Indirect estimation of the prevalence and mortality by Chagas, Malaria and tuberculosis in Bolivia: Two applications to program evaluation

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Prologue

Despite the important progress in the attenuation of infectious diseases and the reduction of adult mortality rates in Latin American and the Caribbean, transmissible diseases still cause substantial damage in many countries of the region. Thus the importance and priority given to their control and eradication. Several international organizations and development banks collaborate in these matters, financing and promoting programs to fight transmissible diseases. However, in the majority of the countries where these problems are important, the epidemiological information is scarce and defective in more than one way. In particular, the statistics on morbidity and deaths by cause and age are often deficient and incomplete. For this reason, the overall magnitude of the public health problems associated with these diseases and their economic impact are not at all well known, and consequently neither are the material resources needed to finance and target the corresponding programs.

In this context, in order to assess the health damage that results from transmissible diseases, their economic impact and the operational requirements to their eradication, it is necessary to use indirect methods to estimate the prevalence and mortality due to these diseases. These methods need to be adapted to the fragmented available information and to the purposes of the analysis. This paper reports on the methods used and the main results obtained from parts of the evaluation of a health project in Bolivia financed by the Inter-American development Bank[3].

Indirect estimates of the prevalence and mortality due to Chagas, malaria and tuberculosis were used in the project preparation and (ex-ante) evaluation in various ways. This paper presents, together with a description of the data and procedures, two of the main applications of the estimation: (a) the economic losses due to the labor income that fails to be generated by those who become ill or die; and (b) the projection of the new cases and the number of Chagas deaths avoided by the interventions contemplated in the project financed by the IDB.

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I. Context and objective

The high prevalence of infectious diseases in Bolivia imposes heavy costs to the country, carrying personal, family and social implications. The first part of this paper develops estimates of the economic loss of national income due the (first-order) effect of labor income losses produced by the prevalence and mortality caused by Chagas, malaria and tuberculosis in the active-age population. This analysis is rather simplified, in the sense that we do not consider other negative effects of these diseases on national income, such as:

(a) Their indirect effects upon the product composition, labor organization, the quality and development of human capital;
(b) The public and private costs needed to support all the chronic patients, including those of the health services and the disability pensions, relative to the cost of control or eradication, and to the ultimate aggregate savings produced by such programs;
(c) The negative effects at the household level, including family dislocation, discontinuation of school attendance of children, and other secondary effects such as of income reduction as a result of malnutrition and deterioration of maternal and child care;

The simplification notwithstanding, we consider it useful to evaluate the annual labor income loss, given that it represents the most important direct economic effect of the prevalence of the diseases under study.

An adequate interpretation of the economic cost requires to specify the conditions under which the estimates are valid for each one of the diseases. These conditions are presented and discussed briefly in the following section. The third section explains the assumptions and procedures used. We then discuss the results of the estimation of the impact the Chagas program on the reduction of infection and deaths due to this disease. A final section provides concluding remarks.

II. The prevalence of transmissible diseases and their effects on the activity rates

The measurement of the income losses related with the prevalence of transmissible diseases requires the estimation of the number of person-years of work lost and the value of each person-year of labor. The calculations need to take into account the effect that each disease has on labor activity. The following sections provide some information along these lines, and about the incidence that they have in the Bolivian population. In quantitative terms, we look for data on the following parameters: the population at risk; the prevalence rate[4]; the cause-specific mortality rates[5]; the case-fatality rates[6] and the labor absenteeism attributed to each disease. In addition, an estimate of the labor income loss associated with each person-year of work of the reference year will be required.

In all cases, the calculations are approximations, based on incomplete data and a few available studies. In particular, the estimation of prevalence and fatality rates correspond to orders of

[4] The prevalence rate is the quotient of the population ill with a specific disease over the population at risk.
[5] Defined as deaths due to the disease in question per thousand exposed persons.
[6] The ratio of deaths to the number of persons ill with the given disease.

magnitude derived from sparse information and from information on the characteristics of the diseases in other countries.

Chagas (tripanosomiasis americana)

A PAHO report (see Box 1) indicates that 22% of the Bolivian population was infected with the parasite *Trypanosoma cruzi* during 1980-1985; by far the largest infection rate in Latin America. Valencia (1990) and SNS/CCH (1993) suggest that that during the 1980s there were between 1.1 and 1.8 million persons infected by Chagas in Bolivia. More recent data have found rates of prevalence on the order of 40% of the population in risk.

