Efficiency and sustainability

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0. This treatment is unique only in linking an explicit definition of sustainability to the concept of price elasticity of demand. For further reading, consult the sections on "price elasticity of demand," "induced demand," "rebound effect," and "Khazzoom-Brookes postulate" in an economics, ecological economics, or transportation planning textbook.

1. A sustainable system is one which persists.[1]

1.1. The sustainability of a particular system is either a prediction or a historical question. At some time we can *observe* whether a system was sustainable over a prior period of time, but we can only *predict* whether it will be sustainable over a future period.[2]

1.2. One system is *more sustainable* than another if it persists, or is predicted to persist, for a longer time.

2. An economic system turns resources into goods and waste.

2.1. Resources are drawn from and waste absorbed by the ecological system of which the economic system is a part.

2.2. The economic system produces a variety of types of goods that meet a variety of demands.

2.3. For participants in the economic system, the ecological system is characterized by different types of resources. At any time there is an amount or stock of each resource.

2.4. Absent appropriation for production, the stocks of many resources grow exponentially until they approach some carrying capacity. The carrying capacity of one resource may vary over time with the stock sizes of other resources.

2.5. To produce one unit of a good the economic system uses some amount of resources from the ecological system. We can call this amount the unit production requirement of the resource for the good. We can call the inverse of the unit production requirement of a resource for a particular good the production efficiency.

2.6. The amount of a particular resource required to meet demand for a particular good is the product of the demand and the unit production requirement. The amount of a particular resource required to meet the demand for all goods in the economic system is the sum over all goods of this product. This sum can be called the total demand for the resource.

2.7. Appropriation for production introduces another element into the dynamics of resource growth. Namely, the total change in the stock of a particular resource at a particular time is the change absent appropriation for production less the total demand for the resource.

2.8. Call the collection of total demands for all resources and production efficiencies at a particular time the *configuration* of the economic system. If the total demand for a resource exceeds the stock at any time, the configuration associated with that total demand is *unsustainable*.

[1] Costanza, R. and B. C. Patten. Defining and predicting sustainability. *Ecological Economics* **15**(3): 193-196, 1995.

[2] Ibid.

That is, it cannot persist; literally, the desired production cannot be sustained.

2.9. Call the collection of intrinsic rates of growth of the various resources and the dependencies of the carrying capacities on the stock sizes of other resources the configuration of the ecological system.

3. Consider two economic systems, one with greater production efficiency than the other but with identical demand and ecological configuration. For empirically plausible ecological configurations, the economic system with greater production efficiencies is more sustainable. That is, **if demand is fixed, sustainability increases with efficiency** because resources are consumed less rapidly.

4. Instead of assuming fixed demand, suppose consumers in the economic system are time-discounted-utility maximizers with fixed preferences and diminishing marginal utility from consuming any particular good.

4.1. Suppose further that demand curves consistent with these preferences interact with supply curves consistent with available resource stocks and the production efficiencies to determine real prices and quantities of goods produced and consumed in the economic system following the theory of supply and demand.

4.2. Under these conditions goods will have a range of price elasticities of demand.

4.3. For a good for which demand is not saturated and for which producers' marginal revenue is nonnegative, increases in production efficiency will lead to increases in absolute production, as more of the good can be produced for a fixed cost.

4.4. If more of the good is produced, the cost to consumers of a given amount of the good falls.

4.5. If demand for a good is elastic, this decline in cost will lead to an increase in demand and in turn to an increase in consumption.

5. Consider again two economic systems, this time with identical production efficiencies and ecological configurations, but one with twice the total demand of each resource as the other. For empirically plausible ecological configurations, the economic system with less demand is more sustainable. That is, **sustainability falls as demand rises**.

5.1. Therefore any change in the economic configuration which leads to increased demand (i.e., increased consumption) leads to a decline in sustainability.

5.2. Therefore **increasing the production efficiency of a good with elastic demand leads to a decline in sustainability**.

5.3. Which goods fall in this category is an empirical question. Studies in energy economics suggest energy does. Studies in transportation suggest that demand of vehicle-miles is elastic to the price of gasoline and that demand of vehicle-miles on a particular route is elastic to the performance of links on that route. (The latter is indexed by the term "induced demand" in the transportation literature.) Computing also appears to fall in this category.

6. If long-term sustainability is the desired goal of design efforts, efficiency of computing should not be a design goal. Rather, designers should take steps to reduce demand for computing.