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Expert Paper One

Infectious Disease

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Secretariat of the International Task Force on Global Public Goods

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Acronyms and Initials

ACT	artemisinin-based combination therapy
AMC	advanced market commitment
APC	advance purchase commitments
ARV	antiretroviral
CCM	country coordinating mechanism
CDC	Centers for Disease Control
CDR	case detection rate
CGIAR	Consultative Group on International Agricultural Research
DALY	disability-adjusted life year
DFID	Department of International Development
DOTS	directly observed treatment-short course
EU	European Union
FDA	Food and Drug Administration
GAVI	Global Alliance for Vaccines and Immunization
GDF	Global Drug Facility
GFATM	Global Fund to Fight AIDS, Tuberculosis and Malaria
GNP	gross national product
GPG	global public good
HPTN	HIV Prevention Trials Network
HRP	Special Programme of Research, Development and Research Training in Human Reproduction
IAVI	International AIDS Vaccine Initiative
IDA	International Development Association
IFF	International Finance Facility
IFFim	International Finance Facility for Immunization
IHR	International Health Regulation
IPT	intermittent preventive treatment

IPV	inactivated polio vaccine
MAP	multicountry AIDS programme
MDG	Millennium Development Goal
NGO	non-governmental organization
NIH	National Institutes of Health
ODA	official development assistance
OECD	Organisation for Economic Co-operation and Development
OPV	oral polio vaccine
PSDP	Primary School Deworming Project
PSDP	Public Sector Development Programme
R&D	Research and development
RBM	Roll Back Malaria
RNTCP	Revised National TB Control Programme
SARS	severe acute respiratory syndrome
STD	sexually transmitted disease
STI	sexually transmitted infection
SWAP	sectorwide approaches
TB	tuberculosis
TDR	Special Programme for Research and Training in Tropical Diseases
UN	United Nations
UNAIDS	The Joint United Nations Programme on HIV/AIDS
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development
WHA	World Health Assembly
WHO	World Health Organization
WTO	World Trade Organization

Transnational Public Goods for Health

Chapter 1

Scott Barrett

Johns Hopkins University
School of Advanced International Studies

This paper examines the transnational public good dimension of global health. It argues that supplying public goods for health has two advantages: the obvious efficiency advantage of supply and a related advantage for economic development. Because the discrepancy in health between rich and poor nations is so large, the second advantage is likely to be especially important for this public good, compared with the others being examined by the Task Force. Five public goods are studied in detail: surveillance, the control of infectious diseases, the eradication of infectious diseases, the control of the spread of resistance and knowledge, particularly for new vaccines. The paper briefly examines the incentive problems associated with each area and the institutional actions taken so far to correct them.

This paper identifies the transnational public goods for controlling communicable diseases and explains why interventions may be underprovided and how their supply might be enhanced. There are two pure global public goods: eradicating disease and preventing resistance. For both, no country can be excluded from the benefits of provision, and no country's consumption reduces the amount available to other countries. Both are discrete public goods. Eradication either happens or it does not. Resistance develops or it does not.[1] Both also require interventions by a large number of countries—and in some cases, by all. The important difference is that eradicating disease is time limited, though surveillance and precautions must continue indefinitely . Preventing resistance requires ongoing intervention (see table 1.1).

Surveillance for emerging diseases (such as SARS) and the knowledge of how to control a disease are both potential public goods, but

Table 1.1 **Policy interventions for infectious diseases**

Intervention	Global public good	External benefits
Surveillance	Yes, if reported	Allows informed countries to take steps to limit imports and consequences of imports
Knowledge	Yes, if access unrestricted	Can be used to control a disease or as an input to further scientific progress
Control	Yes, partially	Breaks international transmission
Treatment	Yes, partially	Reduces international transmission but may also hasten resistance
Resistance/ avoidance	Yes	No risk of importing resistant pathogens; current treatments remain effective
Elimination	Yes	Breaks international chain of transmission
Eradication	Yes	Yields every country a dividend of avoiding both future infections and the need to control them

access to them can be restricted. Surveillance is of little benefit to other countries unless accompanied by an obligation—or, better yet, an incentive—to report. The essential problem revealed by the SARS outbreak was less a failure of surveillance than a failure to report the disease. Similarly, knowledge is a public good when users are allowed access. Sometimes, however, potential users are excluded; knowledge can be kept secret or embodied in patented products.

Control of a disease has some attributes of a public good. If a disease is controlled, the likelihood of its being transmitted to susceptible persons is reduced somewhat. But whether this reduction yields transnational benefits depends on the circumstances. Measles, for example, has been eliminated in the United States, so that further control of this disease in developing countries is of little benefit to the United States.

Similarly, treatment of a disease such as tuberculosis reduces transmission and so offers a measure of protection to others. But treatment can also hasten the onset of resistance, especially if the drug is used inappropriately.

Elimination of a disease involves high rates of control so that a disease stops being transmitted. Where a disease is eliminated, it ceases to be endemic and imported cases cannot spark an epidemic. Elimination is location specific—it is a local public good and, in some cases, a regional public good. Whether elimination benefits other countries depends on the levels of control adopted elsewhere. Measles elimination in the Americas, for example, is of little if any benefit to African countries, where the disease remains endemic.

