

# Infectious Diseases, Non–Zero-Sum Thinking, and the Developing World

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**ABSTRACT:** Despite some improvements in the health status of the world during the last few decades, major obstacles remain. Improvements in health outcomes have not been shared equally among countries and poverty is clearly the main reason. Infectious diseases, which remain the major cause of death worldwide, are an incalculable source of human misery and economic loss. In fact, 25% of all deaths and 30% of the global burden of disease are attributed to infectious diseases. Unfortunately, more than 95% of these deaths, most of which are preventable, occur in the developing world, where poverty is widespread. The 3 major infectious disease killers in these countries are HIV/AIDS, tuberculosis, and malaria. The principles of social justice and health as a human right in the developing world have been advocated as the main justification for health assistance from rich to poor countries. Although we do not disagree with this, we argue that a strategy that emphasizes the shared benefit to rich and poor countries would facilitate this process. We propose that the accomplishment of these challenging tasks should be viewed from the perspective of game theory, where the interests of the parties (in this case rich and poor countries) overlap.

## Health, Development and Infectious Diseases

Our world is marked by extremes of economic inequality, across and within countries in which poverty is a common denominator. With incomes in resource-rich countries exceeding thousands of dol-

As the world becomes increasingly integrated, economic development in resource-poor countries will increase the opportunities for richer countries to profit from investment in the developing world. Global health has political and international security implications for the developed world, as well. In view of the current health status of the developing world, we are not playing a game but facing a matter of life and death. "When health is absent, wisdom cannot reveal itself, art cannot become manifest, strength cannot fight, wealth becomes useless, and intelligence cannot be applied" Herophilus, 325 BCE (Physician to Alexander the Great)

The purpose of this article is to address the relationship between health, poverty, and development in the context of game theory. We will focus on the link between economic inequalities and health outcomes, exclusively concentrating our analysis on the impact of infectious diseases. Subsequently, we will outline the game, the players, and the potential win-win outcomes that may potentially result. **KEY INDEXING TERMS:** Game theory; Infectious diseases; Poverty. [Am J Med Sci 2003;326(2):66–72.]

lars, 20% of the world's population nonetheless survives on less than \$1 a day.<sup>1,2</sup> Inevitably, the economic health of a country both affects and is affected by its people's health and life expectancy. It has been argued that the health effects of inequalities with respect to income and assets impose a major burden on the poor, which reduces the competitiveness of societies and has an effect on the global marketplace.<sup>3</sup> Therefore, it is in the world's best interest to ensure the health of all its people, because human health is the foundation of economic growth and development.

Most developed countries have undergone a prototypical epidemiological and demographical transition. This is primarily attributed to a decrease in mortality from infectious diseases and an increase in chronic diseases. In contrast, many low-resource countries are struggling not only with old and new infectious disease epidemics but also with the emerging epidemics of chronic noncommunicable

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diseases such as heart disease, stroke, diabetes, and cancer. This health status picture is referred to as the “double burden of disease in the developing world.”<sup>4</sup>

Infectious agents have profoundly influenced the establishment of human societies throughout history by playing a key role as agents of natural selection during major epidemics.<sup>5–7</sup> Today, they remain a major cause of death worldwide and constitute a destructive force on social cohesion and political stability. In particular, AIDS has become the world’s leading infectious disease and the fourth leading cause of death worldwide. It not only causes death in adults but also leaves behind millions of orphans whose care results in increased societal costs. In 2001, 3 million people died of AIDS; 1.7 million died of tuberculosis (TB). In 2000, malaria accounted for more than 1 million deaths.<sup>8–10</sup> These epidemics are of special relevance to the poorest 20% of the world’s population living in sub-Saharan Africa and Asia<sup>11</sup> because, together, these 3 diseases cause more than 300 million illnesses and more than 5 million deaths each year.<sup>12</sup>

The association of poverty and infectious diseases is joined by a never-ending cycle that starts with a lack of health, which leads to poverty, underdevelopment, and macroeconomic growth retardation. This cycle ultimately predisposes these societies to the worsening of their overall health status. Human health is the foundation of economic growth and development. The health effect of inequalities imposes a major economic burden, which reduces the competitiveness of societies. We know that healthier and better-nourished children are more educable, more skillful, and stronger as adults, thus better able to contribute to economic growth.<sup>3</sup>

Poverty plays a huge role in the transmission of TB, malaria, and HIV infection. In this case, causation is probably bidirectional, where the economic consequences of epidemic infectious diseases help to trap populations in further poverty and disease.<sup>13</sup> In fact, many have suggested that social factors that result in rural to urban migration, unemployment, illiteracy, and malnutrition can be viewed as the primary culprits behind these epidemics.<sup>10–13</sup>