Box 1
Chagas disease in other countries of Latin America

Studies in other countries provide some elements about the incidence of Chagas disease and allows to place Bolivia in the regional context. A study carried out in Brazil (Gomes Pereira, 1984), showed that in 1980, Chagas was responsible for 1 in every 10 deaths among adults in Brasilia. The death rate due to Chagas was found to be 50% higher for men than for women; and the male/female mortality ratio to be greater in Brasilia than in other cities (PAHO, 1994, p. 16). More than a half of Chagas deaths in Brazil occur in the most productive ages (20 to 54 years old), and mortality rates increase sharply with age.

In Latin America as a whole, Chagas holds the fourth place among the ailments with the largest burden of disease (measured by the disability adjusted life years - DALY) and has the highest weight among infectious diseases. The joint weight of malaria, esquistosomiasis, leishmaniasis and leprosy on the burden of disease represents less than 15% that of Chagas (World Bank, 1993).

A cost/benefit analysis of Chagas prevention performed in 1993 in the Salta Province of Argentina yielded an internal return rate (IRR, a measure of the proportional benefit over and above the cost of a given program) of 64%. All available information suggests that the investment in Chagas prevention is very "profitable" from a social and economic perspective (Cleto and others, 1995): studies for a set of Latin American countries (Argentina, Brazil, Bolivia, Chile, Paraguay, Peru and Uruguay) showed an overall IRR of 14%, without including the indirect benefits of the eradication (Schofield and Díaz, 1991).

The population at risk consists of the population that lives from 300 to 3.500 meters above sea level, which corresponds to the population in the departments of Tarija, Chuquisaca, Cochabamba, Santa Cruz and part of that of Potosí and La Paz (IDB, 1998). In 1992, the estimate of the population at risk was 3.5 million persons; extrapolated to 1998, the estimated figure is of 4.1 million potentially exposed persons.

Around one in four of the infected people develop some type of cardiovascular complications and one in six present disorders of the digestive tract (IDB, 1998). Close to 30% of the infected persons manifest chronic symptoms (SNS/CCH, 1993) more than a half of which are young adults aged 15 to 44 (Valencia, 1990). The prevalence rate in men and women in Bolivia seems to be about the same, in contrast to other countries where Chagas disease is more prevalent among men than among women.

Secondary information showed that chronic Chagas patients reduce around 25% their labor capacity (SSN/CCH, 1993). Using these parameters, the rate of disability of Chagas disease is estimated to be 0.3×0.25, meaning about 8% of labor loss in one year. The fatality rate is taken from the figures provided in the Health Ministry study (SNS/CCH, 1993) which yield a rate of 1% of the infected population.

Malaria

The simplest measures of the economic effects of malaria eradication, undertaken since decades ago, combine an estimate of the number of person-days of work lost due to morbidity and mortality with an average daily wage (Winslow, 1951). More comprehensive simulation studies based on production function concepts (Barlow, 1968) consider separately the effects that malaria infection rates have on per capita income; on the changes in the quantity and quality of the labor, and on the changes of quantity and quality of the capital.

Adopting a different perspective, some studies that focus on the epidemiological and demographic factors that affect effectiveness of the malaria eradication programs distinguish the risks of different population groups: (a) Those who have never been infected; (b) The infected population with fever; (c) The infected population without fever (tested cases with infected blood); and, (d) The previously infected cases, which are immune. Each group is associated with different levels of economic and social burden (Cohen, 1988). We carry out a simplified version of the reviewed approaches, due to the following reasons. The epidemiological-demographically disaggregated approach is very interesting, but it requires detailed clinical and statistical information that is not available in our case. The production function analysis, on the other hand, requires several assumptions that are difficult to sustain in the Bolivian context (speed of decreasing returns in the presence of a fixed factor, degree of economies of scale in production, dependence of the output levels on the quantity and quality of production inputs, etc.).

Regarding the prevalence of the diseases in Bolivia, special studies by the Health Ministry indicate that for each case registered in the routine official information system, four other cases go without notification (MSPS/DGE/BID, 1998). Based on this assumption and using data from the National Malaria Program during the last years we estimate that there were 289 thousand cases of malaria in Bolivia during 1998. Considering that the population at risk is 3 million 733 thousand (MSPS/DGE/BID, 1998), we estimate a 7.7% prevalence rate of malaria.