For which transnational public goods is provision likely to yield the greatest net benefit? The eradication of smallpox may well have yielded a higher return than any other single public investment, but opportunities such as that are unlikely to be available again. The greatest gains are likely to come from two kinds of interventions:

- Surveillance, reporting and controlling of newly emerging and re-emerging diseases and resistance.
- Knowledge—particularly of new vaccines, combination vaccines, antibiotics and antiretrovirals, and vector control—coupled with an efficient system for production and distribution.

To illustrate, one area where both interventions would yield enormous benefit is the early identification of a new pandemic flu, coupled with measures to protect susceptible populations from infection—including the rapid development, production and distribution of a new vaccine. Other fruitful interventions are discussed in what follows.

This paper identifies the transnational public goods for health and explains why they tend to be underprovided and how their provision might be enhanced. The focus is on controlling communicable diseases. Other public goods, such as protecting the ozone layer, have implications for global health but are addressed in the companion paper on the global commons. Other public health issues that are not global public goods, such as smoking, are not addressed in this paper, even though they may be of international concern.[2]

Global public goods have two characteristics: no state can be prevented from consuming them, and consumption by one state does not diminish the amount available to others. As will be explained, control of communicable diseases can be a global public good. But it will not always be so—and understanding when it is and when it is not is important to the design of policies and institutions. Where countries are very different and health is a global public good, it may pay some countries to finance health improvements in other countries. Where countries are very different and health is not a global public good, financing may be undertaken for humanitarian or development reasons—but not because the countries paying for health improvements benefit directly from the investment.

The distinction is emphasized because much recent literature has combined or conflated the two motivations, or stressed the humanitarian and development dimension. The World Health Organization (WHO) Commission on Macroeconomics and Health, for example, produced an excellent report on global public goods for health, but

Box 1.1 Not all global health issues are global public goods

Private health is concerned with the health of individuals. Public health, by contrast, is concerned with the health of a community: the control of infectious disease, improvement of the physical environment (sanitation, pollution), nutrition, safety in the workplace and on the roads, smoking—anything that affects the health of a population at large.

Public health is determined in part by private choices, such as the choice to vaccinate oneself, to sleep under a bednet at night (to ward off mosquito vectors) or to wear a seat belt. It is also determined by public infrastructure investments (sanitation, road safety), regulation (pollution, workplace safety, cigarette advertising) and policies that affect individual behaviour and the provision of medical care.

Public policy is needed because some incentives prevent individual choices from sustaining efficient outcomes. Individuals have strong incentives to be vaccinated when an effective vaccine exists and is safe and affordable and the disease against which the vaccine offers protection poses a substantial risk. When an individual is vaccinated, it becomes that much harder for a disease to be transmitted to unprotected persons in a community—a phenomenon known as "herd immunity". But individuals have little if any incentive to take this effect into account, with the consequence that, from the perspective of the collective good, too few people will be vaccinated. Policies of mandatory vaccination and vaccination subsidies are intended to correct for these incentive problems.

Public health is local, national, regional and global—and policy must address public health on all these levels. And just as individual choices have implications for the community, so policy choices at each level have implications for the other levels of collective decision-making. Control of the malaria vector, for example, exhibits mass effects at the village level and across national boundaries. By definition, disease eradication must be achieved globally, and yet success depends on whether a targeted disease can be eliminated from its last stronghold—perhaps a small village in a remote, war-torn region.

Many public health issues are of international concern; only a subset consists of transnational public goods. The distinction is important because different issues reflect different underlying incentive problems. They also call for different remedies.

Two public health issues have attracted substantial interest in recent years but are not global public goods. The explosive spread of HIV/AIDS in developing countries is among the greatest of all public health concerns today, and the inequity of antiretrovirals being available to infected persons in rich countries but beyond the budgets of HIV-positive persons in developing countries has attracted global attention. It has also attracted funding, including a $15 billion pledge by the Bush administration to supply antiretrovirals to 14 countries. Supplying antiretrovirals to the poor in poor countries is largely a humanitarian concern. It will not reduce the global spread of the disease.[a] There may, however, be indirect effects. Perhaps humanitarian assistance is itself a public good (perhaps all countries benefit from the knowledge that an HIV-positive person and his or her family is being helped by the provision of antiretrovirals). Perhaps it will aid international security—another public good—by avoiding a future source of state failure (National Intelligence Council 2000).

Intervention may also be needed to ensure that the trading system benefits all countries, and is seen to do so.[b] The problem is not only that infected persons in developing countries cannot afford the cost of antiretroviral therapies available in rich countries. The problem is that a one-price policy for patented drugs is inefficient.

The price of antiretrovirals is high because the research and development costs need to be recouped by the companies that risked capital in the effort. Allowing companies to charge a high price is thus justified from the perspective of intertemporal efficiency. But the marginal cost of producing these treatments is a small fraction of the price charged. Because the research and development costs are already being recouped in rich countries, the companies making these drugs should be willing to sell them in developing countries for a price close to marginal costs. And an efficient system would allow this to happen.[c]

continues

Box 1.1 Not all global health issues are global public goods (continued)

But the international trading system blocks such transactions. Arbitrage—normally the friend of efficiency—could create a gray market for the drugs, causing cheap drugs sold in poor countries to be shipped back to rich countries and so depressing the profits of manufacturers in these markets. Even in the absence of trade, differential pricing may put downward pressure on prices in rich countries, where charging high prices may be seen (by consumers and politicians) to be unfair. To avoid these problems, manufacturers have incentives not to offer antiretrovirals at a low price in poor countries. But maintaining a high price in all markets only encourages entry by copycat producers—a development that also cuts into the profits of the original innovator. This helps explain why several companies have offered their products to developing countries on a no-profit basis.[d]

