Governance Implications of Emerging Infectious Disease Surveillance and Response as Global Public Goods

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Emerging infectious diseases (EIDs) are a continuing and serious threat to global health and welfare, but worldwide, country-level disease surveillance and response capacities are generally weak. These weaknesses can lead to late recognition of emerging pandemics and tardy and ineffective responses to these events, which in turn can lead to greater human and economic costs. This article applies a global public goods (GPG) framework to EID surveillance and response, and determines that viewing these activities through the GPG lens helps to explain why current weaknesses exist. As GPGs, EID surveillance and response are prone to collective action difficulties, with countries that act individually failing to achieve coordinated action for mutual benefit. All countries would be better off under a system of greater cooperation and provision of these goods but without better trust-building and properly structured international institutions, continued reliance on individual country-level decision-making only perpetuates the current situation. Solutions for achieving better provision of these GPGs include developing a better understanding of benefits vs. costs of global EID surveillance and response and implementing institutions that take advantage of the pre-existing incentives that countries already have to protect themselves from EIDs.

INTRODUCTION

Emerging infectious diseases (EIDs) are a persistent threat to the health and welfare of people and countries around the world.[1] Research has indicated that diseases have emerged for centuries and we can expect new diseases will continue to emerge in the future because the drivers of emergence continue and have even intensified over time.[2] The expanding body of scientific evidence demonstrating the continuing and likely future impacts of EIDs, along with the world's recent experiences with high profile emergences of disease such as HIV/AIDS, severe acute respiratory syndrome (SARS), pandemic influenza A(H1N1) or "swine flu", and H5N1 avian influenza ("bird flu") have generated increased amount of popular and academic attention, as well as growing political priority, focused on the global problem of EIDs.

Disease emergence events such as SARS and influenza have shown EIDs can lead to significant impacts not only through the morbidity and mortality they cause, but also through their capacity to interfere with economic activity and population movement. The global economic impact of SARS has been estimated at $30 billion to $100 billion, or about $3 million to $10 million per individual case of the disease.[3] Estimates of the potential impact of more severe disease events, such as the emergence of a highly pathogenic pandemic strain of influenza, are catastrophic: one analysis estimated the mortality following the emergence of a hypothetical 1918-influenza-like virus today to be 62 million deaths, with over 90 percent of these deaths concentrated in the developing world.[4] Separately, the World Bank has estimated 71 million people worldwide could die

following the emergence of a severe influenza pandemic, potentially leading to global economic losses exceeding $3 trillion, or about 5 percent of the world's GDP.[5] Other recent EIDs have been less associated with economic impacts but have taken a horrendous human toll, the most notable of course being HIV. This virus, from the time of its detection in the early 1980s through 2006, killed at least 25 million people and currently infects over 33 million people, with most of the burden falling on poor countries.[6] In summary, there are many indications of serious, potentially enormous consequences from EIDs and every reason to believe that more disease emergences will occur in the future.

Given this background, one might expect that countries around the world would want effective systems of surveillance and response that can mitigate, and maybe even prevent, large-scale health and economic impacts following disease emergences. After all, public health has a ready set of well-known, proven solutions that can reduce the impacts of EIDs. Where surveillance and response activities are well-funded and implemented, the impacts of disease are controlled; where they are ignored or only minimally supported, disease impacts are much greater. There is little dispute that supporting more comprehensive surveillance and more robust response capacities will lead to lower impacts of EIDs on human health and welfare. If we take this observation as a starting point, then some key questions for the global community include: are current global capacities for surveillance and response sufficient given the magnitude of character of the EID threat? If not, then why not? What can be done from a global governance perspective to promote more efficient provision of EID surveillance and response globally?

The remainder of this article attempts to provide insights into these questions. After first defining my use of the term "emerging infectious disease", I briefly characterize the current state of EID surveillance and response capacities. Then, I describe the "global public goods" (GPG) concept and evaluate whether it is applicable to the provision of EID surveillance and response. Finally, I consider the implications that considering EID surveillance and response as GPGs has for global governance of these activities.

DEFINING EMERGING INFECTIOUS DISEASES

The term "emerging infectious diseases" has now become commonplace among academics and public health practitioners, but usually remains poorly-defined or not defined at all when it is applied. I do not hope to advance a perfect or universal definition for the concept here, but only wish to define more clearly what *I* mean when I use the term.

