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The Economics of Alternative Strategies for the Reduction of Food-borne Diseases in Developing Countries: The Case of Diarrhea in Rwanda

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Abstract: The paper provides a methodology which is suitable for the analysis of the social cost of disease and the benefits and cost of health intervention by integrating public health analysis and economics. The approach developed in the paper is applied to food-borne diarrhea in Rwanda. The results suggest that simple treatments such as Oral Rehydration Therapy have a higher social rate of return than consumer protection via education.

Key words: public health, consumer protection, social cost, economics of food-borne diseases
JEL classification: I 12, I 18, Q 12

1. Introduction

Food-borne diseases continue to be prevalent and of significant economic importance in developing countries. This is particularly the case with diarrhea. The World Health Organization (WHO) estimates that more than 10 per cent of all deaths caused in Africa by infectious diseases are caused by diarrhea (WHO, 2004c). Young children are particularly susceptible to diarrhea (Käferstein, 2003). On a global scale, three million children die every year as a direct consequence of diarrhea (WHO, 2000). Rwanda is a country which is typical of many low income countries with regard to diarrhea (Schneider et al., 2000).

Diarrhea is caused by viruses, bacteria, bacterial toxins and parasites. Diarrhea causing organisms multiplying in the human intestines generate a strong secretion of water. At the same time, the absorption of water by the intestines is diminished. Both act to reduce the water content of body cells. Some germs also damage the lining of the intestines and cause a loss of blood.

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For quite some time, contaminated water was considered to be the main source of diarrhea. However, it has turned out that contaminated food is even more important. By some estimates, up to 70 per cent of all incidents of diarrhea are caused by contaminated food.

Essentially, there are two types of strategies to combat diarrhea; prevention and treatment. A key prevention instrument in developing countries is education of consumers as to how to store and prepare food in the household (WHO, 2000; Käferstein et al., 1997). Another often promoted instrument is to reduce food contamination in the food chain through what is sometimes referred to as the "Healthy Marketplace" strategy (WHO, 2003).

The most important treatment of diarrhea is the "Oral Rehydration Therapy" (ORT). Death and other serious health effects of diarrhea are most often caused by dehydration. Just drinking a lot of water is not sufficient to offset dehydration caused by diarrhea because water absorption in the intestines is diminished. However, adding minerals and glucose to water can significantly increase absorption of solute and water. ORT is, therefore, an inexpensive and effective way to treat diarrhea at home (www.rehydrate.org). ORT is sometimes referred to as the most important medical advance in the 20th century (Lancet, 1978; quoted in www.rehydrate.org).

The objective of this paper is to determine the social cost of diarrhea in a country in which this disease is of great significance and to analyze the social cost and benefits of the three health policy measures mentioned above. In the remainder of this paper we will first present a methodology developed in public health analysis which is suitable for the quantification of the significance of disease. We will modify this concept, and then use it also to analyze the social cost of diarrhea in Rwanda and to determine the social rate of return to these three strategies to fight diarrhea.