To sum up, there are many reasons for providing international assistance for health, and for adopting international health policies. The focus of this paper is on the provision of transnational public goods for health—most especially surveillance, control and eradication of infectious diseases, control of the spread of resistance and knowledge.[e]

a. There is some evidence that antiretroviral therapy may reduce viral loads and, hence, the probability of sexual transmission (Ahrin-Tenkorang and Conceicao 2003). However antiretrovirals also keep HIV-positive persons alive for longer, possibly creating more opportunities for transmission. As well, the availability of therapy lowers the costs to an individual of getting infected, and so may promote risky behaviour.
b. See WHO and WTO (2001).
c. Economic efficiency requires that a product be available to every person willing to pay more than it costs to produce. This requires that marginal willingness to pay equal marginal cost; it does not require that every person actually pay marginal cost.
d. See WHO Commission on Macroeconomics and Health (2001, p. 88).
e. Working Group 2 of the Commission on Macroeconomics and Health (2002) also emphasizes standardized data collection, and Kremer (2004) notes the importance of randomized evaluations of health programmes.

its main report stresses the need to improve the health of the world's poorest people—a worthy goal, for sure, but not necessarily a global public good (WHO Commission on Macroeconomics and Health 2001) (see box 1.1).

In contrast to ordinary development assistance, the supply of global public goods yields benefits to both developing and industrialized countries (see box 1.2). If industrial countries gain enough from a public good, they might be willing to finance its supply—for their own benefit, even though doing so also aids developing countries. An example illustrated later in this paper is eradicating disease.

Disease eradication is a disease-specific programme. The alternative is to invest in basic public health infrastructure—a capability for controlling a range of diseases. Eradication often suits the countries supplying aid, but infrastructure is typically of greater benefit to aid recipients. As explained later, aid targeted to combating particular diseases can be—and arguably should be—constrained to reinforce basic public health services. This need not benefit only developing countries. A key public good is improved surveillance and control of emerging diseases. Such a capability is of great benefit to industrial countries, but it requires investment in basic infrastructure.

Box 1.2 Global public goods for health can promote development

There are two views of the relationship between health and development, each correct but each very different. One view is that life expectancy improves with increases in per capita income (World Bank 1993). The other is that economic growth is helped by improvements in public health (WHO Commission on Macroeconomics and Health 2001).[a] It is this last view that is especially relevant for the Task Force, since one of the criteria for priority-setting identified in the Secretariat's "Meeting Global Challenges" is net poverty reduction.

Two examples may suffice to emphasize the importance of improvements in health to development: Fogel (1990) estimates that improvements in nutrition and health account for as much as 30% of the growth in per capita income between 1790 and 1980 in Western Europe. Gallup and Sachs (1998) estimate that, if the burden imposed by malaria were lifted, income per head in the malaria-prone countries of Africa would rise by a third.

The decline in mortality over the past century—according to Fogel (1990, p. 44), "one of the greatest events of human history"—had several causes: improved nutrition, public health and personal hygiene; decontaminated food and water; improved housing; and technological advances. It is easy today to forget the progress that has been made. In France, at the end of the eighteenth century, "the bottom 10% of the labour force lacked the energy for regular work and the next 10% had enough energy for less than 3 hours of light work daily" (Fogel 1990, p. 22). It was not until the second quarter of the nineteenth century that per capita daily caloric consumption reached the levels prevailing in India today (Fogel 1990, p. 45).

The contrast between the rich and poor countries today is striking, but so is the contrast between the rich countries today and these same countries one to two centuries before. Of course poor countries today have an advantage over the rich countries of yesterday: the availability of technologies such as vaccines, antibiotics and drugs, not to mention knowledge of the causes of disease. But the ecological circumstances of poor countries today are very different, and as we shall see, the challenge is not just to bring the technologies developed for the rich countries to the aid of the poor. It is also to develop new technologies to address endemic tropical diseases.

a. See Bradley (2001) for a preliminary sketch of the relationships discussed here.

Disease control—always a global public good?

One might think that the control of an infectious disease must be a global public good. However the situation is actually more complicated.[3]

To begin, consider a situation in which an infectious disease is endemic everywhere. If the disease were highly infectious, almost every person could expect to be infected. Under these circumstances, a small increase in control by one country would have no effect anywhere else. That control would not be a global public good.

Now imagine that the disease existed in only one country, and that the persons in every other country were susceptible. If the country with the disease took steps to control it, there would be real benefits to the rest of the world, for control would reduce the risk that other countries would import the disease and spark an epidemic. No country could be

excluded from receiving this benefit. Nor would any country's consumption of this benefit reduce the consumption available to others. In this case, control would be a global public good. The obvious example would be control of a new disease, such as SARS.

Suppose now that control is achieved by means of a vaccine. Suppose, too, that rich countries vaccinate so thoroughly that the disease is eliminated in these countries but is endemic everywhere else. In this case, though prevalence of the disease would be near zero in the rich countries, a little extra control in one poor country would not be a global public good. The rich countries would not benefit because high levels of vaccination make them invulnerable to an epidemic triggered by imports. And the other poor countries would not benefit, because the disease is already endemic in these countries. An example might be measles.

As suggested by these examples, whether control of an infectious disease is a global public good depends on the circumstances. Most especially it depends on the vulnerability of countries to being harmed by imports.