The first widely recognized attempt at defining the concept came from the Institute of Medicine's (IOM) influential 1992 publication titled *Emerging Infections: Microbial Threats to Health in the United States*, which defined EIDs as "new, reemerging, or drug-resistant infections whose incidence in humans has increased within the past two decades or whose incidence threatens to increase in the near future."[7] Several years later, the US Centers for Disease Control and Prevention (CDC) defined EIDs as: "diseases of infectious origin whose incidence in humans has increased within the past two decades or threatens to increase in the near future."[8] Academics Woolhouse and Dye, criticizing these definitions as lacking rigor and operational

applicability, have suggested yet another definition: "an infectious disease whose incidence is increasing following its first introduction into a new host population or whose incidence is increasing in an existing host population as a result of long-term changes in its underlying epidemiology."[9]

All of these prior attempts at defining the term have one common feature: they group together those diseases which are already characterized and circulating to some extent (I term these *endemic* infections) with newly emerging, previously unknown human diseases. While there may be a good rationale for combining these classes of diseases together, as doing so captures the broader threat posed by infectious diseases in the modern world, for the purposes of this analysis a more narrow definition is more useful for reasons which will become clearer as we discuss EIDs as GPGs. Therefore, for this article, I define EIDs to mean "*newly identified human diseases with the potential to spread to most countries*." The remainder of the paper will apply the term EID in this sense, while known infectious diseases, which may be increasing or not, are termed *endemic*.

CURRENT GLOBAL CAPACITY FOR EID SURVEILLANCE AND RESPONSE

In this section, I briefly consider the effectiveness of the EID surveillance and response capacities, both at the national level and the international level. *EID surveillance* is the set of activities undertaken to identify and characterize new infectious disease threats quickly, comprehensively, and accurately. In defining EID response I find it useful to consider two broad categories of response, the *public health response* and the *technical/science response*. By *public health response* I refer to the epidemiologic work needed to verify and characterize an outbreak and the application of public health measures that have the goal of reducing transmission of the disease thereby preventing as many cases as possible. This might include pharmaceutical interventions (e.g. drugs or vaccines when they are available) and/or non-pharmaceutical measures (isolation and quarantine, border closures, etc.). By *technical/science response*, I refer to the laboratory-based effort directed at characterizing the newly emerging disease agent, and the subsequent development of specific diagnostic tests and research and production of disease countermeasures such as vaccines and drugs effective for treating, preventing or containing the EID. While I will discuss these two types of responses somewhat separately, the division is artificial in practice and there is no doubt the two dimensions are related, complementary, and carried out in parallel during an actual EID event.

National Level-EID Surveillance Capacity

Effective EID surveillance requires constant information-gathering covering all individuals potentially at risk for a newly emerging disease and encompassing all geographic regions. National governments, through their application of resources and their policy decisions, remain the primary determinant of the quality and timeliness of EID surveillance information within a nation's borders, but private companies and health care providers, non-governmental organizations, and media, among other actors, are also active participants in EID surveillance.

Even the most cursory glance at EID surveillance systems worldwide indicates a strikingly varied level of quality. No country can boast a "perfect" EID surveillance

system, and even the richest countries come under criticism and scrutiny for their sometimes underfunded, disorganized systems.[10] Still, the most striking characteristic of the set of national surveillance systems is the gap in the quality of these systems between rich and poor countries.

The factors hindering effective EID surveillance are many. Most countries, particularly poor countries, suffer from a persistent lack of basic infrastructure – the physical capital and human resources necessary for surveillance. In 2004, 37 countries had overall per capita health expenditures less than $10 per year – far less than the $40 per year recommended by the Commission of Macroeconomics and Health as the minimum level of health funding needed to provide adequate primary health care.[11] Investment in disease surveillance-specific capacity in these countries comprises only a small fraction of this already tiny amount. One indicator of the lack of surveillance is that even the most basic surveillance information, the "vital statistics" of births and deaths, is missing for most of the world's population. In 2007, 70 percent of the world's populations lived in areas where vital statistics registries were inadequate, and that percentage has not improved over the last four decades.[12] A recent study found "since 1990 74 percent of 152 low-income and middle-income countries had no [vital statistics] data, and another 16 percent were judged to have poor-quality data."[13] Two-thirds of the world's 57 million deaths go unregistered.[14] Another factor weakening EID surveillance in many countries is the tendency to implement vertical, disease-specific surveillance systems instead of systems that look more broadly at infectious disease threats. Narrowly focused surveillance systems often have little overlap or cross-communication, and in fact these systems may compete with one another for limited funding and personnel, leading to a disjointed and poorly-functioning overall EID detection system.[15]