Plasmodium falciparum, resistant to cloraquin, is the more lethal malaria virus; worldwide, the majority of the deaths due to *falciparum* occurs in Africa. In Bolivia, as in the rest of the world, the stump *vivax* is more common; it is less lethal but very debilitating and has a substantial impact upon the health and the labor productivity of adults. Each episode of malaria lasts on average some 15 days and requires approximately one additional week for reintegration into labor activity. This means that the yearly disability rate is around 6%.

As regards to its lethality, it is known that, after the first inoculation with *plasmodium falciparum*, a non-immune person has a high risk of dying (from 5% to 10%, approximately; Molineaux, 1983). If the patient survives, it is likely to acquire partial immunity, although this is reversible. For the sick population as a whole, however, the case-fatality rate is around 1%, that represents the value observed on average global terms (Encarta, 1997). Although the deadliness due to this disease can be far greater in specific contexts and depends strongly on the *vivax*/*falciparum* composition in the sick population, in the absence of more specific information, we adopt the 1% value.

Tuberculosis

The epidemics produced by the bacillus *mycobacterium tuberculosis* are well known in world history. Still today in less developed countries, it causes many deaths and severe public health damage, including prolonged labor disability. At present, tuberculosis kills some 3 million persons around the world, number somewhat higher than that attributable to malaria, that is responsible for 1.5 to 2.7 million deaths per year (OMS, 1999).

About 228,000 new cases of tuberculosis per year are estimated to occur in Bolivia as of the late 1990s, of which 11,400 are lung cases (by far the most common type). If we add an estimate of the number of cases from the preceding year that do not cure (SNS/CCH, 1993), we calculate 304,000 tuberculosis patients in 1998. This translates into a prevalence rate of 3.8% of the Bolivian population.

We estimate the disability and lethality associated with tuberculosis aware of the specific difficulties in early detection and the incomplete treatment of this disease in Bolivia. In general, the complete cycle of the disease in a "normal" case is about 8 months, of which 2 months are dedicated to intensive care and recovery. Some 2 to 4 weeks of convalescence must be added to that period, before the patient can return to labor activity. For this reason, we assume in our calculations an average period of disability of 3 months in a year, which we consider to be on the conservative side, precisely because not all cases are detected at an early stage and an even lower proportion follow the complete treatment rigorously. Unfortunately, no representative data is available that would allow us to introduce a correction for those effects. We adopt the 3 month disability within the year, which implies a disability rate of 25%. In the absence of better national data, the fatality rate of tuberculosis is estimated to be 4% of the cases, a figure taken from international experience.

III Application 1. Losses of national income: method and results

As mentioned in previous sections, this chapter reports on our estimates of the value of national income losses caused by morbidity and mortality of the economically active population, due to Chagas, malaria and tuberculosis. The basic set of parameters to perform the calculations are the population exposed to the disease i (N_i) –i.e., the population at risk-; the prevalence rate of the disease i (p_i), i.e., the quotient of the population that has illness i over the population at risk of that disease; the corresponding mortality rate (m_i), measured as the quotient of the number of *i*-deaths per thousand exposed persons; the case-fatality rate of i (l_i), defined as m_i/p_i ; and the coefficient of labor disability/loss due to i, expressed as a fraction of a year (d_i).

Given that in Bolivia there are no complete or otherwise adequate death registers, is not possible to obtain reliable figures about the number of deaths due to specific causes directly. Accordingly, we estimate the number of deaths and the cause-specific mortality rates using the prevalence rates and the case-fatality rates of each one of the diseases. Specifically, we use the formula $l_i = m_i/p_i$ to derive $m_i = p_i \times l_i$.

Table 1 shows the values obtained for each one of these basic variables, on the basis of the discussion of the previous section. Since our calculations are limited to the annual cost of the diseases and deaths *of the economically active population*, an additional variable was added (a_i) that represents the proportion aged 15 years or more out of the infected population and the deaths due to each cause. This last piece of information was obtained from the notified cases, as reported the Epidemiological Surveillance Report of the National System of Health Information (SNIS) for 1996 and 1997 (MSPS, 1998).