An example of a programme supplying the regional public good of disease control is the Southern Cone Initiative—an agreement signed by Argentina, Bolivia, Brazil, Chile, Paraguay, Uruguay and Peru. The aim was to limit the cross-border spread of the vector transmitting Chagas disease—a regional disease involving a protozoan parasite, *Trypanosoma cruzi*, transmitted to humans by triatomine insects. After a long asymptomatic period, Chagas disease can cause organ failure, especially of the heart and digestive and nervous systems. According to Dias and others (2002, p. 605), the initiative was projected to cost $190–$350 million over 10 years (1991–2000). It has proved an economic success, with financial returns estimated at 30% for Brazil and more than 64% for Argentina.

Surveillance, notification and control

It is interesting that countries are not obligated under international law to control any disease. This presumably reflects two beliefs: first, that the countries with domestic cases have a strong unilateral incentive to control it, and second, that the countries with no domestic cases have strong incentives to protect against imports. Both presumptions are partially true. But only partially.

First, as suggested by the preceding discussion, in some situations control by one country confers real benefits on other countries. Put differently, if the costs of control were high enough, unilateralism could not be relied upon to supply enough control.

Second, control presumes identification of the disease, and identification requires surveillance. Just as countries have incentives to control too little, so they may have incentives to conduct too little surveillance. To take just one example, the BSE (mad cow) inquiry in the United Kingdom noted incentive problems in reporting surveillance of this disease.[4]

Of course, in some cases, the incentive to conduct surveillance may be strong. In August 1997 an outbreak of *E. coli* (*Escherichia coli* O157: H7) identified by the Colorado Department of Public Health and Environment was traced to a meat-processing plant in Nebraska. The company recalled 25 million pounds of ground beef—the largest meat recall ever. According to Elbasha and others (2000), the cost of the surveillance system to discover the outbreak would have been recovered if this discovery had prevented just 15 cases of infection. By comparison, a 1993 recall of just 25,000 pounds of ground beef was estimated to have prevented 800 cases of *E. coli*. While the benefits of surveillance may exceed the costs for some countries, the global benefits will be larger still, and in some cases the costs of surveillance will lie between the domestic and global benefits.

Third, protection against imports is costly. It essentially involves raising trade barriers. If control abroad were weak, trade barriers might be the best response but their use would still be costly. Except when the threat of importing a disease looms large, countries can gain by lowering trade barriers and avoiding the terms of trade externality of protection. But how accurately can a country assess the risk of disease imports? If it were notified immediately of all outbreaks, it could erect trade barriers only as needed. But the trade restrictions would be directed at the country suffering the outbreak, so the incentive for this country to notify is dulled. Making matters worse, countries at risk may have an incentive to overreact to the threat of imports, taking the opportunity to improve their terms of trade. This tendency to overreact only shrinks the incentive others have to notify.

Countries are obligated to notify the WHO of outbreaks under the International Health Regulations (IHR), the only legally binding international agreement on infectious diseases. The IHR also prescribe the maximum measures that can be taken to limit imports. But the IHR are inadequate for several reasons. They apply only to three diseases—cholera,

plague and yellow fever. (China was under no legal obligation to notify the WHO of the SARS outbreak.) Compliance with the IHR is poor—partly because of the incentive problems already noted. And they do not address the related incentive problems of underinvestment in surveillance and the ability to control a new outbreak. These require a basic infrastructure.

Surveillance is needed for new diseases such as SARS, emerging diseases and resistant strains. A surveillance system must do three things (Henderson 1993):

- Detect unusual cases—a task requiring both clinical and epidemiological expertise.
- Report its findings, through either formal or informal channels, to an organization or system capable of seeing broader patterns or trends.
- Investigate these unusual cases.

Investigation often requires special expertise—a facility few countries, and certainly few developing countries, can call on. Currently, that role is often played by the Centers for Disease Control and Prevention (CDC). Believing that the WHO could not fulfil such a function itself, Henderson (1993) argues that the CDC should be acknowledged officially as having this function. Essentially, investigation is a best-shot public good—one that the United States presumably supplies because it is better off supplying it than not, given that others do not supply it.

As Henderson (1993) explains, the institutional demands depend very much on the outbreak. A sudden increase in cases in a particular area is rather easily detected—such as an outbreak of Ebola virus. A more gradual increase in cases, dispersed over a wide area, is harder to detect—an example being the emergence of HIV. The CDC is effective at investigating sudden increases in cases, but Henderson argues that a network of internationally supported health centers is needed—with particular attention to densely populated areas in the tropics. As expressed by Working Group 2 of the Commission on Macroeconomics and Health (WHO Commission on Macroeconomics and Health 2002, p. 53), "Weaknesses in developing countries constrain the world's ability to detect and respond globally to the threat of infectious disease. This situation points to an interesting, and unresolved, feature of global public goods: the solution to their adequate provision and supply rests at local, national and sometimes regional levels."

Countries may respond to an outbreak by raising trade barriers—a matter not handled well by the IHR but that should be handled

adequately by the Sanitary and Phytosanitary Measures Agreement under the World Trade Organization (WTO). The most effective approach is to contain and control the disease at its source—rapidly. Developed countries likely have the capability to do so at home. Developing countries often do not. And because the benefits would be diffused throughout the global system, such assistance may not arise spontaneously (Giesecke 2003, p. 203).

