A Model of the Environmental Kuznets Curve Based on the Dynamics of Quality and Quantity of Consumption Goods

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Abstract

In this work, I present a model explains the concavity of the Environmental Kuznets Curve, an inverted U relationship between per capita GDP and pollution Any change in consumption goods can be divided into two components: quantity and quality. An increase in the amount of the good is quantity as is an increase in the number of units of the good. An increase in the price of a good, after netting out changes in size, is an increase in quality. These definitions assume that the marginal costs of production remain constant as income increases. Thus a higher price represents a higher marginal willingness to pay and a good that provides higher utility.

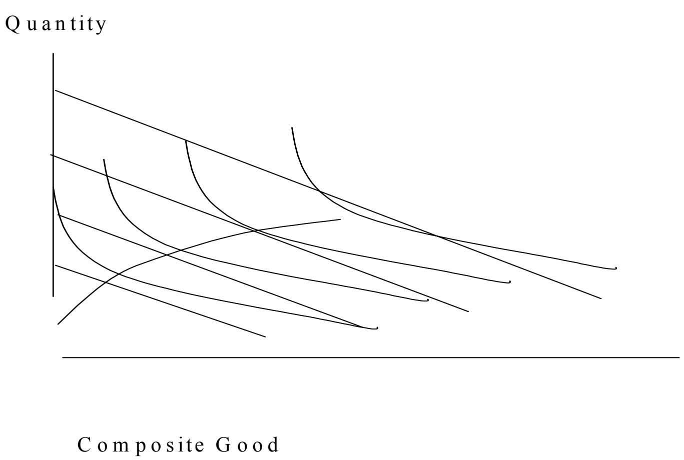
In this model, as income rises, quantity increases as a concave function of income and quality rises linearly.   This is because as consumption of a particular good increases, the desire to have one more of the same good goes to zero, however, the desire for quality will not decrease. Because explanations based on preferences are considered *ad hoc*, two other explanations are also be presented based on shifting budget lines. Because an increase in quantity pollutes substantially more than an increase in quality, pollution will increase concavely with income.

ENVIRONMENTAL KUZNETS CURVE LITERATURE REVIEW

A central question in environmental economics is what the impact of economic growth on the environment is. As per capita income increases, three patterns of pollution growth appear (see figure 1.) Two of these patterns are simple and relatively uncontroversial. Pollution in drinking water and poor sanitation are examples of pollutants or environmental bads that decrease monotonically as per capita income increases. Municipal waste generation and carbon dioxide emissions are examples of pollutants that rise monotonically with per capita GDP.   Holtz-Eakin and Selden (1995) estimate that carbon dioxide concentrations will peak at $35,428.   The reasons for these two patterns are straightforward. Pollutants for which abatement has large benefits and are difficult to externalize predictably fall as income rises. Pollutants that either are byproducts of a consumer society, such as municipal waste, or are easily externalized such as carbon dioxide, rise with income, at least for the incomes as great as the GDP current high-income countries.

The most common and most interesting pattern of pollution emissions is the EKC.   The EKC hypothesis states that for many types of pollution, environmental damage increases up to a certain level of GDP per capita, and then begins to decrease as income increases further. Environmental pollutants for which this relationship holds include particulate matter, sulphur oxides, faecal colliform, ambient air impurities, and the rate of tropical deforestation. Different studies have found a range of estimates for the turning point of the curve. Predictably, the turning point depends on the pollutant. However, in general, the peak of the EKC comes at incomes less than $8000 1985 U.S. dollars.   According to Grossman and Krueger, the null hypothesis that income growth at incomes over $10,000 1985 U.S. dollars will result in further increases in pollution can be rejected at the 5% significance level.   Various other studies have placed turning points at $5000, $6654, and $8500.