Most infectious diseases tend to kill infants as well as persons during their most productive years. The impact of these conditions extends far beyond the suffering of those afflicted. Infectious diseases are not just a problem of developing countries but are also a threat to economic growth, globalization, and international security. In addition to suffering and death, these diseases penalize poor communities, perpetuating poverty through work loss, school drop-out, decreased financial investment, and increasing social instability.<sup>14–16</sup>

In summary, there is an intimate connection between poor health outcomes from infectious diseases and poverty. Interventions against HIV/AIDS, TB,

and malaria could help to alleviate poverty and could substantially boost economic growth in countries where their impact is most significant.<sup>17–23</sup> In our opinion, these interventions could be addressed from the perspective of the game theory.

### Non-Zero-Sum Thinking in the Global Health Arena

Game theory is the study of the ways in which strategic interactions among rational players produce outcomes with respect to the preferences of those players. John Von Neumann and Oskar Morgenstern developed the concept of game theory, distinguishing between zero-sum and non-zero-sum games.<sup>24–25</sup> The players are agents that represent entities with goals and preferences. Each player in a game faces a choice among 2 or more strategies. A strategy is a predetermined program of play that tells the player what actions to take in response to every possible strategy other players might use. The simplest games are those in which agents have perfect information, meaning that at every point where each agent’s strategy tells the player to take an action, the player knows everything that has happened up to that point in the game. A board game of sequential moves in which in both players watch all the actions, such as chess, is an instance of such a game. The payoffs of the game represent an ordinal utility assigned to a player at an outcome. The outcome represents a set of payoffs, 1 to each player in the game.<sup>24</sup>

In zero-sum games, the players’ outcomes are inversely related. The game of tic-tac-toe, which involves only 2 players, represents a simple example of such a game: any move that brings 1 player closer to winning brings the other closer to losing and vice versa. In non-zero-sum games, 1 player’s gain does not necessarily portray a bad outcome for the others. Indeed, in non-zero-sum games, the “players” interests overlap entirely. Game theory can be used to explain a wide realm of events, from Hernan Cortez’s conquest of the Aztec Empire to the evolution from unicellular organisms to multicellular organisms.<sup>25</sup> In fact, some scholars have shown that non-zero-sum and zero-sum interactions have shaped the history of the human species from an evolutionary, social, and biological standpoint.<sup>24–27</sup>

Political scientists and economists have divided human interactions into zero-sum and non-zero-sum elements. From an economic point of view, the game theory applies the concept of the “*pareto optimum*,” or point of equilibrium, as the threshold for non-zero-sum interactions. In this analytical framework, the *pareto optimum* has been reached when it is no longer possible to make anyone in the society better off without making someone else worse off. In other words, this state is reached at the point in which all non-zero-sum games have been realized. When 2 players have a mutually profitable transac-

tion that could be possible, but not yet conducted, then the *Pareto optimum* has not been attained.<sup>24–25,28</sup>

### Applying Game Theory to Control Infectious Disease Plagues in the Developing World

Humanitarian arguments based on the consideration of health as a human right and social justice have been made regarding possible interventions to improve health in resource-poor settings.<sup>29–34</sup> Although we do not disagree with the humanitarian approach, these strategies have been insufficient because they do not incorporate the benefit that would be gained by rich countries. A win-win interaction among governments of poor and rich countries and multinational corporations is what we argue could be a strategy that could benefit all parties.

From the viewpoint of game theory, the *pareto* threshold for resource-poor countries has not been reached. In many instances, it has not even been explored. In attempting to control infectious diseases in these settings, we argue that many profitable strategies can be pursued with overlapping benefits for both rich and poor countries. For illustration, let us create a game with perfect information and dynamic strategies. The setting of the game would be our global village. If the game is a situation in which rich countries provide health assistance to poor countries and it is conceived as a non-zero-sum game, this interaction will result in dramatic and unequivocal payoffs and outcomes for all the parties. Historically, however, developing countries, as 1 of the players, have been predisposed to lose. The other 2 players involved—rich countries and multinational corporations—have been predisposed to win. We believe that the failure of these strategies could be explained by the fact that they were traditionally conceived from a zero-sum perspective in which there had to be a loser for there to be a winner.