Surveillance is essential not only for new diseases but also for old diseases that have been eradicated. In both cases, even one case could amplify into a pandemic. As noted by Lederberg (2002, p. 11), "Given the biological variability of vaccine strains, and the innumerable array of samples in frozen storage, it is not a question of whether a disease outbreak will occur in the post-eradication era but, rather, when and where."

Because of the problems with the IHR already highlighted, the regulations have been revised. The revisions, which will enter into force in June 2007, contain six improvements:

- A focus not on specific diseases but on events "posing a serious and direct threat to the health of human populations". Such a focus obviously imposes an obligation to report a new disease such as SARS.
- A requirement that states develop and maintain surveillance capacity and "report and respond effectively to public health risks and events potentially constituting public health emergencies of international concern" (Fidler 2004).
- A requirement that states notify the WHO of "events potentially constituting a public health emergency of international concern".
- Provision for the WHO to take account of informal sources of information, and not just information provided by official sources.
- Authorization for the WHO to determine independently whether an event constitutes a public health emergency of international concern.
- Authorization for the WHO to take steps to prevent or reduce the international spread of disease by such means as travel recommendations.

Notice that most of these changes reflect actions already taken by the WHO in the wake of the SARS crisis.

Elimination and eradication

According to the Dahlem Workshop on the Eradication of Infectious Diseases, eradication means the permanent reduction to zero of the worldwide incidence of infection caused by a specific agent. Essentially, it means that a disease ceases to exist in the wild. But eradication is not the same as extinction. The smallpox virus, for example, has been eradicated from nature but still exists in laboratories. Eradication is also to be distinguished from elimination—the reduction to zero of the incidence of disease in a defined geographic area.

Elimination provides a local public good: herd immunity. If a large enough fraction of a population is vaccinated, the rest of the population becomes protected because high vaccination rates break the chain of infection. An import may infect an unprotected person, but it would not trigger an epidemic.

Elimination also provides a benefit to other countries where the disease is no longer endemic. It breaks the chain of transmission.

Eradication of an infectious disease is a pure global public good. Every country benefits from it. But any country can also prevent eradication from being achieved. Right now the global polio eradication initiative risks failure after investing over $3 billion and involving some 20 million volunteers over 15 years. In the Kano state of Nigeria, Muslim leaders have claimed that the polio vaccine is tainted with the AIDS virus and sterility drugs—a global conspiracy against Islam. The Kano government declined to participate in a national immunization days programme in 2003, and the European Union then declined to pay for the national programme in Nigeria, believing the money would be wasted (Roberts 2004, p. 1,967). One consequence has been a leakage of the virus, with nine polio-free countries importing polio from Nigeria in 2003 (Brown 2004).

This underlines that eradication is a weakest link public good. It succeeds or fails depending on whether the disease is eliminated from its last holdout. The economics of eradication are interesting and important. If a disease is eradicated, not only is the number of infections reduced to zero but there is also no longer a need to vaccinate susceptible persons. That means every country can benefit from eradication: the rich countries that previously eliminated the disease and the endemic countries still suffering from infections.

This is sometimes misunderstood. For example, Working Group 2 of the Commission on Macroeconomics and Health claims that, "Although

Table 1.2 **Benefits and costs of smallpox eradication**

(millions of US dollars)

	Amount
Annual benefit to India	722
Annual benefit to all developing countries	1,070
Annual benefit to the United States	150
Annual benefit to all industrial countries	350
Total annual benefit	1,420
Total international expenditure on eradication	98
Total national expenditure by endemic countries	200
Combined total expenditure on eradication	298
Benefit-cost ratio of international expenditure	483:1
Benefit-cost ratio of combined total expenditure	159:1

Note: The benefit-cost ratio is found by dividing the annual benefit by 0.03 (3% discount rate) and dividing that number by the one-time expenditure estimate.
Source: Fenner and others (1988), pp. 1364–66.

all countries benefit, the enormous financial gains that accrued to the United States in the case of smallpox eradication, for example, were not matched by similar gains in most developing countries. The greatest beneficiaries were likely to be the developed countries that needed eradication to consolidate the gains of their national immunization programmes" (WHO Commission on Macroeconomics and Health 2004, p. 52). According to estimates in Fenner and others (1988, pp. 1364–65), this view is wrong: India gained more from smallpox eradication than did the United States (see table 1.2). True, the United States saved more in avoided vaccination costs, but India saved more in avoided infections costs.

Estimates of the benefits and costs of smallpox eradication are shown in table 1.2. The benefits, as just noted, reflect avoided vaccination and infection costs. These are annual estimates. Assuming that the annual savings would be realized forever and discounting future benefits at 3%, the present value benefit of eradication would be about $47.3 billion in 1967 US dollars.[5] The costs in table 1.2 are the additional costs over routine vaccination necessary to achieve eradication. Taking this cost to be a one-time expenditure, the benefit-cost ratio is 159:1 if all costs are included ($47,333/$298) and 483:1 if international finance is counted ($47,333/$98). International finance is the money given by industrial countries to finance smallpox elimination programmes in developing countries. These numbers are plainly extraordinary.

Because eradication is essentially an investment (Barrett and Hoel 2004), its economics can be unusually attractive. But there still are

incentive problems. Eradication may yield every country a windfall, but the last country to eliminate the disease would get only a fraction of the global benefit, and under some circumstances it may not pay this last country to eliminate the disease, even though the entire world would be better off if it did (Barrett 2003). This is especially so when countries are highly asymmetric, and the last country is a poor developing country. In this case, eradication will have to be financed by the rich countries or private foundations.