The EKC is particularly interesting because its causes are unclear and likely quite varied. Five broad categories of explanations have been developed, each with very different implications for policy and each with varied implications for the prospects of the environment.   The most common explanations relate to changes within the structure of the economy. According to the sectoral change argument, as the economy grows, the proportion of different sectors within the economy changes (see figure 2.). Other explanations refer to decreasing rates of population growth and to technological improvement as motivations for the EKC. A fourth category of explanations attributes the shape of the EKC to changes in social factors such as education, environmental awareness, and government institutions. Finally, a fifth category of explanations sees trade as the main cause of the



II. Shifting Budget Lines

Prices of Complementary Goods

Consumption bundles change when the prices of complementary goods change. Most goods, including transportation but excluding food, are complementary goods with space. Thus if the quantity of a good is directly proportional to the space requirements of that good, the shifting budget line generated by the changing price of space will yield the expected dynamics of quantity. If a budget line is drawn with space on the vertical axis and quantity of good X on the horizontal axis, the utility curves will be L shaped because the goods are perfect compliments. As the price of land increases, the budget line will become flatter. After the shift, the budget line will be tangent to an indifference curve at a lower quantity of good X.

The extension of this theory to account for quality is simple. Space is not a complimentary good for quality. Since higher dollar value due to a good being bigger is accounted for in the measurement of quantity, there is no reason why, in general, a more desirable good would need more space than a less desirable good. Thus the budget line between space and quality does not shift and thus amount of quality consumed does not change.

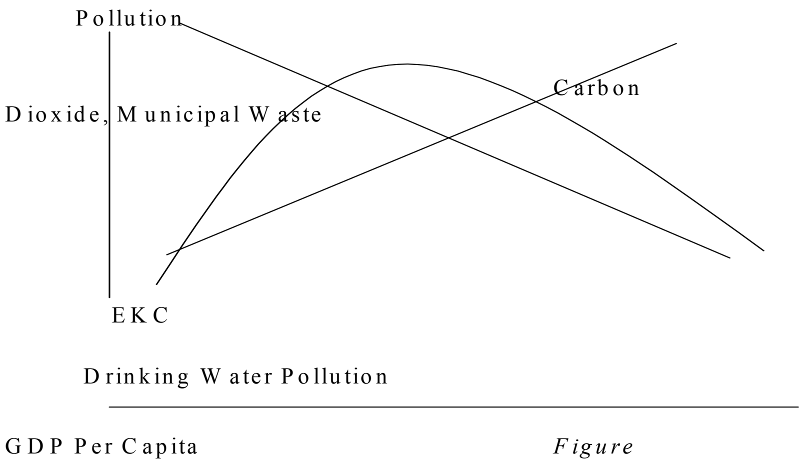
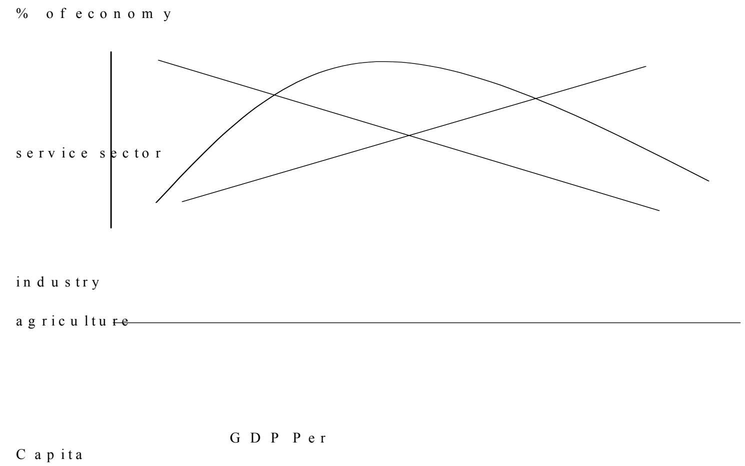


Figure I



Prices of Inputs

Prices to inputs for quantity may rise because increasing quantity requires more inputs. If prices of inputs rise, the price of the good can be expected to rise as well. This will cause the industry supply curve to shift inward. As a result, the equilibrium quantity will fall as prices of inputs rise. Because prices of inputs rise as income rises, an increase in income leads to a decrease in new quantity purchased. The amount of inputs will not rise systematically with quality; they will rise for some goods and fall for others. Thus, prices of inputs will not rise and increases in quality will remain constant. If, however, inputs to quality overlap with inputs to quantity, then the supply curve for quality will shift in and amount of new quality purchased will fall.