Table 1
Basic demographic-epidemiological variables for the estimation of the economic losses associate to three infectious diseases - Bolivia, 1998

Disease (i)	N_I (thousands)	p_i	m_i (per thousand)	l_i	d_i	a_i
Chagas	4.035	0,400	4,00	0,01	0,08	0,93
Malaria	3.733	0,077	0,77	0,01	0,06	0,63
Tuberculosis	7.957	0,038	1,52	0,04	0,25	0,87

Source: own calculations, based on the references given in the main text. Definitions: N_i = population at risk of disease i; p_i = prevalence rate of the disease i (i.e., the quotient of the population ill of cause i over N_i); m_i = the casue-specific mortality rate (the number of *i*-deaths per thousand exposed persons); l_i = the case-fatality rate of i, defined as m_i/p_i; and d_i = the coefficient of labor disability/loss due to i, expressed as a fraction of a year.

Based on these data, we can calculate the number of adult person-years (APY) lost by the morbidity and mortality due the respected diseases. The average number of sick adults during the year (S_i) is defined as the product of the population under risk (N_i) by the prevalence rate (p_i) and a_i, the proportion adult (15 years or older) of the population affected by the morbidity and mortality due to each cause. The number of PAA lost by disability by patient's disability to work (D_i) is calculated as the product of S_i by the coefficient of disability (d_i). Given that we do not know the dates of occurrence of the deaths during the year, we suppose simply that the deaths are distributed uniformly over the year in question. Based on these assumptions, the number of PAA lost by mortality (M_i) is calculated as $[(N_i.m_i.a_i)/2]$. Table 2 shows the results of all these calculations.

Table 2
Number of adult-person-years lost by morbidity and mortality from Chagas, malaria and tuberculosis: Bolivia, 1998

Disease (i)	S_i ($Ni \times pi \times ai$)	D_i ($Ei \times di$)	M_i ($(N_i.m_i.a_i)/2$)
Chagas	1.501.020	112.577	7.505
Malaria	181.088	10.865	905
Tuberculosis	263.058	65.765	5.261

To get the final result (the economic loss), it is necessary to perform an valuation of the labor losses due to morbidity and mortality. There are, in principle, many ways to do the valuation. The crudest is the assignment of the economy average wage or per capita income to each person-adult-year. A more refined way is to assign productivity differentials according a set of variables (age profile, activity rate, occupational characteristics and branch of activity associated to the infected population). Unfortunately, this last type of information is simply not available in Bolivia. So, we consider three possible alternatives based on the available data for 1997-98: (a) valuation according to income per working-age adult; (b) the value of income per economically active person and; (c) the value of average income of the employed population.

The first option is the most conservative of all, since it has GDP (the official, national accounts based published figure) but the entire working-age population in the denominator. This assumes tacitly that those ill and those who die of the given disease among the inactive and unemployed population, do not have any productive potential, which is certainly questionable. We know that many persons that show up as unemployed or even inactive in the official statistics carry out some type of labor activity, that tend not be reflected in the employment survey statistics. A well known example is the domestic work carried out by women and children, specially in rural areas, that are not classified as "active" in the surveys, which are more geared to remunerated work.

The third alternative represents another extreme, because it assume that the productive loss of the infected and those who die of a given disease, even that of the unemployed and inactive among them, is equivalent to the value of the production generated by the employed workers, which is surely is incorrect in many cases.

The second alternative, the valuation according to the GDP per economically active person, is probably the best option for the purpose of this paper. It maintains the implicit assumption that the economically inactive population does not generate economic value, but it assigns to the person-years of illness and death a production loss equivalent to the average income of the labor force.

Table 3 presents the estimates according to the three alternatives discussed above. We highlight the second alternative in the table.

Table 3
Economic cost / loss of productivity due to three infectious diseases in Bolivia, 1998

(a) Valuation according the product per working age person

I	Y_a	c(D_i) (Di× y_a)	c(M_i) (Mi× y_a)	Total Cost *(thousand US$ of 1997)*	c(D_i)	c(M_I)	Total Cost *(% of GDP)*
Chagas	1.680	189.129	12.609	201.737	2.4%	0.2%	2.6%
Malaria	1.680	18.254	1.521	19.775	0.2%	0.0%	0.3%
Tuberculosis	1.680	110.485	8.839	119.323	1.4%	0.1%	1.5%
				340.835			4.4%