This is precisely how the smallpox and polio campaigns have been financed. For smallpox, international financing essentially paid to increase the control programmes already in place in endemic countries to a level sufficient to eliminate the disease domestically (this is the cost of $98 million in table 1.2). Some contributions were bilateral. Some were through a special fund, agreed to by a vote by the World Health Assembly. Some were voluntary. For polio the contributions are much greater. The total cost will exceed $3 billion, whether the effort succeeds or fails (WHO 2003). One difference between the two initiatives is the injection of private foundation funding. Rotary International has contributed more than $500 million, and the Bill & Melinda Gates Foundation and the United Nations Foundation have contributed more than $25 million each (WHO 2003).

Since eradication is a global public good, financing has been difficult, as might be expected. The incentives to free-ride are strong. Elsewhere (Barrett 2004) it is shown that the United States had a strong incentive unilaterally to fund the entire smallpox effort, and yet financing proved difficult. As explained by Fenner and others (1988, p. 423), financing "constituted a serious, continuing problem". One reason may be that each country preferred that others pay—and that enough effort was devoted to coordinating the burden-sharing problem. Another reason may be the lack of strong domestic political interests promoting financing. Though everyone would benefit from eradication, the benefit would be diffused (Barrett 2004).

The polio eradication initiative has learned from this, identifying the "fair shares" that countries should pay. And yet, financing has proved difficult (Aylward and others 2003, p. 48):

> [Of the 22 WHO Member States who are members of the OECD's Development Assistance Committee that makes up the community of 'traditional' ODA donors, only 16 have contributed to the eradication initiative. Of these, only seven contributed the equivalent or

more than their estimated 'share,' six are 'free-riders' in that they made no financial contribution to eradication, while the remaining nine contributed substantially less than their estimated 'share' of the total budget of $2,750 million dollars between 1985 and 2005.

The polio eradication initiative is underfunded by $130 million for 2004–05 (WHO 2003).

While the financing of polio eradication has been successful, the economics of polio eradication are not as attractive as the economics of smallpox eradication. Indeed, polio eradication may be technically infeasible in the sense that vaccination may need to continue even after wild polio viruses have been eliminated globally. The reason is that the live vaccine used to eliminate polio in developing countries—the oral polio vaccine, or OPV—is excreted into the environment by vaccinated persons and can revert to a pathologic state, causing the disease's re-emergence. Such outbreaks have already occurred several times. Partly because of this risk, industrial countries intend to continue vaccinating with the inactivated polio vaccine (IPV) indefinitely. But doing so compromises the economics of eradication.

Box 1.3 Vertical versus horizontal programmes: do they conflict?

While eradication can benefit every country, implementation of an eradication programme can also distract endemic countries that may have higher priorities. As noted by Aylward and others (2003, p. 47), "An often heated debate has flared between and within ODAs, academics, NGOs, and the United Nations itself as to whether the massive opportunity costs of eradication, particularly to conduct national immunization days, were simply too high to merit the production of this [global public good for health]."

The polio eradication initiative is a "vertical" disease-specific programme. It is distinguished form horizontal approaches that cut across diseases. Eradication may be best achieved by national immunization days, but basic health is better provided by the primary health care system.

In general, vertical approaches both weaken and strengthen horizontal systems. The Taylor Commission, convened by the Pan American Health Organization in 1995, concluded that polio eradication had "contributed positively to overall strengthening of health systems in the Americas" (Loevinsohn and others 2002, p. 19). Two follow-up studies drew mixed conclusions. One found that the "health system effects of polio eradication had been mostly positive but that there were 'threats' that had to be recognized explicitly and dealt with pre-emptively" (Loevinsohn and others 2002, p. 20). The other concluded that "polio eradication had not had a very significant impact, either positive or negative, on health systems" (Loevinsohn and others 2002, p. 20).

This evidence warns that pursuit of a global public good may undermine development. But the choice is not between one and the other. The challenge, rather, is to design vertical programmes in a way that supports horizontal health systems.

The current plan adopted by the WHO is to stop vaccination with OPV after global elimination has been certified. But such a policy runs the risk of reintroducing the disease. If OPV is then used to extinguish an outbreak, the problem will be compounded because opportunities for reintroduction of the disease will increase. If IPV is used, interventions will be costly—not only because the vaccine is more expensive to administer but also because it is less effective in suppressing outbreaks. For all these reasons, stopping OPV will prove risky. By contrast, continued vaccination of OPV may not be sustainable: once the disease is eliminated, there will be an incentive to divert resources to the control of other diseases.

Plainly, the polio eradication initiative must proceed carefully, and the current plan for ceasing vaccination may need to be reconsidered. A more important point to emphasize is that the World Health Assembly needs to be much more careful before embracing future eradication efforts. The feasibility of eradication needs to be demonstrated. Plans for the post-certification period need to be developed. And an agreement should be reached for financing such an effort even before the first dollar is spent. Since eradication succeeds or fails depending on whether the last case of infection can be isolated and future vaccination avoided, any eradication policy must project into the distant future before taking even a first step towards realizing such an ambition.

Limiting resistance

Many public health interventions develop resistance with (inappropriate) use, and so become less and less effective. Examples include resistance to antibiotics such as penicillin, antimalarials such as chloroquine, treatments for tuberculosis, and antiretrovirals for HIV; resistance by the malaria vector to DDT; and resistance by the hepatitis B virus and the pertussis (whooping cough) bacterium to vaccine. Interventions impose "selective pressure" on target organisms, causing them to adapt or die. The organisms that survive can pass on their genetic advantage, and so render the interventions less effective.