The lack of national capacity for disease surveillance has been noted by countries themselves and by the World Health Organization (WHO). WHO has written: "there is gross under-investment in this system... it depends on strong, capable, and transparent national systems, which again are the subject of under-investment."[16] In 2008 the UK government summarized the state of international infectious disease detection and control capacity this way:

> In many developing countries surveillance of infectious disease is not routine, nor can there be complete reliance upon the diagnoses given nor the cause of death. In developing countries epidemiologic studies are not routinely conducted thoroughly in connection with outbreaks to identify the source. Improvements in capacity within countries is still the pre-requisite for good diagnostics and surveillance and consistency of data.[17]

International-Level EID Surveillance Capacity

Under current international law, the WHO is the global coordinating body for disease surveillance and has taken on this role very prominently since at least the 2002-2003 SARS outbreak.[18] In fact, between 2001 and 2008 the WHO reported its surveillance efforts identified 2,415 unique infectious disease events worldwide that met its "importance" criteria, and the organization's staff verifies about 300 of these events every year.[19] The WHO remains the only organization with the international legal mandate, the legitimacy, and the technical capacity to serve in this role. Even so, the

organization suffers from chronic funding shortages and rigid "earmarked" expenditure limitations, so that its contributions are stretched thin over its six regional offices and 140 country offices as demands have grown.[20] The WHO has even described itself as a "strong network which is well structured", but also one that is "inadequately staffed, especially at the country level."[21]

Clearly, the WHO is an important surveillance resource and serves as a critical supporter for the global EID detection system. Still, it relies heavily on country reporting of disease events and many countries lack efficient surveillance systems. The recent broadening of the WHO's mandate under the revised International Health Regulations (IHRs) allow it to utilize non-governmental surveillance data. While this is important for the global system, it has not entirely solved the problem and important gaps remain even after adding these "informal" sources of information. For example, researchers from HealthMap (a prominent aggregator of disease outbreak information and an important source of EID information for the WHO and others) found "a clear bias towards increased reporting from countries with higher numbers of media outlets, more developed public health resources, and greater availability of electronic communication infrastructure."[22] Their study found that from 2006-2007 there was not even a single disease report identified through HealthMap for the Democratic Republic of Congo or the Central African Republic (among other countries). In contrast during this same period the two most frequent HealthMap-contributing countries, the United States and the United Kingdom, logged 4,351 and 1,018 reports respectively. Clearly, effective global surveillance requires strong national and local systems.

National-Level EID Response Capacities

Just as the case with surveillance, capacities for both the EID *public health* response and *technical/science* response vary dramatically between countries. In general, rich countries have a greater ability to implement both types of responses while poor countries have a more limited response capacity. At the heart of this inequality is a health resource gap between the rich and poor. According to one study:

> Funding for health ranges from "$22.60 per year in low income countries to $2,841 per person per year in high income countries – a hundredfold difference. Access to a physician ranges from four physicians for every 10,000 people in poor countries to 28 physicians for every 10,000 people in wealthy countries ...in many countries access to care is simply not adequate.[23]

The WHO found that in general, developing country capacity for outbreak response is severely lacking, writing "Presently, there is a little capacity to identify and to have access to experts (epidemiology/laboratory), poor knowledge about which specimens to collect and how to ship specimens, there is a shortage of epidemiologists and laboratory capacity is poor."[24] Not surprisingly, given these constraints many poor countries have a severely limited ability to mount effective and timely *public health* responses to EIDs.