2. The Social Cost of Disease

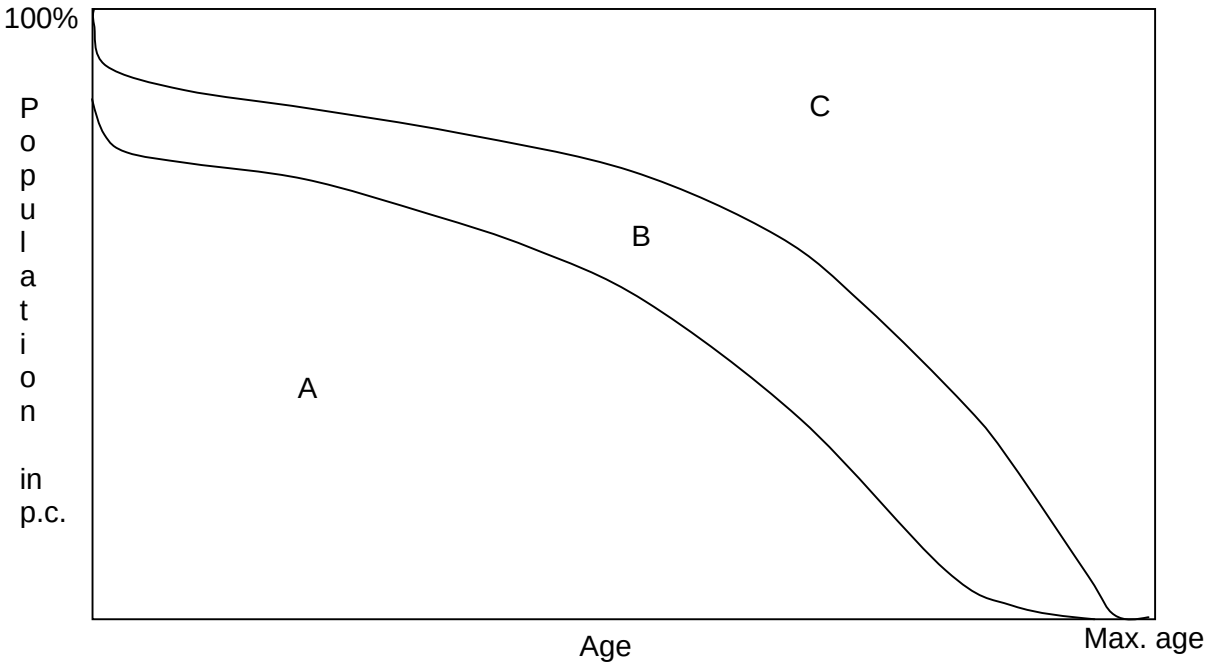
2.1 The Public Health Framework

The impact of disease is analyzed in the public health literature within a framework proposed by Murray (1996). It is based on the number of years lost to disease through time lived with a less than perfect health, and time lost due to premature death as a consequence of disease. Pivotal in this analysis is an aggregate measure of health referred to as DALY. DALY is the acronym for disability adjusted life years. It is defined as

(1) DALY = YLL = YLD
YLL = years of life lost due to premature death
YLD = years of life lived with disability, sometimes adjusted for the severity of illness.

DALYs, YLLs and YLDs can be illustrated graphically by means of a survivorship function. This is exhibited in figure 1. The horizontal axis depicts the age in years from birth to the maximum age possible,[1] while the vertical axis depicts the population being dead, ill, or in perfect health (e.g. Murray, 1996).

Figure 1: A Survivorship Function



Source: Adopted from WHO, 2001.

Area C represents the total years lost to premature death. This is equivalent to YLL. Area B is the time lived with disease; it is equivalent to YLD. Therefore, areas B plus C represent DALY, while area A is the time lived in perfect health.

YLL can easily be calculated as:[2]

$$(2) \qquad YLL = \sum_{x=0}^{L} d_x \cdot (L - x)$$

L = end of life

x = age at death

d_x = number of deaths at x; (x = 0, ... ,L); d_x can be total deaths or number of deaths attributable to any given disease.

[1] Alternatively, life expectancy may be used as a benchmark for calculating DALYs. For details, see Murray (1996). An extensive survey of the DALY concept can be found in Murray (1996), Goerdt et al. (1996), Murray et al. (eds.) (2002), Anand and Hanson (1997).

[2] Alternative definitions for the years of life lost have been presented in the literature. They are referred to as PYLL, CEYLL, PEYLL or SEYLL (Murray, 1996).

YLL goes up with increasing incidence of death, declining age at death, and increasing end of life. There is an extensive debate in the public health literature about the appropriate choice of L which cannot be replicated here. In empirical analyses, L usually is in the range of 60 to 80 years (Murray, 1996).

For an economic analysis of health issues it is not, however, the maximum length of life or the life expectancy that matters. Rather it is the end of the economically productive phase of life. In developing countries, this is usually close to the end of life. Therefore, for the purpose of our analysis it makes sense to define L as economic life expectancy (= end of productive phase of life).