Resistance is a growing problem today for several reasons. The scale of interventions has increased, thus increasing selective pressure. The discovery of new interventions has slowed. And little action has been taken to stop resistance. In rich countries, resistance develops from over-

use of antibiotics. In poor countries, it develops from underuse of antibiotics, antimalarials and other medicines.

Because resistance creates an externality, we should expect too little to be done to slow or stop resistance by countries acting independently. But the incentive problem is more interesting than this. As noted in a recent WHO document (2002) on resistance to antimicrobials, resistance is a global problem, and a special one at that:

> No single nation, however effective it is at containing resistance within its borders, can protect itself from the importation of resistant pathogens through travel and trade. Poor prescribing practices in *any* country now threaten to undermine the potency of vital antimicrobials *everywhere* [emphasis added].

In other words, resistance is unlike disease control. A country that vaccinates against measles is protected from imports. A country that prevents resistance is not protected from imports of resistant strains.

Resistance can be slowed. When a single drug is used—and used widely over a long period—the chances of resistance developing can be high. Consider malaria. The antimalaria drug chloroquine, inexpensive and once highly effective against the *Plasmodium falciparum* parasite, began losing its potency in the 1960s. A substitute drug, derived from artemisinin, a traditional Chinese herbal medicine, is more expensive—and so is rarely used in Africa, where most malaria deaths occur. To slow or even stop resistance, a combination of artemisinin-based drugs must be used: a combination dramatically reduces the chance of a mutation conferring resistance. However, for the reasons mentioned previously, this intervention only works if it is applied universally. If just one country uses an artemisinin in monotherapy, resistant strains may develop and spread around the world, undermining the efficacy of the combination drug. Monotherapies using artemisinin are being used in Asia, threatening the spread of resistance globally.

What is the net benefit of adopting artemisinin-based combination therapies (ACTs)? According to Arrow and others (2004, p. 81), "It is impossible to assign a dollar value to this international public good, but it must include both the ability to treat hundreds of millions of cases of malaria with these drugs (over the number of years of extra effective life produced), and potential moderation of future R&D costs for first-line antimalarials." The cost of adopting ACTs is easier to

quantify. Arrow and others (2004, p. 101) estimate this cost to be about $300–$500 million a year.

Addressing this problem will likely require a centralized approach. The challenge is to make it one that both individuals and states will want to adhere to. To ensure compliance by individuals will require making the combined drug at least as inexpensive as the alternative, and doing that will require a subsidy. To ensure full international participation, the programme will need to be organized centrally, perhaps under the WHO or UNICEF (or both). Countries would need to pledge to rely on the combined drugs. If each country were assured that all others would use only the combination drug, the incentive for each to use only that drug would be increased.

It will nonetheless remain true that each country will receive only a fraction of the global benefit associated with fulfilling its pledge, and so it may be necessary to subsidize participation by some countries. Arrow and others (2004, p. 100) note that most "African countries are unlikely to be able to contribute large amounts directly to a global antimalarial subsidy", so they recommend that international assistance be made available. (Details for how this might be administered, and how the incentive problems of international financing might be corrected, are not addressed in their report.)

As with the other global public goods for health, there are important connections between the global and local levels—not only in creating the incentives discussed above but also in complementing this approach with environmental controls, such as using bednets, spraying walls with insecticide, draining breeding areas and so on.

Another connection is with a related public good: the creation of knowledge. When resistance can only be slowed, new drugs must be developed to substitute for the old line once it becomes ineffective.

Knowledge

One reason for the improvement in global health over the past century has been the availability of technologies such as antibiotics and vaccines, derived from knowledge about the underlying biology of infection. Other kinds of knowledge have also helped, including knowledge of the Guinea worm life cycle, which makes eradication feasible using only cloth water filters.

Knowledge has public good characteristics (Stiglitz 1999). One person's use of knowledge does not deprive others of the knowledge, nor can others always be excluded from certain kinds of knowledge—such as the knowledge of how and why to use water filters. Patented knowledge, of course, is exclusive by design, but patents are essential. If knowledge could not be patented, firms would have little incentive to invest in research and development. Though the pricing of antiretrovirals has been criticized—with some justification, as noted earlier—were it not for the patent system, these drugs would not be available in the first place. Weakening patent laws favours the current generation but harms the future.

Many vaccines were developed only to help particular countries or markets but have been widely used elsewhere. Developing countries have benefited hugely from the technologies developed by and for industrial countries. But this observation exposes another truth: that little research has gone into developing technologies to protect people against diseases endemic to the poor countries only—such as malaria, Chagas disease, African sleeping sickness and schistosomiasis. To prove the point, one of the great successes in public health in developing countries has been the elimination of river blindness (onchocerciasis) from many parts of Africa—a feat made possible using a drug (ivermectin, donated by Merck) developed for the veterinary market in developed countries.

One reason for the lack of innovation in tropical medicine is that patent protection in developing countries has typically been weak. Another is that patent protection would likely need to apply to a lot of developing countries to create strong incentives to innovate. Allied to this is the need for basic research into the underlying science—the kind of role performed by the National Institutes of Health in the United States. Here again, an international approach to tropical medicine research is likely to be needed.