Inequalities are perhaps even greater in *technical/science response* capacity. While the technical/science capacity of advanced infectious disease laboratories in rich

countries to identify and characterize infectious disease agents has grown remarkably over the last few decades,[25] access to this capacity in poor countries is extremely limited.[26] Poor country capacity to perform molecular analyses of infectious disease agents is severely lacking,[27] and even basic laboratory capacity is limited, as indicated by a review of laboratories in Africa that found there was approximately "1 microscope per 100,000 population in Malawi, with almost one half of these not in use or in need of repair. Skilled [laboratory] personnel are scarce."[28] A recent paper on tropical infectious disease research funding found that of approximately $2.5 billion spent on such research in 2007, developing county expenditures accounted for only 1 percent.[29] Further highlighting this unequal distribution of technical/science capacity, a 2005 World Bank report found that between 1980 and 2000 the number of patents filed (a measure of research and development leading to innovation) by high-income countries was about 5 per 1,000 persons while the equivalent number for low income countries was about 0.001 per 1,000 persons, a greater than 100-fold difference.[30]

International EID Response Capacity

The WHO has an important facilitating role in both the *public health* and *technical/science* dimensions of EID response, but the IHR places the development of response capacity squarely on member states, not on the WHO. As for the *public health* response, according to the IHR countries must "develop, strengthen and maintain...the capacity to respond promptly and effectively to public health risks and public health emergencies of international concern" (PHEICs).[31] The IHR allows the WHO to directly assist if invited by a member country, saying "at the request of a State Party" the WHO can provide "technical guidance and assistance."[32] During PHEICs the WHO is authorized to assist countries to "mobilize international assistance."[33] The network of institutions and professionals upon which the WHO relies on for assisting in a response is organized under its Global Outbreak Alert and Response Network (GOARN) system – sometimes referred to as the "global disease fire brigade".[34] Since its foundation in 2000 through 2007 GOARN has mobilized over 550 experts to respond to 97 health events in 63 countries.[35] So, the organization does not have the funding nor the manpower to provide much more than a basic level of assistance, but instead relies on its country-based partners to contribute response resources that it then coordinates in conjunction with the requesting country.

On the *technical/science* response side there is little truly *multilateral* capacity as almost all scientific resources are controlled and directed by national and local-level governments, NGOs, private companies or academic institutions. The WHO does not have a "central global laboratory", but rather supports laboratory infrastructure and capacity building in many countries and relies on its network of "collaborating centers" for scientific contributions. Likewise, the WHO does not own or control any large-scale medical device or pharmaceutical manufacturing assets. Instead, the organization assists by coaxing and coordinating the international scientific endeavor by partnering with public and private scientific organizations and private pharmaceutical firms worldwide. This have proven to be a difficult job in the context of previous EIDs such as the recent influenza A(H1N1) outbreak because international distribution of technological innovations such as diagnostic tests and countermeasures (i.e. drugs and vaccines) is restricted under current intellectual property laws.[36] Poor countries, lacking

the resources to purchase the patent-protected goods or develop the goods themselves, tend to have little or no access to them, further hampering their ability to respond effectively.

In summary, the global capacity to detect and contain newly emerging diseases is limited and disjointed, and a massively unequal distribution of national-level capabilities exists. The skewed distribution of capacity runs counter to the truly global, equal opportunity threat of EIDs, but why might this be so? The GPG framework, examined in the next section, may help explain the current situation and offer insights as to how the situation may be improved.

EID SURVEILLANCE AND RESPONSE AS GLOBAL PUBLIC GOODS

Pure *public goods* are those goods that are both *non-rival* (one consumer's use of the good does not interfere or detract from another's use of the good) and *non-excludable* (once produced, no party can be excluded from consuming the good). Classic examples of public goods are national defense, clean air, and a lighthouse used to warn ships at sea. Public goods are also characterized by *externality* effects. *Externalities* refer to economic, social, or other impacts (which can be positive or negative) that occur, affecting actors not directly involved in the production or consumption of a good. In other words, parties producing or consuming goods may not necessarily bear all costs or reap all benefits associated with them, and instead some costs or benefits can be accrued by other parties. Because of these unique characteristics, public goods are commonly associated with *market failures*, in which the goods are provided at sub-optimal levels or are not provided at all in the absence of intervention or regulation.[37] Governments usually enforce regulations or directly provide public goods: for example, governments collect and appropriate taxes to pay for national defense, and governments regulate firms' pollution levels to protect clean air and water. Those public goods that affect all (or most) countries around the world are known as *global public goods* (*GPGs*). The same market failures and collective action problems that exist in the provision of public goods at the local and national levels apply to GPGs.[38] Outside national borders though, there is no "global government" to correct global market failures.

