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On lessons from energy and environmental cost–benefit analysis

Per-Olov Johansson

Stockholm School of Economics, PO Box 6501, SE-113 83, Stockholm, Sweden

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ABSTRACT

This short paper introduces a few concepts from environmental, energy, and health economics that may be useful in evaluations of infrastructure investment in R&D. These concepts focus on valuing commodities and resource stocks under uncertainty. In particular, households may value a commodity (or a resource stock or a species) even if they never will consume the commodity. This may also be true for services generated by R&D infrastructure. Similarly, there are existence values, i.e., a household may be willing to pay for the saving of an endangered species. This may also be true for some R&D infrastructure, i.e., they may be classified as a (world) heritage. They also generate new medical treatments saving lives as well as curing non-fatal diseases. Health and environmental economists have since long dealt with the valuation of such benefits.

1. Introduction

This short paper reviews some common concepts from environmental, resource, and health economics in order to assess their relevance for the economics of particle physics. How to evaluate infrastructure investment in research and development has been discussed in detail by Florio and Sirtori (2013). Therefore, no attempt is made her to discuss what types of benefits such an investment may generate. Rather the focus is on a few concepts that could be applied to cost–benefit analysis of investment in R&D. To the best of my knowledge, this exercise has not been undertaken previously. Hence, no summary of previous research is possible.

The paper is structured as follows. Section 2 introduces the classification of values typically employed in environmental economics. The basic distinction is between commodities that are consumed and commodities that are valued although they are not directly consumed. Section 3 turns to Weisbrod's (1964) notion of option value. This value seems to be of great interest when evaluating investment in R&D but is shown to be somewhat problematic. Section 4 introduces some other and more recent option value concepts that may be of interest in the current context. Section 5 turns to a difficult and controversial issue. Particle physics saves lives through its impact on treatments of cancer and other serious illnesses. The question arises how to value such gains. The section briefly reviews how economists try to value life-saving treatments. Section 6 is devoted to a few concluding remarks. An Appendix provides some technical detail.

2. Use and Non-use values

Every good or service (commodity) that is consumed provides *use values*, i.e., it is an argument in individual utility functions.[1] This is obviously the case for commodities that we pay for, like food, drinks, television programs, movies, and so on. However, the same holds for environmental commodities. For example, a river provides different recreational services like fishing, canoeing, and kayaking. In addition, the river and its surroundings might provide scenic beauty and other aesthetic values. These values too are consumed and hence are arguments in individual utility functions. All kinds of commodities from pure public ones to purely private ones that are consumed generate what here is termed use values. A pure public good like air to breath can be consumed by everyone; it is non-excludable and non-rival (my consumption of the good does not preclude your consumption). In contrast, a pure private good is both excludable and rival; my consumption of a pure private good like a hamburger precludes your consumption of it. Many goods are in between these extremes. For example, cable TV is non-rival (my consumption of a show does not limit your ability to also view the show), but nonsubscribers are excluded from this so-called club good. Another example is common pool resources: people cannot be excluded from fishing in the sea but the fish I catch cannot be caught by others.

However, a commodity or a resource stock might provide value even if it is not consumed. Such values are often referred to as *non-use values*, but sometimes they are labeled passive-use values or intrinsic values. In

E-mail address: per-olov.johansson@hhs.se.

[1] This and the following paragraphs draw on Johansson and Kriström (2015).

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particular, since they are not consumed, they leave no "fingerprint" in markets. Such values date back to conservation movements in different countries of the late nineteenth and early twentieth century. Economists began looking at the concept in the 1960s. Krutilla (1967, p. 781) observes that

> "There are many persons who obtain satisfaction from the mere knowledge that part of the wilderness of North America remains, even though they would be appalled by the prospect of being exposed to it."

One could interpret Krutilla's observation as meaning that the utility function of a typical individual looks like $U = U(x,z;v)$, where x and z refer to consumption (use values) of private and public goods, respectively, and v denotes non-use values; the utility function is typically assumed to be increasing in all three arguments. There are several different categories of non-use values. Among these are *existence values*. The survival of a species or the preservation of a resource is attributed value. To illustrate, one might attribute value to the preservation of a species, e.g., the blue whale (*Balaenoptera musculus*), even though one will never see ("consume") one. A person might also positively value the option to consume a resource sometime in the future, see below. Another type of non-use values is represented by *altruistic motives*. Such considerations may refer to individuals/generations that one cares for, sometimes labeled bequest motives. A distinction is made between *pure* and *paternalistic altruism*. A pure altruist respects the preferences of others, i.e., include their utility functions as arguments in his/her own utility function. In contrast, a paternalistic altruist values a particular argument of others' utility functions. For example, an income-focused altruist is concerned with income distribution in society, while a safety-focused one is concerned with public health. An altruist derives extra satisfaction from a policy change that improves the altruistic argument he or she is focusing on (overall utility, income distribution or public health).