A serious effort at global development will require more financial support from the rich countries to help overcome the burden of disease imposed by these 3 major infectious killers. Resource rich countries should take an active role, both by addressing health disparities within their own countries and by committing resources to address health problems in the developing world. Improving the health of the poor is critical from both an ethical and a self-interested perspective. From an ethical perspective, the relief of suffering caused by illness is the moral basis for public health work.<sup>14,30,32,34</sup> From a self-interested approach, the health problems of the poor worldwide pose an increasing threat to all populations in the world.<sup>35</sup>

There are a vast number of reasons to recommend why the developed world should become interested in halting the persistent inequalities that predispose these societies to the devastating impact of

infectious diseases and the underdevelopment that comes attached to them in the framework of a non-zero-sum thinking approach. Some of the most important reasons are the following:

### *We Are Morally Obligated in Our Self-Interest*

Unequivocal responses to the AIDS, TB, and malaria epidemics are in our self-interest, morally.<sup>36–37</sup> We have been unable to raise our voices loud enough to demand what really needs to be done to help the destitute sick in poor countries. The developing world is crying for money and development.<sup>38</sup> Directing the resources to health conditions that have the greatest burden of diseases could potentially be the most appropriate approach.<sup>39</sup> This is why we believe that an attempt to control the epidemics of HIV/AIDS, TB, and malaria could have a significant impact. A response like this would ultimately save the lives of more human beings than those that died in the Holocaust.<sup>36–37,40</sup>

Health care specialist, Donald Berwick, has argued that people living in poverty being denied access to modern health care constitutes a form of systematic and violent social deprivation.<sup>37</sup> In a controversial editorial, Berwick argues that if drug companies were to decrease their costs for HIV medications for the developing world, such as happened with the cost of medications to treat multidrug-resistant TB, for the small profit they would lose, they would gain the trust and gratitude of the entire world. In his words: “they would have created a story to be told for a millennium, and those who depend on the prudence of these leaders—on their ‘fiduciary responsibility’—might chose then not to blame them but to join them in celebration, as fiduciaries of humankind.”<sup>36</sup> The achievement of health would then be an entire societal reward.

### *Infectious Diseases Pose a Rising Global Health Threat*

This important issue will complicate US and other developed countries and global security over the decades to come. These diseases will endanger citizens of the developed world and may exacerbate social and political instability in key countries in which the United States and the developed world have significant interests.<sup>35</sup> The persistent epidemics of HIV/AIDS, TB and malaria, as well as other infectious disease killers, provoke or aggravate economic decay, social fragmentation, and political destabilization in the hardest-hit countries in the developing and former communist worlds.<sup>35</sup>

From an economic perspective, the macroeconomic costs caused by the burden of infectious diseases for the most seriously affected countries will take an even greater toll on productivity, profitability, and foreign investment in the future.<sup>3,20,21,23</sup> The World Bank considers AIDS to be the single major threat to economic development in sub-Saharan Afri-

ca.<sup>35</sup> In addition, multiple studies have suggested that HIV/AIDS, TB, and malaria will reduce GDP in several sub-Saharan countries by 20% or more by 2010. This in turn can precipitate political and social instability.<sup>35,29,33</sup> The health crisis faced by the developing world created by the uncontrolled spread of HIV/AIDS, TB, and malaria threatens to reverse the hard won development gains of the last decades.<sup>35,41–42</sup>

#### *Threatened Global Travel and International Commerce*

Global travel, immigration, and commerce with wide-ranging interests, and a large military and civilian presence overseas, within countries such as the U.S., will remain at risk from the devastating consequences of epidemics of infectious diseases. This in turn will hamper the progress against the control of infectious diseases.<sup>41,35</sup>

### The Game and the Players

#### *Player No. 1—Benefits of a Non-Zero-Sum Thinking Approach in Resource-Poor Countries*

As has already been argued, the benefits of playing the game are directly involved in promoting health and development. Some of the benefits include:

1. New economic resources to be allocated in health.
2. Technical and scientific input with indirect impact on other fields of research and development.
3. Overall increase in a population's health and economic capabilities.
4. Political stability with creation or reinforcement of democracy.

#### *Player No. 2—Benefits of Non-Zero-Sum Thinking for Developed Countries*

Macroeconomic stability is a public good that the government must maintain for all to benefit from it. In the case of infectious diseases, the government has the fundamental role of preventing the spread of infections while protecting those affected from discrimination and stigmatization. This is especially true in the case of developing countries in which resources are limited and only available through public and private institutions.<sup>43</sup> We think that the benefits obtained from the perspective of non-zero-sum interventions (win-win situations) between rich countries include:

**Increase in Economic Trading.** High-income countries with a relatively small burden of disease, such as Japan, are likely to experience the greatest economic impact, not from infections in the Japanese work force, but rather from a fall in trade because of infections in other countries. This suggests that it may be in Japan's economic self-interest to invest in HIV prevention in developing countries that are major trading partners.<sup>22</sup>