(b) Valuation according to the product per economically active person

I	**y_b**	**c(D_i) (Di× y_b)**	**c(M_i) (Mi× y_b)**	**Total Cost** ***(thousand US$ of 1997)***	**c(D_i)**	**c(M_I)**	**Total Cost** ***(% of GDP)***
Chagas	**2.782**	**313.188**	**20.879**	**334.067**	**4.0%**	**0.3%**	**4.3%**
Malaria	**2.782**	**30.227**	**2.519**	**32.746**	**0.4%**	**0.0%**	**0.4%**
Tuberculosis	**2.782**	**182.957**	**14.637**	**197.594**	**2.3%**	**0.2%**	**2.5%**
				564.407			**7.2%**

(c) Valuation according to the product per employed person

i	y_c	c(D_I) (Di× y_c)	c(M_i) (Mi× y_c)	Total Cost *(thousand US$ of 1997)*	c(D_i)	c(M_I)	Total Cost *(% of GDP)*
Chagas	2.928	329.624	21.975	351.599	4.2%	0.3%	4.5%
Malaria	2.928	31.814	2.651	34.465	0.4%	0.0%	0.4%
Tuberculosis	2.928	192.559	15.405	207.963	2.5%	0.2%	2.7%
				594.027			7.6%

Definitions: y_a = product per person in working ages, y_b product per economically active person, y_c = product per employed worker; c(D_i) is the "cost" or annual value of the productivity loss due to the disability produced by i; c(M_i) is the cost of the loss of productivity due to the mortality produced by *i*.

The figures clearly show the high economic importance of these diseases in the country, even when the measurement is restricted to the direct production losses. The value of the loss due to the three diseases under assumption *b* represented a cost over 560 million dollars in 1998, equivalent to 7.2% of the GDP. Chagas disease alone cost more than US$334 millions (4.3% of the GDP). The production loss due to tuberculosis reached US$197 million (2.5% of the GDP) and Malaria almost US$33 million (0.4% of the GDP). Note that, when we focus on a single year, most of the yearly economic loss is due to the labor disability produced by these diseases. However, the conclusion might be different if one adopts a longer term perspective, a context in which the effect of mortality would be many times greater than that reported here. The reason is that mortality produces a permanent decrement of adult-person years from the future labor force, whereas at least malaria and tuberculosis morbidity prevalence may be reduced or its impact on productivity moderated by future health interventions.

In interpreting the results, it is useful to recall that some assumptions could lead to an over or underestimation of the reported economic cost. For example, the assumption that the risks of mortality and morbidity are independent across causes could overestimate the measured cost, although this effect should be relatively low, given the short (annual) time period considered. The utilization of the average income of per employed or economically active person could also lead to an overestimate of the cost, if the patients and the dead due to these diseases are in reality employed in lower productivity sectors of the economy. For these reasons, and in the absence of more detailed information to fine tune the calculations, some analysts may prefer the more conservative versions of our estimates.

On other hand, it is evident that the preceding estimations are very low by comparison to the active-lifetime productivity losses of the adult cohorts alive in 1998. A rigorous projection of the present value of the flow of future losses would require a more complex model and much more detailed information about the dynamics of each disease, along the lines of the studies cited above.

IV. Application 2. Evaluation of the impact of the Chagas Program in Bolivia.

As stated earlier, Chagas disease is one of the most serious public health problems in Bolivia today, in terms of its magnitude and its social impact. The regions at risk represent 60% of the Bolivian territory and cover more than a half of the municipalities. Recall that in 1998, the population at risk was estimated to be more than 4 million people, which would require to spray about 700 thousand households, near 40% of the national total. Table 4 shows the population, the number of households and localities in areas at risk of Chagas.

Table 4
Dimensions of the Chagas Disease in Bolivia - 1992

Departamentos	Municipalities with infestation	Localities with infestation	Population at risk	Households to de sprayed
Cochabamba	40	1.173	951.682	192.163
Chuquisaca	28	571	453.774	83.518
La Paz	24	531	226.148	39.668
Potosí	16	332	301.912	50.587
Santa Cruz	39	922	1.328.506	268.368
Tarija	11	247	314.688	63.845
Sub-Total (1)	158	3.776	3.576.710	698.149
Bolivia (2)	311	-	6.420.792	1.700.000
Rate of Infestation (1)/(2)	**50,8 %**	**-**	**55,7 %**	**41,1 %**

Source: Government of Bolivia, “Program for the Control and the Elimination of Chagas Disease in Bolivia”, La Paz, 1998.