Three general classes of GPGs have been identified, each with different implications for the kinds of institutions and governance most effective in achieving their optimal provision: *single best effort* (also known as "*best-shot*"), *weakest-link*, and *summation*.[39] *Single-best effort* GPGs are those whose overall production is based solely on the level of the greatest single contribution. An example would be discovery of an effective vaccine for HIV/AIDS, because once an effective vaccine is discovered all countries benefit from this success and no further discoveries are necessary (theoretically at least).[40] In contrast, *weakest-link* GPGs are those in which the total level of GPG production is based solely on the lowest individual contribution level. An example of a weakest-link GPG is disease eradication, as achieving eradication requires that every last country be successful. A country unable or unwilling to eliminate a disease within its borders jeopardizes the entire eradication effort.[41] Finally, a *summation* GPG is one in which individual country contributions added together determine the total level of production of the GPG. An example is averting global warming through reducing countries' carbon emissions. The global level of carbon production is the sum of the emissions of all countries, and a reduction made by one

country only reduces global level by that contributed amount. Only when many (or all) countries decide to reduce their emissions cooperatively does a meaningful global reduction in carbon emissions take place.

Endemic vs. Emerging Infectious Diseases

Previous work has already partly examined the application of the GPG concept to the problem of *endemic* infectious disease.[42] Several authors have concluded the GPG concept has only a very limited or no application to the problem of endemic disease. For example, Smith et al. determined the GPG concept is "clearly limited as an organizing principle" for communicable disease control.[43] Kremer concluded: "Cross-border benefits of disease control are typically small relative to the within-country benefits...[therefore] disease control is largely a national, not international, public good."[44] Barrett echoes this point in his analysis of incentives to combat malaria, a disease endemic in many poor countries but not rich ones: "big, rich and powerful countries – the countries that take the lead in supplying global public goods – do not have the incentive to undertake [malaria control abroad]...as they eliminated malaria within their borders decades ago."[45] The same reasoning can be applied to any number of other endemic diseases of poor countries which have been mostly or completely eliminated as health threats in rich countries. The GPG framework is not easily applicable to these endemic diseases because they pose little or no cross-border risk – i.e., they are not *global* so detecting them and controlling them are not GPGs.

It should be noted though, that diseases which can be *cost-effectively* eradicated comprise a small group that can be differentiated from diseases in the "endemic" category discussed above (*eradication*, the worldwide reduction of new cases of a disease to zero, is not the same as *elimination*, which refers to the reduction of cases of a disease in a specific geographic area to zero) There are only very few diseases thought to be technically eradicable at this time, but the eradication of a disease that only exists as a threat to poor countries is in fact a classic example of a global public good, as mentioned above.[46] For example, the campaign to eradicate smallpox was started when the disease had already been eliminated from the rich countries, and the ultimate success of the effort stands as a massive global achievement, albeit one that almost did not occur because of a tight budget and continual funding shortfalls stemming from a lack of enthusiasm and support from international donors, even as the world closed in on the eradication goal.[47] Should the current effort to eradicate polio succeed, it would be another staggering global victory and represent another global public good achieved. Still, there are currently very few diseases for which eradication could even be considered, making this group a very select one indeed.

In contrast to the case of most endemic diseases, the unique characteristics of EIDs as I have defined them make the GPG concept much more applicable to their detection and control. EIDs as they emerge can theoretically be contained at their point of origin thus never becoming endemic anywhere. Such containment prevents cross-border spread in the first place and provides a unique, possibly very powerful incentive for countries that do not face the disease. Consider an extreme (and granted, unrealistic) case: let us say we are able detect and stop the emergence of the next pandemic after a single human infection. The benefit derived from extinguishing the EID at its source extends to all countries that would have experienced cases in the absence of early

detection and control measures. The global benefits of this early identification and control over an emerging disease are akin to *eradication* of an existing endemic disease – except in this case you have "eradicated" the disease before it even begins. Even in the more realistic case where an EID cannot be detected immediately and completely contained at its source, the EID's impact could be reduced significantly through interventions undertaken in the country (or countries) of emergence, which could reduce the likelihood other countries would import the disease, or could at least reduce the overall number of imported cases or lengthen the time that a country has to build up defensive measures. These characteristics make the GPG concept more applicable to countering EIDs vs. endemic diseases.