The second component of DALY is YLD. It can be defined as:

$$(3) \qquad YLD = \sum_{l=0}^{L} \sum_{i=1}^{n} LT_{li} \cdot \Delta PR_{li}$$

LT_{li} = Length of the i-th incidence of disease at age l

ΔPR_{li} = Severity of the i-th incidence of disease.

n = population size.

In the public health literature there is an extensive discussion as to how to determine ΔPR_i (e.g. Murray, 1996). Usually, a range of activities is defined such as reproduction, market production, education and leisure, and then it is determined how much each activity is affected by any given disease. For the purpose of an economic analysis this issue can be simplified by reducing it to the decline in productivity during the time lived with disease.

Another controversial issue in the public health literature is discounting for future health (e.g. Keeler and Cretin, 1983; Sen, 1984; Weinstein, 1990; Olsen, 1993). This is not the place to replicate this discussion. Rather we propose to quantify DALYs without discounting. However, as we will be calculating the social rate of return to the three health measures, we will implicitly discount future health in the economic rather than the public health part of the analysis.

In the classical work directed by Murray and Lopez (1996), years lived are weighted as a function of the age of a person based on the following exponential function (figure 2):

$$(4) \qquad C \cdot x \cdot e^{-\beta \cdot x}$$

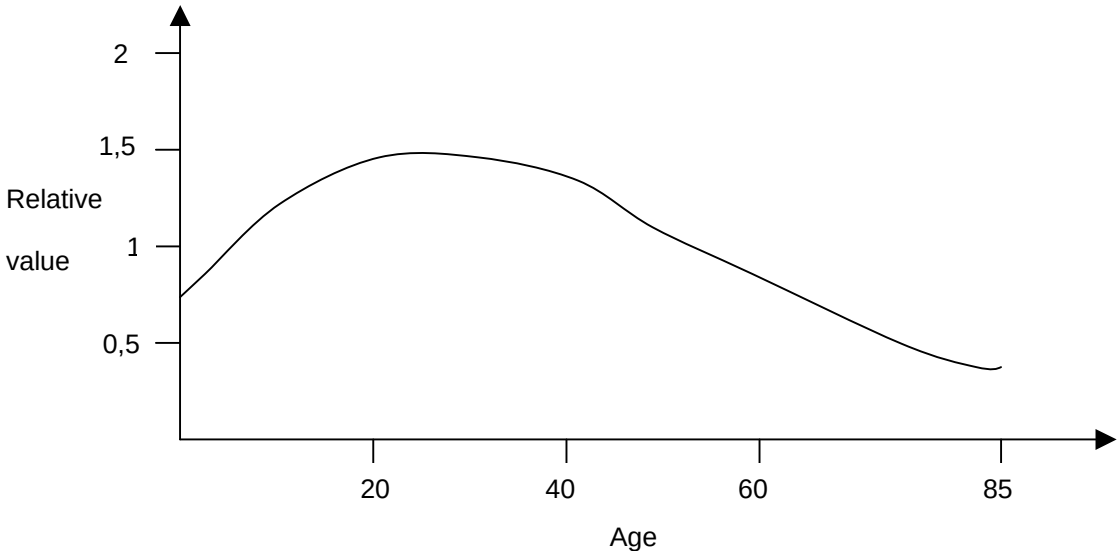
C = parameter

x = age

β = parameter which determines the weights; β is chosen such that YLL does not change because of the weighting procedure.

Ultimately, the value judgement behind this approach is that life has an intrinsic value from birth to death and that this value changes characteristically during the life cycle of a human. From a utilitarian perspective, years of life, in principle, could be weighted by the marginal utility derived from each additional year of life. Obviously, it would be most difficult to estimate the utility weights in empirical analyses.

Figure 2: Relative value of a year of life lived at different ages



Source: Adopted from WHO, 2001.

For the purpose of an economic analysis this a priori weighting of years lived at different ages is not appropriate. Rather each year of life should be weighted by the age-specific labor productivity, provided that such information is available.