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A study carried out by the Health Ministry (MSPS, 1998) suggests that the ratio of household infestation in the rural areas is somewhere between 70% and 100%, in the suburban areas between 40% and 60% and in the urban areas, between 20% and 40%.

Although the direct vector infection represents around 82% of all cases, the intense rural-urban and inter-departamental migration in Bolivia leads to the additional transmission through blood transfusion (15% of the cases). An evaluation carried out in 1994 showed that the seroprevalence of Chagas in blood banks reaches very high magnitudes in the Departments of Santa Cruz (51%), Tarija (41%), Sucre (39%), Cochabamba (28%), Potosí (24%) and smaller proportions in La Paz (5%) and Oruro (6%). It is also necessary to consider the effect of infected pregnant women on congenital transmission, which the study of the Health Ministry estimates at 3% of the cases.

The Bolivian government is adopting a strategy to fight against Chagas based on three simultaneous actions: a) the (double) spraying of households and adjacent areas and home improvements, aimed at eliminating the vectorial transmission; b) the control of blood banks and of blood products in order to reduce the risk of the transmission by blood transfusion; and c) the treatment of the disease in infected children under five years old, to eliminate the illness in this age group. Box number 2 explains the main activities foreseen in the Chagas program, and provides some details of the program costs and financing.

Box 2. Activities of the Chagas program, its cost and financing

The spraying activities and their logistic have a cost of US$ 23.5, to be financed by the Inter-American Development Bank (IDB). The home improvement activities should start 3 to 6 months after the first spraying. About one third of the 700 thousand homes in the country will need improvements, at an average cost of US$ 400 by residence. Therefore, the home improvement component needed to fight Chagas disease in Bolivia has an estimated cost of US$ 92 thousand. The activities directed to the control of blood banks will cost US$ 3 million.

The project does not include funds for the treatment of all Chagas patients., but will cover the cost of treatment of children under 5 years old, as well as the control of pregnant women and births in the infected areas to prevent fetal Chagas transmission. This is justified because even though the disease affects the entire population in the regions at risk, the treatment has proved efficacy only for children under five years old. The probability of success of the treatment for other age groups is quite low. The effectiveness ratio of 100% among the under 6 year-olds, falls to 80% in the group 6 to 14 years %, and above 15 years of age the effectiveness of the treatment is extremely small, because the chronic phase of the illness is incurable. The treatment for the target population is estimated to cost US$ 31 per patient year. Given the estimated 260 thousand infected children under 5 years infected, the total cost of the treatment for them is of the order of US$ 8 million.

The program contemplates the eradication of the Chagas disease in Bolivia in gradual way. If correctly executed, it will be expected that nobody born after 2016 will have the disease. At the same time that the vectorial transmission will be stopped, the epidemiologic surveillance local systems will be fortified to avoid new risks for the strategy.

Elements for the Economic Evaluation of the Chagas Program

The economic evaluation of the program was carried out applying cost-effectiveness criteria (BID, 1998), taking into account the program effects from 1999 and 2016. The program could be also evaluated according the cost-benefit criteria, considering the direct and indirect costs and benefits of the program. The reduction in the number of person-years of labor withdrawn from the labor force after 2016, when the program will begin to produce an impact on the active age population, should be one of the most important benefits. This paper does not reach that far into the future, but some illustrative results are provided in annex 1, which reports on evaluations carried out previously in Bolivia and in Brazil.

As regards the cost-effectiveness analysis, we first compare the cost of each death avoided and the cost of each person-year gained by the reduced prevalence of Chagas with those of other diseases in Bolivia. The main difficulty in carrying out this kind of evaluation is, again, the limitation of the statistical information for the endemic Chagas areas. These deficiencies were overcome using expert opinion and some information regarding the epidemiology and a few available regional studies.

The application shown next was carried out in two parts. First, we calculated the impact of the program on the infected population under 5 and under 15 years old; in the second phase we estimate the number of deaths avoided in these age groups.

Estimation of the Number of Infected Cases

Since 1994, the Bolivian government had not developed a comprehensive program to confront Chagas diseases in Bolivia. Studies from Pan-American Health Organization estimate that in 1998 the rate of infection in the exposed areas varied between 21% for children under 1 year of age to 61% for those under 15. This result is to be expected, given that that the Chagas infection is not reversible, and thus the prevalence is accumulative over the life cycle.