**Safer Global Village.** We now live in a single epidemiological world system without defined boundaries. With travel and commerce among different regions in the world, diseases that exist in 1 region can easily spread to others. Without a wide and intelligent use of currently available antibiotics, antimicrobial resistance may threaten the national security of many countries.<sup>41,35</sup>

**Political Reputation to the World.** The rewards of good citizenship are not a matter of charity, but more accurately, a matter of national interest. A country's interest in being seen as a good international citizen is important within the context of national security and economics.<sup>44</sup>

**Political Stability.** Experience learned from societies substantially impacted by the HIV/AIDS epidemic has illustrated the enormous weight imposed on an already frail structure, which ultimately threatens peace. The correction of vulnerable structures and economic stability will be reflected in the reinforcement of young democracies and social peace.<sup>42,35</sup>

**Political Allies.** If the required public health interventions are put in place, the promoting countries will establish a trust bond with the intended developing countries. Confidence will be built surrounding internal and external affairs, thus facilitating future political collaborations.<sup>35,42</sup>

**Setting a Joint Effort for International Collaboration.** Previous international collaboration experiences and the current epizoonosis in Western Europe underline the importance of developing and strengthening present and future international networking.

#### *Player No. 3—Benefits of Non-Zero-Sum Thinking for Multinational Corporations*

**Globalization of Economic Markets.** There is growing realization that investments in public health programs and infrastructure may ultimately prove to be extremely profitable in terms of economic growth as well as invaluable to those whose lives are affected. An adequate public health system is a requirement for sustained economic development. The returns on investments to address these inequalities may be far greater than the returns on other economic investments.<sup>45–46</sup>

**Social Responsibility and Stock Performance.** The lack of commitment of pharmaceutical companies to address the distribution of drugs in the developing world is associated with the concept of cost recovery. Bringing a new antimicrobial drug to the market costs about US\$224 million a year<sup>47</sup>; therefore, a major obstacle for pharmaceutical companies is the fact that they have no market incentive to address the health problems of the world's poor. Private firms do not have sufficient incentives to develop the technology, namely because it is a public global good and because beneficiaries are people

with low ability to pay. This problem needs to be addressed in a different way.

Recently, pharmaceutical companies have acknowledged the importance of providing the necessary drugs to patients in developing countries.<sup>36-37,48-49</sup> Nevertheless, the risk of lowering the cost of drugs is to set a precedent that can be followed by the current market in the developed world. This will probably bring research and development to an abrupt halt. Therefore, the following are some alternatives for the involvement of pharmaceutical companies in providing assistance to resource-poor countries: (1) public-private partnerships in which international grants are directed toward the purchase of large amounts of drugs at developing countries-intended prices, while maintaining current market prices and intellectual rights and (2) a contingent loan or promissory note in which money will be kept until a manufacturer invents a vaccine or drug that will fulfill the specifications that countries have insisted upon.<sup>49</sup>

Pharmaceutical companies should take advantage of the link between reputation and stock market performance. The public is now reading about companies that are not responsible and making value judgments.<sup>50</sup> If the unmet need for medications to attack these infections continues in the developing world and pharmaceutical companies fail to address these issues promptly, manufacturers from developing countries alternatively will start compulsory licensing of antimicrobials ignoring patent rights, as has already occurred in India and Brazil.<sup>51-52</sup>

In summary, the moral challenge of this era offers the hope and opportunity where all players *could* and *should* participate in a game that will bring tremendous payoffs. Moreover, these outcomes will be shared equally by every player and will ultimately benefit humankind.

### Failure Is Not an Option

The major infectious disease epidemics have affected the lives of people worldwide. The stage was never set for these epidemics to be controlled because of a lack of scientific knowledge, international affairs, and socioeconomic organization to attack these maladies.<sup>37,53</sup> Considering the privileged historical moment in which we are currently living, with its advances in scientific knowledge, globalization, and abundance of economic resources in the most developed countries, we ought to take advantage of this precious opportunity and intervene now. Many researchers suggest that disease-oriented interventions are impossible without the proper infrastructure, but this is more of an excuse than a legitimate analysis. Science should not be a prerogative of the rich. Science should be devoted to the betterment of humankind; poor and rich people alike should obtain the benefits of these advances.