Using productivity to weight years of life is not without problems either. The focus on productivity would result in no benefits when health measures result in a longer life for those who are retired and whose productive economic life, thus, has ended. In this case, some marginal utility weight would have to be determined for years lived past the productive period of life has ended. Using productivity to weight life years is not a major problem in our analysis, as the retirement age in poor countries tends to be close to the end of life. Moreover, years of healthy life gained through the prevention and/or treatment of diarrhea are, for the most part, due to a reduction in child morbidity and to not extend life at an older age by much.

Public health analyses typically culminate with the calculation of DALYs. However, for an economic analysis this is not sufficient. A person living with disease often requires additional resources. This may be the case because other members of the household take care of a diseased person, or because medical personnel and medical procedures may be involved,

either ambulatory or in a hospital. At any rate, the additional resources used to care for and treat a person stricken by disease need to be considered as well. Therefore, we propose the use of an expanded measure of aggregate disease that we refer to as HDALY:

(5) HDALY = DALY + HYLD

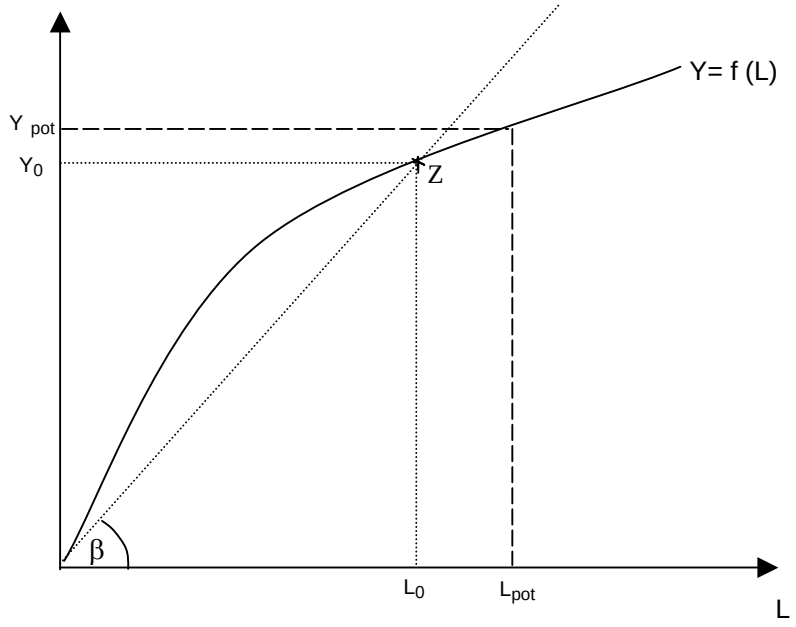
where HYLD captures the economic value of all resources used to care for and treat diseased individuals.

In developing countries, professional medical services are typically marginal or not available at all. Therefore, at early stages of economic development HYLD is for the most part the reduced productivity of household members while they care for another diseased household member.

2.2 The Economic Framework

The economic framework is fairly straightforward. Premature death caused by disease and time lived with disease both act to reduce labor input over the life-cycle and thus life-time production.

Figure 3: The Productive Effect of HDALY



Consider figure 3 which depicts a production function relating labor input and aggregate production. Let L_0 be the actual labor input with disease, then Y_0 would be the corresponding aggregate production. In the absence of disease, L_{pot} would be the labor input while Y_{pot} would be production. The change in production caused by a changing labor input is determined by labor productivity. Average labor productivity (Π) is easily obtainable in published statistics. Average labor productivity at labor input L is determined by the slope of the straight line from the origin of the graph through Z; that is, $\Pi = \mathrm{tg}\,\beta = Y_0 / L_0$. Therefore, one could approximate the loss in production caused by disease as:

(6) $$\Delta Y = \Pi \cdot (L_{pot} - L_0) = \Pi \cdot \mathrm{HDALY}$$

As depicted in figure 3, this approximation procedure overestimates the actual loss in production caused by disease. The extent of overestimation is the more pronounced the larger HDALY is.

