.S. as income has increased, which seems to support the EKC theory, but is it then justified to say, in light of figure 3 and the First Law, that we don't have a sulfur pollution problem? Wealth may allow societies to deal with pollution in a more efficient manner or transform pollution into a less harmful form, but the idea that all nations can become wealthy by consuming the world's resources yet be pollution-free is antithetical to the laws of thermodynamics.

The quote by Yandle et al. (2004) is deeply troubling on a conceptual level also. It not only encourages policy makers to place priority on economic development over environmental stewardship, it implies that a growing economy *by default* will resolve environmental issues and hence direct environmental action is unnecessary. This idea may be supported by faithful EKC believers, but as York, Clark and Foster have eloquently and thoroughly discussed, it is farcical to most natural scientists. To ensure that economic and environmental policies work together to promote a healthy economy and planet, policy makers should use scientific concepts that enjoy wide empirical support, such as the Laws of Thermodynamics, as a unifying theme governing pollution patterns and draft policies based on these laws, rather than EKCs.

Beckerman, W. 1992. Economic Growth and the Environment: Whose Growth? Whose Environment? World Development 20: 481 – 496.

Cole, M.A., Rayner, A.J., and J.M. Bates. 2001. The Environmental Kuznets Curve: An empirical Analysis. Environment and Development Economics 2(4): 401 – 416.

Cropper, Maureen, and Charles Griffiths. 1994. The Interaction of Population Growth and Environmental Quality. American Economic Review Papers and Proceedings 84(2): 250-254.

Grossman, Gene M., and Alan B. Krueger. 1991. Environmental Impact of a North American Free Trade Agreement. NBER Working paper 3914.

Kuznets, Simon. 1955. Economic Growth and Income Inequality. American Economic Review 45(1): 1 – 28.

Panayotou, Theodore. 1995. Environmental Degratdation at Different Stages of Economic Development. In Beyond Rio: The Environmental Crisis of Sustainable Livelihoods in the Third World, ed. I. Ahmed and J. A Doeleman. London: Macmillan, 13 – 36.

Seldon, Thomas M., and Daqing Song. 1994. Environmental Quality and Development: Is there a Kuznets Curve for Air Pollution Emissions? Journal of Environmental Economics and

Management 27: 147 – 162.

Yandle, B., Bhattarai, M., and Maya Vijayaraghavan. 2004. Environmental Kuznets Curves: A Review of Findings, Methods, and Policy Implications. PERC 2(1).