Paul Samuelson and Global Public Goods

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May 5, 2005

A commemorative essay for Paul Samuelson

It is both easy and hard to write an essay commemorating Paul Samuelson's contributions to economics. Easy, because he has created so much of modern economics that you could write on virtually anything – stabilization policy, economic growth, international trade, welfare economics, or just about any topic that caught your fancy. Hard, because, like Buridan's ass, you could easily procrastinate forever in deciding which of the many treasures of his ideas to draw from.

In the end, I chose to draw from Paul's writings on public goods. In two and one-half pages, he reshaped the way economists and political philosophers think about the distinction between private goods and public goods.[2] Once those concepts are learned, we can never again forget why the allocational questions for bread are fundamentally different from those of lighthouses. I will focus on an important example of this topic, and one that poses particularly thorny practical

[1] The author is Sterling Professor of Economics at Yale University.

[2] Paul Samuelson, "The Pure Theory of Public Expenditure," *The Review of Economics and Statistics,* Vol. 36, No. 4, Nov. 1954, pp. 387-389.

issues, which is the case of global public goods. A brief intellectual history of the concepts is appended.

What great blessings or scourges have befallen humanity? Consider issues as disparate as greenhouse warming and ozone depletion, the Internet and William Shakespeare, terrorism and money laundering, the discovery of antibiotics and nuclear proliferation. Each is an example of a complex system whose effects are global and resist the control of individuals and even the most powerful governments. These are examples of *global public goods*, which are goods whose impacts are indivisibly spread around the entire globe. These are not new phenomena. However, they are becoming more important in today's world, because of rapid technological change and of the astounding decline in transportation and communication costs.

What makes global public goods different from other economic issues, however, is that there is no workable mechanism for resolving these issues efficiently and effectively. If a terrible storm destroys a significant fraction of America's corn crop, the reaction of prices and farmers will help equilibrate needs and availabilities. If scientists discover the lethal character of lead in the air and soil, the government is likely, eventually and often haltingly, to undertake to raise the necessary resources and regulations to reduce lead in gasoline and paint. But if problems arise for global public goods, such as global warming or nuclear proliferation, there is no market or government mechanism that contains both political means and appropriate incentives to implement an efficient outcome. Markets can work wonders, but they routinely fail to solve the problems caused by global public goods.

This essay examines four facets of global public goods. I begin with a discussion of the nature of global public goods. I then discuss the stock nature of many global public goods and the consequent involvement of the time dimension. I next discuss why global public goods pose such a difficult decision problem. Finally, I describe how the production technologies may affect the production of global public goods.

The Character of Global Public Goods

Most of economic life involves voluntary exchange of private goods, like bread or blue jeans. These are commodities consumed by one person and which directly benefit no one else. However, many activities involve spillovers among producers or consumers. A polar case of an externality is a *public good*. Public goods are commodities for which the cost of extending the service to an additional person is zero and for which it is impossible or expensive to exclude individuals from enjoying.

In other words, public goods have the two key properties of non-rivalry and non-excludability. Non-rivalry denotes that the consumption of the public good by one person does not reduce the quantity available for consumption by another person. Take global positioning systems as an example. These are used for hiking, missile guidance, and determining the distance of a golf ball from a hole. These are public goods because people who find their location are not reducing the value of signals for others. The second feature of a pure public good is non-excludability. This means that no person can be excluded from benefiting from or being affected by the public good (or can only be excluded at a very high exclusion cost). In the case of smallpox eradication, once smallpox was eradicated, no person could be excluded from the benefits.

The important point about public goods, which was carefully analyzed in Samuelson's 1954 article, is that private markets generally do not guarantee efficient production. In this respect, then, production of public goods such as GPS signals differs from production of bread. Efficient production of public goods requires collective action to overcome the inability of private firms to capture the benefits of a cure for malaria. The inefficiencies are the greatest for global public goods, whose benefits are spread most widely across space and time.

In reality, there are many shades of privateness and publicness; there are "pure" public goods and "impure" public goods. Consumption of bread probably has some public-good qualities from fertilizer use, emissions from the transportation system, and garbage. Similarly, few public goods are really pure because most public goods have some privateness at different points of space or time. Global public goods are not qualitatively different from other public goods. They are only ones where the effects spill widely around the world and for a long time to come.

Stock Externalities and the Time Dimension in Global Public Goods

One of the distinguishing features of most global public goods is that they are generally "stock externalities." This term means that their impact depends upon a stock of a capital-like variable that accumulates over time. For example, the impacts might be functions of pollution concentrations or knowledge, which are augmented by flows of emissions or learning, and which depreciate according to some process such as precipitation or obsolescence.