If one wishes to correct for this, some information about the production function is necessary. Let the production function be of the Cobb-Douglas type, then for two factors of production we obtain:

(7) $$Y = F \cdot L^{\alpha} \cdot C^{(1-\alpha)}$$

F = parameter of the production function
C = capital
α = production elasticity of labor

Given the capital input, the percentage change of production is:

(8) $$\frac{\Delta Y}{Y} = \alpha \cdot \frac{\Delta L}{L}$$

Thus, eq. (6.) can be rewritten as follows:

(9) $$\Delta Y = \alpha \cdot \Pi \cdot \mathrm{HDALY}$$

Under competition, α is equal to the factor share of labor. This variable can often be calculated from publicly available data sources without major problems.

By analogy, the effect of a consumer protection measure of medical intervention on production (ΔY^*) can be determined by calculating the gain in HDALYs resulting from such action.

(10) $\Delta Y^* = \alpha \cdot \Pi \cdot \Delta \text{HDALY}$

Health measures employed in one period often impact on subsequent periods. To account for this in the empirical analysis, we consider a 20-year time period from 2000 to 2020. In order to be able to project the effects of health interventions over a twenty year time period, it is necessary to also consider population growth, growth in life expectancy, and change in general health parameters during this period.

UNPP (2003) estimates that population growth will be declining from an annual 2.2 per cent in 2000/05 to 1.8 per cent in 2015/20. These numbers have been employed in our analysis. Likewise, we have used UNPP (2003) life expectancy projections. General health is projected to improve along the trend of the recent past which implies an autonomous annual reduction in diarrhea of .3 per cent (Hamer et al., 1998).
In the empirical analysis, the gain in production in each period and the social cost of the health or consumer protection measure has to be determined for every period. This allows one to calculate the social rate of return of alternative health measures:

(11) $\Delta NY_t = \Delta Y_t^* - \Delta K_t$

(12) $\sum_{t=0}^{T} \frac{1}{(1+i)^t} \cdot \Delta NY_t = 0$

NY = net benefit
K = social cost of health intervention
i = social rate of return.

2.3 The Social Cost of Diarrhea in Rwanda: Empirical Evidence

The empirical analysis of the social cost of diarrhea in Rwanda have been based on information published by WHO (2002). No age weighting has been done, nor have life years been discounted. The total number of years lost to diarrhea in Rwanda in 2000 is at HDALYs = 386 547.[1] HDALYs and its components for the productive period of life (years 10 to 59) by age cohort and gender are exhibited in table 1.

[1] In calculating this number of the DALYs published for Rwanda by WHO (2002), we have assumed that in 90 per cent of all incidents of diarrhea, household members are involved in the care of a diseased person and that the labor input of the care taker is reduced by 50 per cent. For details, see Donovan et al. (2003).

The total loss in productive life years in 2000 alone was at almost 300,000 years. It is obvious that by far the most important component of HDALYs for both genders is mortality caused by diarrhea in children of four years and younger. Productive years of life lost due to child mortality accounts for more than 80 per cent of total HDALYs. The total HDALYs for females is 10 per cent below that of males. This is largely due to lower mortality of females during the first four years of life.

Table 1: Aggregate Measures of Years of Productive Life (ages 11-59) lost to Diarrhea in Rwanda, 2000

age cohort	YLL	YLD	DALY	HYLD	HDALY
Males					
< 1	24197	0	24197	0	24197
1-4	116399	0	116399	0	116399
5-9	2353	0	2353	0	2353
10-14	2065	983	3047	0	3047
14-20	1322	303	1626	190	1816
20-29	1616	447	2062	280	2343
30-39	2164	267	2431	168	2599
40-49	2004	157	2160	99	2259
50-59	985	108	1093	68	1161
total males	**153104**	**2265**	**155369**	**803**	**156172**
females					
<1	19690	0	19690	0	19690
1-4	94847	0	94847	0	94847
5-9	3908	0	3908	0	3908
10-14	3458	993	4451	0	4451
14-20	2103	308	2411	1694	4105
20-29	2651	450	3101	2478	5580
30-39	3040	264	3304	1451	4755
40-49	1989	162	2152	892	3044
50-59	879	119	999	654	1652
total females	**132566**	**2297**	**134864**	**7169**	**142032**
total	**285670**	**4562**	**290233**	**7972**	**298204**

Source: Own computations based on WHO (2002).