A different approach is to make innovation an arm of development assistance. Michael Kremer's "Global Public Goods in Communicable Disease Control" in this volume has proposed using advance purchase commitments to supply the pull incentive for innovation. The basic idea is that if countries were committed to purchasing new vaccines at a price high enough to reward successful innovation, the pharmaceutical industry would innovate, the vaccines would be distributed and health in developing countries would improve. This approach may hold some promise but it also suffers deficiencies. One is that it is difficult for governments to make commitments (Schelling 1960). Another is that

the financing of the advanced purchase would itself be a public good and so would be vulnerable to free-riding. Numerous other proposals have been made, including modified "orphan drug" legislation and private-public partnerships (WHO Commission on Macroeconomics and Health 2002, p. 38). They suffer similar incentive problems.

Conclusions

This paper has identified several priority areas for action:

- A systematic review is needed of the gap in the global infrastructure for surveillance, especially of outbreaks of new diseases, and how this gap should be filled and financed.
- The IHR revisions are to be welcomed. The trade restrictions objective is now covered by the Sanitary and Phytosanitary Measures Agreement under the WTO, but this agreement applies only to the 147 WTO members. This leaves out about 50 countries. Because infectious disease control must be comprehensive, the IHR revisions will improve protection for all countries, even for the trade dimension.
- The revised IHR also affirm the international legal obligation of countries to notify the WHO of outbreaks or suspected outbreaks of any disease (even though modern communications allow outbreaks to be reported through informal channels). They also empower the WHO to issue global warnings directly, as the organization did in the wake of the SARS outbreak.
- A systematic review is also needed of the gap in resources available for responding to new outbreaks. It is much more efficient to control a disease at the source than to erect trade barriers globally to prevent its spread. The offer of such assistance would also increase the incentive for countries to report and for other countries not to overreact in their trade policies. Rules would need to be devised for the rights and obligations of states in allowing entry into their country of an outbreak response team, and for the team's rules of engagement.
- Full support should be given to the polio eradication initiative at this critical time, but this support needs to take account of the risks associated with the initiative. Full support should also be given to the Guinea worm eradication initiative, particularly interventions in the remaining war-torn endemic regions. But

before embarking on future eradication initiatives, a careful review is needed to establish criteria for selecting future candidates for eradication, to delineate the rights and obligations of participating states and to develop an effective financing mechanism. Eradication succeeds only if the last case can be isolated, so planning needs to extend to this last case—and beyond, given that certification, surveillance and possibly other interventions will be needed indefinitely.

- A review is needed of the design of vertical systems and of the balance of development assistance for the vertical and horizontal dimensions of health programmes (see box 1.3). International initiatives typically involve vertical programmes (disease-targeted programmes, for example). Public health in developing countries, however, is often better supplied by horizontal systems (basic public health infrastructure). Moreover, strong horizontal programmes aid surveillance and control in the event of new outbreaks, to the benefit of all countries.
- Resistance is already a problem, one that will get worse unless major changes are made in the use of drugs (and pesticides) worldwide. As with surveillance and eradication, a centralized approach is needed, particularly for the use of combination therapies. If just one country fails to cooperate in stopping resistance, all will be more vulnerable. In addition to establishing rules for slowing resistance, specific mechanisms will be needed for financing such efforts.
- A number of initiatives are under way to promote research and development for new vaccines and drugs needed by poor countries, especially in the tropics. A systematic review is needed of the effectiveness of these approaches in stimulating investment.
- Ways must be found to ensure the efficient distribution of essential drugs and vaccines, not just their efficient supply. The international pricing of pharmaceuticals is not a global public good issue, but it does have a bearing on the incentives for research and development investment and on the support given broadly to a liberalized trade regime.

Notes

1. Where resistance has a fitness cost, it may develop but would not survive—provided use of the drug were low enough.
2. Article 19 of the Constitution of the WHO authorizes the body to initiate treaty negotiations. However the WHO has exercised this authority only once—in 2000 when it launched political negotiations on the WHO Framework Convention on Tobacco Control. This agreement, adopted in 2003, will enter into force in February 2005.
Control of smoking is not a global public good. Smoking impairs the health of smokers and of people who consume their smoke second-hand; smoking is addictive (smoking now makes it harder for an individual to stop smoking in the future); and smoking is also a social activity (people are more inclined to smoke—and find it harder to quit—when others around them are smoking). There are thus a number of reasons why public policy may be needed to discourage smoking. But if one state bans smoking, the welfare of other states is pretty much unaffected. What makes smoking policy an international issue is primarily trade, including smuggling and advertising. If one state controls smoking—say, by imposing a very high tax on cigarettes and by banning advertising—the effectiveness of these policies may be undermined by the policies of other countries (see Taylor, Bettcher and Peck 2003).
3. Herlihy (1997) offers a more complex hypothesis of a singular event: the Black Death of 1348–49, an epidemic that cut the population of Europe by as much as 70% or 80%. His thesis is that the shock of this event "elicited a social response that protected the European community from comparable disasters until the present" (Herlihy 1997, p. 17). Loss of labour created incentives for factor substitution—of land and capital for labour, and of new technologies for old. Chiefly because of the Black Death, Herlihy (1997, p. 49) argues, "the Middle Ages were a period of impressive technological achievement." McNeill (1998) makes a more sweeping assessment of the role of disease in shaping development.
4. See www.bseinquiry.gov.uk/report/volume2/chapter4.htm.
5. Adjusting for inflation only, this is about $268 billion in current dollars. (The consumer price index inflator of 5.67 is taken from http://minneapolisfed.org/Research/data/us/calc/hist1800.cfm.)

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