EID Surveillance as a GPG

What *good* does surveillance produce? When effective, it produces timely information or knowledge about an EID. Surveillance information is globally *non-rival* because use of knowledge by one country does not restrict its use by another country. On the other hand, EID surveillance is *non-excludable* only when there is transparent international reporting of the information. Where there is a lack of transparency, or where reporting is incomplete, surveillance is *partially-excludable*. For example, if a country is able to use surveillance to identify an EID outbreak inside its borders but does not share this information, it demonstrates an ability to control access to the knowledge that its surveillance system produced; it has *excluded* potential users from the information. Such actions restrict the GPG nature of EID surveillance. EID surveillance has important global *externalities*. Timely knowledge of a disease outbreak is extremely valuable not just to the country experiencing the outbreak, but for all countries that could potentially be affected by the disease.[48] One can contemplate a world in which there is a single country with no domestic surveillance capacity while all others have effective surveillance systems in place. If a new disease emerges in the country lacking surveillance, all other countries face the threat of importing the disease despite the fact that they each have an effective domestic surveillance system. This is the *negative externality* of poor surveillance – the disease spreads from the origin country without the possibility of a timely response to contain it. On the other hand, effective surveillance can provide a *positive externality* to all other countries at risk (assuming transparency). If an EID emerges in a country with good early detection capacity, then a timely response might be undertaken that can contain the outbreak quickly or at least reduce the impact of the outbreak, hopefully sparing infections and avoiding international spread.

Given these characteristics, EID surveillance meets the criteria for being a GPG, and we can consider the lack of effective EID surveillance (outlined above) as a global "market failure" that should be addressed. Individual countries make independent decisions about whether and how much to invest in their surveillance capacities after considering the costs and benefits. Some governments have significant resources available and place a high priority on surveillance and therefore invest in their domestic EID surveillance systems. Other countries have limited resources and place little priority on EID surveillance, consequently providing little or no support for it. The problem is that EIDs appearing in one country do not just threaten that country alone – they threaten all countries around the world. When a country chooses not to invest in

effective surveillance after weighing its own costs and benefits, all other countries are placed at greater risk of suffering the consequences of an EID outbreak emanating from the poorly prepared country. Countries do not take into consideration the additional benefits surveillance provides to the rest of world – i.e., the external benefit to other countries that EID surveillance can provide. As there is no super-national authority that can mandate or administer surveillance activities by individual countries and incorporate global externality benefits, each sovereign nation retains the right to determine its own level of investment and we are left with what we have now – a patchwork of highly unequal systems of surveillance.

What about the *kind* of GPG that surveillance represents? Sandler and Arce wrote that "surveillance of outbreaks, which allows for rapid reaction to isolate the disease before it spreads...abides by a weakest-link technology."[49] This line of reasoning posits that because an EID can emerge anywhere, the absence of good surveillance in any country puts all other countries at risk. Therefore, disease surveillance is only helpful when it exists in all countries. But framing EID surveillance as a weakest-link GPG presents a very extreme view about how its benefits are accrued globally. Take as an example an international system consisting of 100 countries in which all of them, save for a single stubborn country, have effective EID surveillance systems. Is it realistic to posit that no benefit at all comes from the investments made in surveillance in the other 99 countries? Ninety-nine effective surveillance systems out of 100 would surely bring benefits above no surveillance at all. In other words, EID surveillance is not as rigidly a weakest-link GPG as disease eradication. Still, the reasoning presented in this article, along with Sandler and Arce's previous discussion of it, indicate that surveillance for new diseases demonstrates characteristics of a weakest-link good. It may be more applicable to consider surveillance as a *weaker-link* GPG,[50] which refers to the less-strict form of the weakest-link good corresponding to one in which the smallest country contribution has the largest effect on overall production, but for which other contributions still provide a positive, but marginally lower, benefit.