THE MODEL

Definitions

I view goods as collections of characteristics. Consumers purchase goods to obtain these characteristics, but the goods have no value separate from their characteristics. Each good can be separated into quantity and quality.

Dynamics

As income increases, measures of quantity will gradually level off; the derivative of quantity will go to zero. This is because as the amount of a good one begins with increases, the desire to have one more of the same good goes to zero. The same intuition holds for food. Once I can obtain my daily caloric requirement or however much food it is that I desire to consume, my desire for more food, measured in quantity, goes to zero.

Quality, on the other hand, will not decrease for any relevant level of GDP per capita that is likely to be experienced in the foreseeable future. Intuitively, for a given number of cars that I own, my desire to increase the quality of my cars remains positive. For example, if I have a Ford Taurus and Subaru Legacy, my desire to replace one of my cars with a Porsche is positive. Equivalently, for a given quantity of food that I consume, my desire to obtain better (tastier or healthier or more environmentally friendly) food is positive.

I hypothesize that quantity is associated with a positive quantity of pollution whereas quality close to zero, however, food is an exception to this relationship. Quantity would create a positive amount of pollution because producing more of a product requires more inputs, more production waste, more pollution due to use for many goods, and more waste associated with disposal of the product. Quality, on the other hand, should not systematically produce more pollution. In some cases, quality will produce less pollution because a better product may be smaller (such as in the case of computers) or more efficient (as in the case of cars.) Quality may also produce more pollution. The one important example of this is food.

EMPIRICAL SUPPORT

Although empirical results cannot validate the theoretical justifications behind the model, they can support the results of the model. I analyzed data on food quantity, food quality, automobile quantity, and automobile quality. As expected, I find that quantity of food and quantity of automobiles have a logarithmic form. I must reject the hypothesis that quality of food and quality of transportation have linear forms. However, both of these measures of quality are much less concave than the measure of quantity. While my

hypothesis that the form is linear must be rejected, the form obtained is actually stronger than my initial hypothesis since quality increases more than linearly with income.

Estimated Relationships

Food

$\ln(\text{calories per capita}) = 6.702+0.1669[\ln(\text{GNP})]$.

$\text{dpc} = -.0069 + .0000565(\text{dipc}) + 7.45*10^{-9}(\text{dipc})^2 + 4.74*10^{-13}\,[\ln(\text{dipc})]^3$

Transportation

$\ln(\text{number of vehicles per capita}) = \alpha + \beta_1[\ln(\text{per capita GNP})] + \beta_2[\ln(\text{per capita GNP})]^2 + \mu$

$(\text{dpv}) = -0.00137 + 4.78*10^{-6}(\text{di}) - 8.11*10^{-10}(\text{di})^2 + 5.53*10^{-14}(\text{di})^3$.

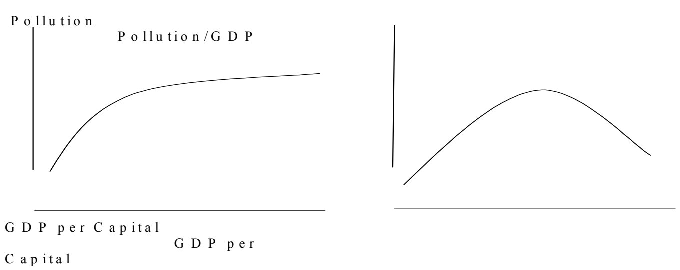
Environmental Impacts of Transportation Quantity

$(\text{tm}) = -.601 + .0001124(\text{number})$.

$(\text{CAFE}) = 22.0739 + .0003246(\text{automobiles})$.

Environmental Impacts of Transportation Quality and Food Quality and Quantity

No equations



Motivation

I Preferences Shape of Indifference Curves

Both intuition and the data support my assertion that the income consumption curve is not linear with respect to quantity. Instead, I propose that the indifference curves are shaped such that the expansion path of the quantity component of a good is convex