Leaders from the most powerful countries agreed at the summit in Okinawa, Japan, in July 2000 to reduce the 3 diseases of poverty, AIDS, TB and malaria, by devoting more funds to the developing world.<sup>54</sup> Important contributions have set the stage for an unprecedented international and political response that has now been mobilized and translated into real commitments that will improve access to information, goods, and services that people so urgently need.<sup>8</sup> Economist Jeffrey Sachs has argued that with effective treatment for AIDS now available at low prices, and global attention as never before, we can actually fight the scourge and save millions of lives in the process.<sup>29,33,39,55-56</sup> On May 2002, Dr. Sachs briefed the United Nations Economic and Social Council on HIV/AIDS.<sup>56</sup> During this session, he established that HIV/AIDS has devastating consequences for economic development in many of the poorest countries in the world, particularly in Africa. He urged a dramatic scaling up of the access of the world's poor to adequate HIV/AIDS prevention and treatment regimens as a matter of priority for rich and poor countries alike. Public health heroes like Jeffrey Sachs, Paul Farmer, and many others have finally attracted the attention of powerful countries and organizations by showing them that there is an urgent need for a significant increase in resources to address the challenges created by the severe epidemics of HIV/AIDS, TB, and malaria. Their arguments are based on economic benefits for both parties and moral obligations. For these persons, if a Nobel Prize follows their achievements, it would be redundant.<sup>37</sup>

In April 2001, the United Nations Secretary General issued a call to action for the creation of the Global Fund to fight these maladies. Global investment may actually be surging in the fight against HIV/AIDS, TB, and malaria with the creation of the Global Fund to Fight AIDS, Tuberculosis, and Malaria (GFATM). The purpose of the fund is to attract, manage and disburse additional resources through a new public-private partnership that will make a sustainable and significant contribution to the reduction of infections, illness, and death, thereby mitigating the impact caused by HIV/AIDS, TB, and malaria in countries in need and contributing to poverty reduction as part of the goals.<sup>8,57</sup>

Global health is now seen as an issue with political, economic, and security implications.<sup>35</sup> Despite the increased attention paid by the international political leaders, major obstacles remain including the targeting of efforts, adequacy of funding, and implementation of the proposed strategies.<sup>11,36-37,57</sup> At this point in time, there is enough scientific evidence and applied strategies to prove that with the help of GFATM and the continued political and economic support of different countries, the fight against poverty and its associated diseases will be attainable.<sup>8,9,11</sup>

Examples of this, though small scale, have already been shown in the international health arena by such organizations as Partners In Health, which operates under a banner of social justice.<sup>14,32</sup> Through this organization's contribution in halting the devastating epidemic of multidrug-resistant TB in Peru and Haiti, they have clearly shown that treatment programs can be successfully implemented through a diverse array of community-based approaches. By training local residents to act as healthcare promoters who can administer complex regimens of drugs to patients by directly observed treatment, in the process providing the patients and their families with psychological support, Partners In Health has countered the objections to the widespread use of highly active antiretroviral therapy and treatment of multidrug-resistant TB in resource poor settings.<sup>9,58-61</sup>

In addition, many pharmaceutical companies are already offering to sell their antiretroviral and antimalarial products to the fund at significantly discounted preferential prices. Pharmaceutical companies are also working with national governments, agencies of the United Nations, global and African nongovernmental organizations, and HIV/AIDS community groups to strengthen their health systems and treatment capacities.<sup>48,62</sup>

The current response witnessed by the world represents an unprecedented and historical event, where important international leaders have set the stage for further cooperation to improve global health. Nevertheless, this effort should continue for the next decades to come. The Commission on Macroeconomics and Health has suggested that to improve the current global health situation, donor funding would have to increase by \$27 billion by 2007 and by \$38 billion by 2015.<sup>11</sup> During the XIV International AIDS Conference in Barcelona in 2002, Dr. Julio Frenk, current Mexican Minister of Health, established that to achieve these numbers, support from most countries in the world, not only well-developed countries, is needed.<sup>63</sup> "A few moments of thinking could change history," stated Jeffrey Sachs, in an eloquent editorial.<sup>55</sup> Don Berwick puts it in different words, "I deeply believe we are one world and all humankind are connected."<sup>37</sup>

### Summary

The belief that each human life has absolute value entails an important duty to preserve it under all circumstances. In this regard, we possess the knowledge to prevent, cure, or halt the progression of HIV/AIDS, TB, and malaria anywhere on our planet. We argue that the scientific knowledge attained at this time in history should not be viewed as a prerogative of rich countries.

Providing health aid to the developing world is a duty of rich countries, understanding shared bene-

fits to both parties in the perspective of the game theory. An unprecedented response in the past 2 years has changed the perspective in the international health arena. Global health is now seen as an issue with political, economic, and security implications and it is clearer that win-win situations are in the horizon for both resource-rich and resource-poor countries if a game is continued to be played over the next few decades. However, we should never forget that alleviating suffering in these societies is not a game; it is a matter of life and death.

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