To calculate the loss in production resulting from diarrhea we have multiplied the sum of the HYLDSs in table 1 by the average labor productivity of US $ 356 per person and year.[1] As the factor share of labor in Rwanda has not been available, we have assumed values between .5 and 1.0 for this parameter. The results are exhibited in table 2.

Table 2: The Social Cost of Diarrhea in Rwanda (mill. US $), 2000.

α	ΔY
0.5	53.08
0.75	79.62
1.0	106.16

Source: Own computations

Social cost of disease: $\Delta Y = \alpha \cdot \Pi \cdot \text{HDALY}$

$\alpha = \{0.5, 0.75, 1.0\}$

$\Pi = \text{US\$ } 356$

As can be seen, the social loss of diarrhea in Rwanda in 2000 was somewhere between US $ 53 mill. and US $ 106 mill. This is a loss in the range of 2.5 to 5.0 per cent of the GNP (World Bank, 2002).

3. Benefits and Cost of Diarrhea Prevention and Treatment Strategies

The analysis of the impact of diarrhea prevention and treatment strategies is analogous to the procedure discussed in section 2 of this paper. First, the effects of three measure to reduce the negative health impact of diarrhea on HDALYs will be quantified. Second, this gain in healthy life years will be multiplied by average productivity and the production elasticity of labor. Third, the cost of the health measures will be determined.

3.1 Three Strategies to Combat Diarrhea

As mentioned earlier, the three measures to combat diarrhea which will be analyzed here are Health Education, Healthy Marketplace procedure, and Oral Rehydration Therapy (ORT). The first two measures are preventative in character while the third is a curative measure.

[1] This number was obtained by dividing the GDP by the number of individuals between ages 10 to 59.

3.1.1 Health Education

Health Education is defined as training in the safe preparation of food and storage of food in the household of consumers along the lines developed in WHO's (2001b) "Five Keys to Safer Food". The cost of this intervention is caused by the resources required to train persons involved in food preparation and storage in the household.

We define a one-week training course for 25 participants and assume that each participant transfers the acquired knowledge to eight other individuals. Thus, one training course acts to educate 200 persons. The knowledge is assumed to depreciate by 20 per cent per year of the initial human capital stock; i.e. the training effect has disappeared altogether after five years.

One training team can deliver 40 training courses per year; that is, one training team could reach 8,000 individuals per year directly and indirectly. Given the depreciation of knowledge, a training team would work four five year cycles and educate 40,000 persons during this time period. The population in Rwanda in 2000 was about 7.6 million. To cover the entire country in five year cycles, 190 training teams would be required.

WHO (2004b) estimates the annual cost of one training course to be at US $ 42,000 plus 50 per cent of this cost in the first year to initiate the program caused by planning and implementation processes as well as train the trainers programs. The annual cost of such workshops (including initiation cost and accounting for population growth are US $ 12.0 Mill. in 2000 (190 training teams); US $ 8.15 Mill. in 2001 (194 training teams); ... ; US $ 12.0 Mill. in 2020 (286 training teams).

3.1.2 Healthy Marketplaces

A Healthy Marketplace is a concept promoted by WHO (2003) which attempts to avoid food contamination with disease causing organisms and substances throughout the food chain from producers to the purchase of food by consumers. Again, diarrhea causing agents are the main target of this concept, as it is the most important disease transmitted on the local food markets. For a Healthy Marketplace, market participants have to be trained. The training cost has been calculated analogously to the procedure in the previous section on Health Education. The data used are from WHO's (2003) PHAST concept.[1] One training workshop

[1] PHAST is an acronym for participatory hygiene and sanitation transformation.

trains 40 market participants for one week. The multiplier effect of each person trained is higher than in Health Education, as each market participant's knowledge is spilling over to more individuals. The multiplier used here is 20; that is every person trained impacts on 20 consumers' health.