All of these value concepts seem to be of relevance when assessing investment in large scale research infrastructure. Such investment contribute to generating and spreading knowledge, generate new technologies that contribute to sustainable energy solutions, new medical technologies that help to cure serious diseases, and so on; a detailed account of the benefits generated by research infrastructure is found in Florio and Sirtori (2013). Hence, there are use values but people may also attribute value to the services for altruistic reasons. Even existence values come to mind since a research infrastructure may be classified as a (world) heritage.

3. Weisbrod's option value

We now turn to another concept that seems to be of interest for the economics of particle physics. Recall that the time horizon for this science is far, far in the future. We do not know for sure how consumers will value the goods and services generated by science. Even if a person does not currently consume a particular good, he or she may value the option to consume the good in the future. Thus, retaining the pure possibility of future consumption has a value. This is Weisbrod's (1964) concept of *option value* when demand is uncertain. According to Weisbrod, an individual is willing to pay a sum in excess of the expected consumer surplus to ensure that the good is available, using a natural park as the example: "To see why, the reader need recognize the existence of people who anticipate purchasing the good (visiting the park) at some time in the future, but who, in fact, never will purchase (visit) it. Nevertheless, if these consumers behave as 'economic men' they will be willing to pay something for the option to consume the commodity in the future. This 'option value' should influence the decision of whether or not to close the park and turn it to an alternative use" (Weisbrod, 1964, p. 472).

An extremely simple attempt to interpret Weisbrod's argument is as follows. Suppose there are just two states of the world. Either the household will consume the good or service or not. There is no other type of uncertainty. The household's expected utility is defined as

$$V^E(p,y,z) = \mu \cdot h(p,y,1) + (1-\mu) \cdot l(p,y,0) \quad (1)$$

where V^E is expected utility; p is the price of a commodity purchased in the market; y is income; z is either unity or zero; μ is the probability that the considered commodity, denoted z, is consumed; and $h(.)$ and $l(.)$ are sub-utility functions. Ex ante, the household is uncertain with respect to its preferences for z; either it would like to consume the commodity or it would prefer to abstain from consuming it. However, uncertainty is assumed to be revealed before consumption decisions are taken.

Now, given the high-value sub-utility function $h(.)$, define the household's willingness to pay (WTP) for having the good/service, i.e., $z = 1$. Denote this willingness-to-pay CV. Paying this amount of money, the household is as well off with $z = 1$ as without payment and the good/service, i.e., $z = 0$. Next, define the expected willingness to pay as $CV^E = \mu \cdot CV$: this is the probability that the commodity is purchased (the park is visited) times the WTP for the commodity. Ex ante, before uncertainty is revealed, this is what the household is expected to be willing to pay. Finally, option value (OV) is simply defined as the difference between CV and CV^E. Hence, there is no option value if the household knows for sure that it will consume the good/service, $\mu = 1$: $OV = 0$ in this case (while the concept lacks meaning in the other extreme case where $\mu = 0$). In the intermediate case, where μ is strictly positive but less than unity, then there is a strictly positive option value, $OV > 0$. Then the household is willing to pay for having the option to consume the good/service in the future.

To the best of my knowledge, Weisbrod never presented a formal argument so we do not really know if the above model properly reflects his ideas. Around 1985, he told me in a private conversation that he would never reveal what he meant. Since then, further analyses of the concept (and further references to his work) would cease; its "option value" would vanish.

The problem with the definition appears if we turn to a more general case. Drawing on Johansson (1993), the state i indirect utility function is defined as $V^i = V(p,y,z^i)$ for $i = 1,2,\ldots\ldots\ldots,I$. This case represents supply-side uncertainty. The household does not know for sure how much of the commodity will be available (but could also be interpreted as demand-side uncertainty, i.e., the household does not know for sure how much it optimally will consume but it sees I different optimal levels as possible). Suppose that we consider the possibility to stabilize supply at its expected level. Denote this expected or mean level $\bar{z}$. Then we could define an expected WTP by calculating the WTP for having the mean supply rather than the stochastic supply in state $i = 1,2,\ldots\ldots\ldots,I$, multiplying by the probability that state i occurs, and summing across states of the world.

Alternatively, and as is further developed in the Appendix at the end of the paper, one could define a uniform or state-independent WTP for going from the stochastic supply to the mean supply. This non-contingent WTP, sometimes referred to as an option price, is strictly positive for a risk-averse household but zero for a risk-neutral household. The former household prefers to take the expected outcome of a gamble to participating in the gamble. The latter kind of household is indifferent to risk as it cares only about expected outcomes.

Thus, just as in the previous case, one could define an option value as the difference between the option price and the expected WTP. The problem is that the expected WTP lacks meaning in this more general case, in general. The reason is that the WTP in state i is correlated with the marginal utility of income in that state, in general. The marginal utility of income acts as an exchange rate between units of utility and monetary units. Typically, it will depend on the size of income (here constant across states of the world) and the supply/availability of z. Due to the correlation, the expected WTP might be negative even if the project, i.e., going from a stochastic supply to a stabilized supply, increases expected utility. In the general case, the expected WTP measure is flawed