EID Response as a GPG

Public Health Response: As discussed above, if a new disease is only of a regional or local concern, a non-threatened country has little incentive for providing its support for public health response abroad. For the subset of EIDs presenting a true global risk, an important question in regard to the response GPG is: *at what point is the disease first detected?* When new, threatening diseases are identified while still affecting only a circumscribed geographic area or small risk group, then powerful incentives to contain the EID in the affected area or group before it spreads further will be present. This scenario fits a *single-best effort* response, because it is in every country's best interest to support a response to the EID at its point of origin but it is theoretically not important which country (or countries) actually provides the resources, only that the response is successful; when this is done all countries benefit. The benefit is particularly clear when the disease is contained and no others have to confront it, but there would also be benefits to mitigation without complete containment.

In theory, as a single-best effort good, the country (or countries) best able to mobilize the necessary assets (epidemiologic and clinical expertise, stockpiled countermeasures, etc.), would have the incentive to provide the public health response

in this scenario. In reality though, EID response relies on the capacity being present in the country of emergence, because each country remains sovereign and a response cannot be mobilized entirely from resources external to the country of emergence regardless of the incentives. Sovereign nations are unwilling to turn over response inside their borders to external actors. The IHRs contain language supporting the notion of an internationally supported response, but the regulations are also clear that external resources can only be put to work in countries experiencing a health event *upon the* request of the country and with its ongoing permission. Therefore, continuing the status quo of allowing poor response capacity in many developing countries will likely continue to result in failures to contain or effectively mitigate emerging diseases.

Under a different scenario –detection of the EID occurs after it has already become widely disseminated geographically – the response takes on a *weakest-link* character. That is, when a disease is identified only after it has started circulating in multiple countries, an effective response must be provided in *each country* for the overall response to be effective. If even one country fails to contain the EID in this scenario, all countries will remain at risk. If the response to a geographically-distributed EID fails, the disease may become entrenched, eventually resembling an endemic infectious disease. In other words, at some point a widely disseminated EID ceases to be a GPG problem, losing the unique incentives that were present when it first emerged. This is the situation that describes the global experience with HIV/AIDS – at one point it could have been contained or more effectively managed with a proper response, but it is now an endemic disease problem for each country around the world.

Technical/Science Response: The generation of scientific/technical knowledge is considered a quintessential *single-best effort* global public good. Sandler says "the discovery of a cure for a disease is an example of the best-shot technology...other examples include the achievement of a scientific breakthrough ...The race to find a cure for Ebola, AIDS, and antibiotic-resistant tuberculosis...adhere[s] to a best shot technology, where the first over the line wins for everyone."[51] So, when an EID is identified, countries will feel the need to fill critical information gaps, trying to learn as much as possible, as quickly as possible, about the agent causing the threatening disease. Only the effective application of scientific and technical research can generate the necessary knowledge so a pre-existing capacity to perform such research would be required. The discoveries that result from this research are non-excludable and non-rival in nature, and therefore they are GPGs. Because providing single-best effort GPGs requires only a single actor (or only a limited set of actors), whenever there is an overwhelming incentive to discover the answer to a pressing scientific question ("what causes this new disease *x*?") there will be an actor willing to provide resources for the research. In other words, when the need for the knowledge is intense, there is likely to be at least one country that will make the required effort to supply the GPG. As Barrett writes, "When a multiple of states have the incentive to supply a global public good, we can be pretty sure that the good will be supplied. What we can't be sure of is which country (or countries) will supply it."[52] If multiple countries are interested in finding answers to vexing scientific questions about an EID, the research will be done by someone, or perhaps several working as a group. To a large extent, this has been the world's experience with SARS[53] and influenza A(H1N1), as rich powerful countries with the research capacity have invested their resources into doing the required research with

little attempt to wait for the participation of less-developed countries. As with other single-best effort GPGs, though, when multiple groups are involved, a coordinating mechanism or body is helpful in reducing duplication of effort and avoiding conflicts between the groups or countries.