The stock character is particularly important when depreciation rates are low, as with Plutonium-239, which has a half-life of 24,000 years. In global warming, the impact of greenhouse gases depends upon the concentrations of greenhouse gases in the atmosphere rather than on the current flow of emissions, and the most important gas, carbon dioxide, has an atmospheric residence time with a half-life in the order of a century. Most important global public goods involve some kind of stock – stocks of pollution, piles of radioactive wastes, stocks of knowledge, biological or genetic stocks, reputational stocks in the case of monetary systems, and institutional stocks in the cases of market and democratic systems.

Being stock externalities gives global public goods special characteristics. By their nature, stocks accumulate, often very slowly, so that it may be difficult to recognize the symptoms of the associated ailment until it is too late to cure. Moreover, because stocks accumulate slowly, and some depreciate very slowly, stock externalities often have long-lasting consequences and are irreversible or near-irreversible. For example, once the stock of a species has disappeared, it is gone forever (or until science fiction becomes science reality) as a viable biological system. Because of the long time lags, the impacts may fall far in the future, which lends enormous uncertainties to the problem. Our actions today will affect the climate many decades in the future, but who knows where, when, how, or how much? These features of stock public goods make analysis and policy making more difficult than with transient or flow public goods.

The stock character of global public goods also adds a time dimension to the dilemmas involved in public goods. The nature of the spillover depends upon the depreciation rate of the stock. If the depreciation rate is high, then most of the impacts will occur quickly (as would be the case with flow pollutants). However,

when the depreciation rate is low (as in global warming or many radioactive wastes) or even negative (as might be the case of knowledge), then the impacts will occur over many generations as well as many nations, and presumably even for nations that have no current legal existence. Just as children and the unborn cannot vote, so unborn nations cannot represent their interests under international law.

Just as global public goods involve externalities over space, in the case of stock public goods they involve externalities over time. While markets are linked over time through capital markets, there is no similar linkage over time for stock global public goods. No market today accurately reflects the impact of global warming on the possible deterioration of air quality or cross-country skiing a century from now. Appropriate decisions must weigh the intergenerational benefits across time just as in conventional public goods they must weigh the benefits across space. It seems likely that, for stock global public goods with low depreciation rates, we will shortchange unborn generations, and even unborn nations, because their interests will be discounted by under-representation and too-high market or decisional discount rates.

Global Public Goods, Federalism, and the Westphalian dilemma

While global public goods raise no new analytical issues, they do encounter a unique political hurdle, which is the Westphalian dilemma. Whenever we encounter a social, economic, or political problem, one of the first questions concerns the level at which the problem should be addressed. We expect households to deal with children's homework assignments and taking out the trash; we expect local or regional governments to organize schools and collect the trash;

we expect national governments to defend their borders and manage their currencies.

For the case of global public goods, there exists today no workable market or governmental mechanism that is appropriate for the problems. There is no mechanism by which global citizens can make binding collective decisions to slow global warming, to cure overfishing, to efficiently combat AIDS, to form a world army to combat dangerous tyrants, or to rein in dangerous nuclear technologies.

The decision-making difficulties of global public goods raise what might be called the Westphalian dilemma. National governments have the actual power and legal authority to establish laws and institutions within their territories; this includes the right to internalize externalities within their boundaries and provide for national public goods. Under the governing mechanisms of individual countries, whether they are acts of democratic legislatures or despotic decrees, they can take steps to raise taxes or armies and command their citizens to clean their air and water.

By contrast, under international law as it has evolved in the West and then the world, there is no legal mechanism by which disinterested majorities, or supermajorities short of unanimities, can coerce reluctant free-riding countries into mechanisms that provide for global public goods. Participants of the Treaty of Westphalia recognized in 1648 the *Staatensystem*, or system of sovereign states, each of which was a political sovereign with power to govern its territory. As the system of sovereign states evolved, it led to the current system of international law under which international obligations may be imposed on a sovereign state only with its consent.

Because nations, particularly the United States, are deeply attached to their sovereignty, the Westphalian system leads to severe problems for global public goods. The requirement for unanimity is in reality a recipe for inaction. Particularly where there are strong asymmetries in the costs and benefits (as is the case for nuclear non-proliferation or global warming), the requirement of reaching unanimity means that it is extremely difficult to reach universal and binding international agreements. One answer to the political vacuum is to create international institutions, such as the Intergovernmental Panel on Climate Change or the International Maritime Organization. Such organizations generally work by unanimity, have few provisions that are binding on recalcitrant countries, and in any case apply only to countries which have agreed to participate. Even for life and death issues such as nuclear weapons, if a state like North Korea declines to participate in the Non-Proliferation Treaty, there is no provision for forcing its agreement.

