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Boosting resource productivity: Creating ping-pong dynamics between resource productivity and resource prices

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ABSTRACT

This paper briefly reviews the economic literature on resource scarcity, resource availability and economic growth. The Club of Rome study "Limits to Growth" was given short shrift by economists because it contradicted historical evidence that resource prices have been declining, not increasing, since the industrial revolution thanks to technological progress in exploration, mining and refining of metals and fossil fuels. Recent events, however, suggest that resource prices are no longer declining, either because of increasing demand by developing countries (e.g. China) or because of limits to technological progress – or for other reasons. In any case, this situation suggests that resource productivity is far too low, today, and needs to be boosted sharply. This can be done by cutting subsidies and shifting taxes away from labor and capital onto resource extraction and consumption, thus promoting technological innovation in resource efficiency.

1. Introduction: the environment as a resource

A recent report to the Club of Rome by Anders Wijkman and Johan Rockström (Wijkman and Rockström, 2012) includes the statement:

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> "The economists models ... focus foremost on the relationship between producers and consumers. Access to energy and raw materials – not to mention ecosystem functions – have more or less been taken for granted." (Wijkman and Rockström, 2012)

Today, unlike past centuries, the environment itself is now considered – at least by some researchers – as a natural resource subject to depletion (e.g. Arrow et al., 1995; Wackernagel and Rees, 1997; Simpson et al., 2005; Rockström et al., 2009). The observation that the economy is inseparable from the environment has been made by others in recent years, to be sure, but rarely before the 1990s. Robert Ayres and Allen Kneese were among the first economists to recognize the essential link between economics and physics. The physics connection arises from the first and second laws of thermodynamics (Ayres and Kneese, 1969, 1989).

The Second Law of thermodynamics is a kind of non-conservation law. Energy is the sum of two components, viz. *exergy* and *anergy*. Exergy is the useful component that is capable of doing physical work, such as lifting a weight against gravity, or accelerating a body to overcome inertia or driving a chemical reaction. Anergy is the useless part that cannot do any work. The second law says that the useful component of energy, the component that is capable of doing *work* is not conserved. Exergy is consumed, or destroyed, in every activity or transformation, while its complement, anergy, increases in every action or transformation.

There is another expression of the second law, in terms of a mysterious quantity called *entropy*. This is not a substance, but a measure of the state of the universe, that increases with every action or transformation that occurs. The best way to understand entropy intuitively is as a measure of disorder.[1] Low entropy corresponds to a state of orderliness, such as a biological structures or a work of art, while high entropy corresponds to disorderliness, such as a mixture of gases. Productive activities tend to create local order from disorder. Léon Brillouin added the notion that information can be interpreted as "negentropy", meaning that low entropy contains high information, high entropy little information (Brillouin, 1962). Although this is a widespread and useful notion, it can be challenged on the grounds of a better understanding of Claude Shannon's theory of information.[2] Leaving this rather philosophical controversy aside, we can interpret economic processes as relating to entropy. For instance when a mineral ore is extracted from the earth's crust, it is progressively concentrated, refined, and finally purified, creating a lot of negentropy or information. Then the pure metal – perhaps gold – may be re-formed into a shape such as a coin: more information again. Or one can think of a computer chip, with a very precise pattern of thin layers of different elements, with very high information content.

The economic implications of the Second Law of Thermodynamics were first taken seriously by the Romanian economist Nicolas Georgescu-Roegen, in his 1971 book "The Entropy Law and the Economic Process" (Georgescu-Roegen, 1971). But Georgescu-Roegen underestimated the potential for utilizing solar energy to compensate for declining ore grades by collecting and recycling wastes. For a more recent book on the implications of entropy in relation to social-technological evolution see "Information, Entropy and Progress" (Ayres, 1994). The implications are quite easy to summarize: all creation of negentropy, i.e. all intentional and productive activities, is accompanied by the increase of entropy (disorder) somewhere else. Hence, there is no such thing as a transformation process that is actually reversible. There is no such thing as a perpetual motion machine. It follows that every industrial or domestic use of resources to make useful things unavoidably creates wastes and pollution. Zero emissions and 100% recycling are possible only locally, and at the expense of more pollution elsewhere. The best strategy available to reduce pollution is to use resources more efficiently.

The other side of that coin is resource depletion. Just as waste and pollution are inevitable companions of production and consumption, so is resource depletion. Several major studies were initiated to assess the problem during the Truman Administration after WW II. One of them led to the creation

[1] This popular understanding only holds if repulsive forces dominate. For attractive forces the notion of "order" is less easily definable.

[2] See Von Weizsaecker and Von Weizsaecker et al. (1998a,b) based on a 1972 publication in German. For Shannon, clearly "information" is entropy, not negentropy.