DISCUSSION AND IMPLICATIONS FOR GOVERNANCE

I argue that the current level of provision of EID surveillance and response is low and likely to be inefficient in the face of future EIDs. Ultimately, a more thorough and detailed economic analysis of the costs and benefits of investing in surveillance and response that is beyond the scope of this article would be required to fully investigate efficient levels of provision for these GPGs. Such an analysis would help countries and multilateral institutions shape the most cost-effective policies and support optimal provision of the GPGs. An important reason for the lack of a more robust coordination mechanism for global public health action may be an incomplete understanding of the real benefits that could be realized from more coordination, along with a natural tendency for countries to prefer pursuit of internally-focused defensive health measures vs. supporting outwardly-focused, preventative international measures. The vision of many countries remains, for the most part, circumscribed within domestic borders with little recognition of the potentially powerful but currently unrealizable benefits that might be gained from true, globally coordinated actions to combat newly emerging diseases. Shedding light on the potential benefits through further analysis of this issue might help shape country policies to be more rational and efficient from a global standpoint.

Correcting the global market failures identified here ultimately requires improvements in the capacity of poor country health systems to detect and respond to disease events. EID surveillance is an important and undersupplied GPG because the containment/mitigation of an emerging disease is most probable (and therefore benefits are greatest) when it is detected early, but the existing capacity is low in poor areas. Rich countries may actually be *better off* – individually and collectively – by subsidizing poor countries for these activities given that pandemic diseases can (and do) emerge from the developing world that negatively impact developed countries. Still, without an effective institution or trustworthy mechanism to foster greater subsidization of EID surveillance, the current status quo is likely to continue. The IHRs as they stand now have the *intent* of performing this function, but this regime is insufficient in its current form to realize these potential global gains from better EID surveillance and no attempt at outlining a functional mechanism has so far been included in the agreement. Should increased support for surveillance be forthcoming, there could be substantial programmatic issues to contend with, including how to train and equip enough quality personnel, ensure country needs and desires are heard and incorporated into improvements, and how to develop the human resources needed while not exacerbating the out-migration of health workers from poor countries to rich ones.

Another factor to consider is that the ultimate goal of earlier detection through better surveillance is to ensure that an effective EID *public health* response is provided on a timelier basis. If countries are unable to effectively respond to an emerging disease due to a lack of capacity, then regardless of how early an EID is detected, it will not be controlled and any potential benefits from better surveillance would be squandered. The

containment of a future EID at its point of origin – a response outcome with a potentially great global benefit – is likely to be challenging, but without pre-existing response capacity present in a country where a disease emerges, containment may never even be a possibility. Therefore improved surveillance must be linked to effective response, as the two activities are inextricably linked; an over-emphasis on improving surveillance capacities without a commensurate improvement in response capacities (or vice-versa) may in fact not be the most beneficial path.

Regarding the *science/technical* response, given the single-best effort nature of knowledge-generation and the incentives that highly advanced countries are likely to perceive when threatened by a new disease, the most efficient provision of the science/technical response is likely to come from having only a limited number of motivated and well-resourced developed countries engage in these activities. High efficiency in the science/technical response is realized when the country with the greatest scientific capacity (and the incentive) to perform the research is the one that undertakes the task. In reality, the best approach will likely include teams of scientists from different countries working on the scientific problem, but the principal idea is the same: the countries with the resources best suited for the research task can efficiently provide the science/technical response to EIDs, the research and development needed to develop critical, time-sensitive diagnostics, drugs and vaccines. The most challenging global cooperation aspect of the science/technical response provision likely comes *after* the diagnostics and countermeasures have been developed, when these goods need to be produced in sufficient quantities and provided to countries in need. As we saw with the 2009-H1N1 influenza pandemic, vaccine production was extremely limited and very few countries had timely access. An institution that ensures enough response tools and countermeasures are produced for and distributed to affected countries, including poor ones, is important to ensure public health preparedness and response globally. Currently no such mechanism exists, other than a flawed TRIPS agreement that has so far hindered the movement of EID countermeasures. Large differences in access to important response tools, dramatically illustrated in the context of HIV/AIDS, hinder realization of the full global benefits of coordinated response.

Further questions in this topic area clearly remain, so it is hoped that this paper prompts further research and analysis of the issues of EID surveillance and response as GPGs. We already possess much of the knowledge and capability to detect and protect ourselves from the next great pandemic, but we have so far failed as a global community to successfully apply these resources optimally. By taking advantage of already existing incentives that countries have to protect their populations, we could develop better institutions and policies that reduce the health and welfare effects of future emerging diseases.

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