To the extent that global public goods may become more important in the decades ahead, one of our major challenges is to devise mechanisms that overcome the bias toward the status quo and the voluntary nature of current international law in life-threatening issues. To someone who is an outsider to international law, the Westphalian system seems an increasingly dangerous vestige of a different world. Just as economists recognize that consumer sovereignty does not apply to children, criminals, and lunatics, international law must come to grips with the fact that national sovereignty cannot deal with critical global public goods.

The Production Technology for Global Public Goods

Most discussions of public goods focus on the non-rivalry and non-excludability in their *use*. A neglected feature is the nature of the technology for

production of public goods, that is, the technology underlying the production of the indivisible benefits. Most analyses of public goods such global warming, deforestation, or information tend to view the production of public goods as an "additive" technology, akin to pouring water in a vat or adding houses in the suburbs. In fact, the production technologies of public-goods vary considerably, and the kinds of policies or institutions that are necessary for efficient provision of public goods will also differ according to the technology.

Three production technologies

Three interesting examples of production technologies for public goods provide quite different outcomes. [3]

1. Additive technologies. The conventional case, stemming from the original Samuelson 1954 model, comes where the production of the public good is simply the sum of the contributions of the different producers. This is exemplified by global warming, where total emissions are equal to the sum of the emissions of different parties. In this case, it makes no difference whether 10 units are produced by one country or by 10 countries.

2. Best-shot technologies. Quite a different situation comes when the outcome is the result of the maximum of the individual contributions. For example, if ten missiles are fired at an incoming warhead, then the success of the effort will be largely determined by the missile that comes closest to the target. Another important example is technological change: If ten researchers are trying to find

[3] This discussion draws upon Jack Hirshleifer in "From Weakest-Link to Best-Shot: The Voluntary Provision of Public Goods," *Public Choice,* vol. 41, pp. 371-386, 1983.

a cure for malaria, the payoff will generally come from the best outcome.

3. Weakest-link technologies. Many cases exhibit a technology where the overall production is only as good as the weakest link in the chain. For example, when different communities are building a dike, the success in holding back the waters will depend upon the minimum strength or height of the different parts. Similar outcomes sometimes occur in protecting the spread among countries of infectious diseases like SARS, combating illegal drugs, or preventing money laundering. Perhaps the most frightening example is nuclear proliferation, where countries or groups can buy or steal nuclear materials and designs from countries with the weakest security protection.

Efficient provision

We introduce the different cases because they have different implications for efficient provision and for the equilibrium outcome. (This discussion relies on the analysis referred to earlier by Hirshleifer.) In the additive case, efficient provision requires the familiar rule that everyone contribute to the point where private marginal cost equals social marginal benefit.

While the equilibrium condition is unchanged, the outcomes for the other cases are different and even strange. Efficient production for the weakest-link technology would require that all parties contribute equally. Efficient dike building requires that each section have equal height and strength (ignoring water pressure, water flows, and other similar factors). If a virulent influenza or SARS-like illness began to spread, good public health protocols in our highly linked world require that all countries are vigilant in tracking and treating the disease. Similarly, efficient prevention of nuclear proliferation requires stringent minimum standards for all

countries possessing the relevant technologies.

The best-shot technology is the opposite of the weakest-link technology. It requires that production be concentrated in the low-cost or most efficient producer. Ignoring uncertainty, production should follow the rule that private marginal cost of production of the low-cost producer should equal social marginal benefit, while production of all other higher-cost producers should be zero. In climate-change policy, this rule would definitely not be appropriate for emissions reductions. However, in other aspects of global warming, specialization might be appropriate. For example, we would expect that the research and development on low-carbon fuels should be concentrated in the most efficient research environments. Similarly, if it were thought that geoengineering approaches to climate change (such as shooting smart particles into the stratosphere) were appropriate, it would be natural that the high-technology countries would undertake this task.

Non-cooperative provision

Similarly, we can inquire into the equilibrium production of global public goods for different production technologies. It is sensible for global public goods, given the Westphalian dilemma, to examine an equilibrium in which different parties (nations) behave in a non-cooperative fashion. The additive case would provoke the standard syndrome of free riding and underprovision of the public good, with small and poor countries underproviding more than large and rich countries.

In the weakest-link case, by contrast, we see strong incentives for parties to cooperate and provide for the common defense. Since I will be inundated if I do not keep up my share of the dike, there is little incentive (or possibility) for free riding.

Weakest-link technologies, then, are ones where the non-cooperative outcome most closely approaches the efficient outcome as long as countries have similar tastes and incomes. With weakest-link technologies, coordination and technological cooperation may be sufficient to produce reasonably efficient outcomes.