3.1.3 Oral Rehydration Therapy (ORT)

As mentioned above, ORT represents a curative measure to combat diarrhea. It is relatively simple to administer in developing and developed countries alike. And it is inexpensive. The average cost of ORT per incidence of diarrhea is at US $ .30. Total annual cost of ORT is determined by the number of incidents of diarrhea and the percentage of incidents treated. As with the other health strategies discussed here, we assume a 100 per cent coverage of the population. In 2000, there had been 9.6 million cases of diarrhea in Rwanda which results in a cost of US $ 2.88 million. As before, planning and implementing such a nationwide program have been chosen at US $ 4 million which is identical to the other two health programs. It turns out that Health Education is the most expensive health measure while ORT results in the lowest cost.

3.2 The Social Rate of Return of Three Strategies to Fight Diarrhea in Rwanda

In order to be able to calculate the social rate of return to the three measures to combat diarrhea, information is required about the impact of these measures on the HDALY. The numbers reported in the literature vary considerably. PSI (2004) reports a reduction of 40 per cent which can be realized through training activities. Hamer (1998) has observed reductions between 9 and 20 per cent. In our calculations, we have assumed this number to be at 15, 20, and 25 per cent respectively. Likewise, we have parametricized the cost of each measure to be at 75 and 125 per cent of the cost calculated in section 3.1. The production elasticity has been assumed to be at .75.

The results of our analysis are summarized in table 3.

Table 3: The Social Rate of Return to three Strategies to Fight Diarrhea in Rwanda (2000-2020), $\alpha = .75$

Cost[1]		Health Impact[2]		
		15%	**20%**	**25%**
Health Education	low	34	48	60
	average	22	34	44
	high	14	25	34
Healthy Marketplaces	low	82	112	141
	average	65	92	117
	high	52	76	99
ORT	low	177	245	314
	average	148	210	271
	high	126	181	237

Source: Own computations.

As can be seen, the social rate of return is positive and exceptionally high for all health measures analyzed here, ranging in the main scenario from 34 per cent for Health Education to 210 per cent for ORT. This result is not surprising. As the health impacts of the three measures are comparable, it is the differences in cost that matter for the social profitability of the three health strategies analyzed. ORT is the least cost approach. Therefore, the social rate of return to ORT is significantly higher than for the other two measures. Both training activities have a similar cost. However, the Healthy Marketplace strategy is characterized by a higher multiplier for each person trained, as a market participant's knowledge can spill over to more persons than a private household member trained in the safe preparation and storage of food. Therefore, Health Education's social rate of return is below that of Healthy Marketplaces.

[1] low = 75 per cent of calculated cost
average = 100 per cent of calculated cost
high = 125 per cent of calculated cost

[2] Reduction in morbidity and mortality

4. Conclusion

In this paper, we have attempted to demonstrate how an approach commonly used in public health analysis can be employed in economic analysis in order to quantify the social cost of disease and the social profitability of health interventions. We found the social cost of diarrhea in Rwanda to be very high.

The three measures analyzed here are all characterized by exceptionally high social rates of return. Either one of the two preventative strategies (Health Education, Healthy Marketplaces) or the curative strategy of ORT can be considered to be socially exceptionally profitable and, therefore, very useful in the fight against Diarrhea in Rwanda. As the public health environment and the diarrhea incidence in Rwanda is characteristic for most low income countries, the results obtained for Rwanda can be considered to be characteristic of poor countries in general.

The implications of our results for public health policy in developing countries are obvious. Public health strategies should put significant emphasis on the fight against diarrhea. Priority should be given to strategies that make ORT readily available for everyone. While ORT is characterized by the highest social rate of return of the three measures analyzed here, relying on ORT alone to fight diarrhea would be a suboptimal strategy, because frequent re-infection will occur as long as the hygienic conditions in the food marketing chain and in the households do not improve. Thus, prevention through health education is an essential element in an appropriate mix of measures against diarrhea.

It is also important to keep in mind that the economic benefits of preventing diarrhea increase with labor productivity. Thus, in the course of economic development the potential social gains from education will tend to go up further.

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