The best-shot case poses serious problems. In the case of a single superpower, that country will naturally be the low-cost provider and is likely to end up being the single provider. The equilibrium outcome is likely to be the most inefficient of all three cases. This result occurs because the low-cost provider still equates marginal private cost with marginal private benefit, but other providers drop out and produce nothing. Thus, in the cases of providing security guarantees, GPS systems, or combating international security threats, the United States is clearly the dominant provider, with more than half of defense and intelligence spending. It is likely to remain the sole provider of the public good (if this term is aptly applied here) as long as it remains so dominant.

However, as long as the U.S. decisions adopt a non-cooperative strategy, provision of global public goods will be highly inefficient. Particularly when the benefits of action are widely dispersed or perceived as insignificant by the United States (as is apparently the case for technological development of low-carbon fuels to slow climate change or developing effective treatment against African AIDS or malaria), it is likely that there will be serious underinvestment in the global public good.

It is tempting to divide views of global issues into those who see the world largely in terms of the additive technology and those who view events through the lens of the non-linear technologies. Those who see the world in terms of additive public goods would tend to emphasize policies requiring cooperative efforts by all

or most nations. There is, in that view, no substitute for finding cooperative Coase-type solutions in which bargaining leads to efficient outcomes. By contrast, those whose worldview is largely shaped by conflict and military doctrines may view the world more as one in which unilateral or imposed solutions are necessary. Action in the best-shot world requires but a single actor, whose role is to govern benevolently while taking into account the aggregate of impacts across all nations. Alas, it is but a small step from the benevolent actor to the nationalistic actor, one who acts unilaterally and concentrates on the benefits to the dominant country, perhaps with a bow to the interests of friends and coalitions of the coerced.

Conclusion

In this discussion, I have reviewed the fascinating problem involved in managing global public goods. All public goods pose severe challenges, but global public goods are even more daunting, and stock global public goods are the polar case of affecting vast numbers of people for long periods of time. The structure of international law and political power raises enormous obstacles to obtaining the unanimous or near-unanimous consent of sovereign nations to take collective international action. Problems of global public goods will also differ depending upon the production process underlying the public good. The peril of using the incorrect mental model of global public goods is that a proposed solution will lead to little improvement over the status quo. Solving the problems involved in global public goods is an open and fascinating economic question with major consequences for our world.

These thoughts recall for me a time when I was a graduate student at MIT and we were having a bad day in one of Paul's classes on advanced capital theory. His questions – perhaps on E. v. Böhm-Bawerk or I. Fisher – were eliciting no sensible

answers. Eventually, he looked out at us and remarked to the effect that we were the returns on his human capital, but he was not sure that he was earning a supernormal return. Fortunately, the returns on his human capital are the ultimate global public good. To paraphrase Jefferson, Paul does not diminish the light of his wisdom and generosity when he passes that light to his students and colleagues; rather it glows larger than ever.

Historical Notes on Public Goods

The germinal article on public goods is Paul Samuelson, "The Pure Theory of Public Expenditure," *The Review of Economics and Statistics,* Vol. 36, No. 4, Nov. 1954, pp. 387-389. He originally called these "collective consumption goods." The first use of the term "public good" in this context in the JSTOR archives appears to be in Paul A. Samuelson, "Diagrammatic Exposition of a Theory of Public Expenditure," *The Review of Economics and Statistics,* Vol. 37, No. 4, Nov. 1955, pp. 350-356.

Samuelson referred to earlier writings on the theory of public expenditure of Emil Sax, Knut Wicksell, Erik Lindahl, and Richard Musgrave. Early writers, such as Musgrave, generally used the term "social goods." An early definition of what we today mean as public goods (using the term "social goods") appears in Howard R. Bowen, "The Interpretation of Voting in the Allocation of Economic Resources," *The Quarterly Journal of Economics*, Vol. 58, No. 1 (Nov., 1943), pp. 27-48. The notion of public goods is implicit in the discussion in Richard Musgrave, "The Voluntary Exchange Theory of Public Economy," *The Quarterly Journal of Economics,* Vol. 53, No. 2, Feb. 1939, pp. 213-237. One of the most influential analyses was in Richard Musgrave, *The Theory of Public Finance,* New York, McGraw-Hill, 1959.

The notion of global public goods appeared sometime in the early 1990s in the context of global environmental issues. These were analyzed in my work on global warming, particularly William Nordhaus, *Managing the Global Commons: The Economics of Change,* MIT Press, Cambridge, MA, 1994. An excellent early study surveying the area is Todd Sandler, *Global Challenges: An Approach to Environmental, Political, and Economic Problems,* Cambridge, U.K., Cambridge University Press, 1997. Many of the issues discussed here were presented in a lecture I delivered, "Global Public Goods and the Problem of Global Warming," Annual Lecture of The Institut d'Economie Industrielle (IDEI), Toulouse, France, June 14, 1999. The United Nations has a web page devoted to global public goods at www.undp.org/globalpublicgoods/.