Based on the referred data, we estimated the Chagas prevalence rate in the risk areas for the population under 5 and under 15 years old, taking into account the population forecasts prepared by the National Institute of Statistics (INE), and the different types of intervention contemplated in the program, which are explained next. The results of the projections are found in table 5.

Table 5
Forecasting of the Number of Infected Population under 5 and 15 years old with Chagas Disease: 1998-2016

Years	Under 5 years old			Under 15 years old		
	Without Intervention	Spraying	Spraying and Treatment	Without Intervention	Spraying	Spraying and Treatment
1998	288247	288247	288247	1204209	1204209	1204209
1999	295165	282692	220270	1233110	1215142	1152720
2000	302249	264905	151124	1262705	1214106	1081004
2001	309503	230829	77376	1293010	1197049	983218
2002	316931	176511	0	1324042	1160018	858203
2003	324537	112883	0	1355819	1119995	787436
2004	332326	59288	0	1388359	1068282	709401
2005	340302	20390	0	1421680	1006743	621485
2006	348469	0	0	1455800	939040	526325
2007	364484	0	0	1498391	858374	420305
2008	373231	0	0	1534352	772174	306659
2009	382189	0	0	1571177	674770	189657
2010	391361	0	0	1608885	569909	94293
2011	400754	0	0	1647498	452401	32232
2012	410372	0	0	1687038	327461	0
2013	420221	0	0	1727527	198472	0
2014	430306	0	0	1768987	97200	0
2015	440634	0	0	1811443	32117	0
2016	451209	0	0	1854918	0	0

This table shows the forecast of the number of Chagas cases under three scenarios: (a) status quo; i.e., no intervention; (b) intervention based on the household spraying and (c) intervention using spraying and treatment for children under 5 years of age. The first type of intervention is, as indicated earlier, intended to eliminate the vectorial transmission. Figures 1 and 2 show the expected impact of these strategies on the number of projected cases.

Figure 1
Forecast of the population under 5 years old infected with Chagas: Bolivia, 1998-2016

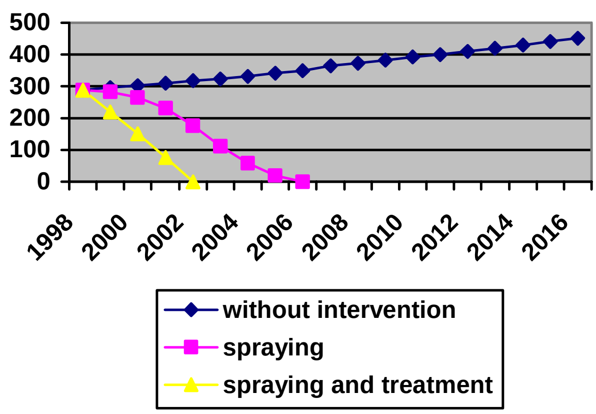
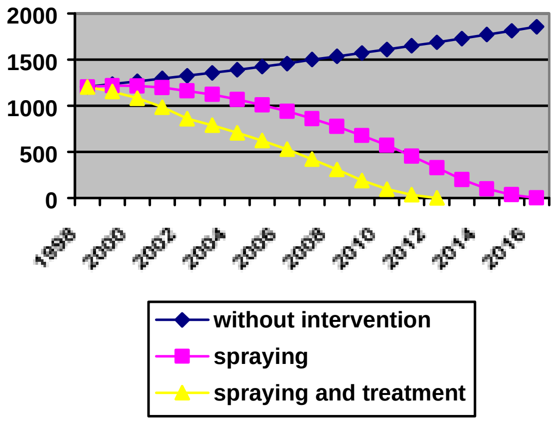


Figure 2
Forecast of the population under 15 years of age infected with Chagas: Bolivia, 1998-2016



The results show that, over the period 1998-2006, the program is expected to avoid the infection of 1.8 million children under 5 years old in 1998. Table 5 also suggests that several hundred thousand children (under 5 years of age) could be cured through appropriate treatment; but since this component is not financed by the project, an additional US$ 8 million would be needed to make that possible.

Forecasting of the number of deaths due to Chagas

Besides the progressive elimination of Chagas infection, the program will enable the reduction of the Chagas mortality among children under five years old. Without the program, the number of Chagas deaths in this age group is expected to increase from 2800 to 3300 between 1998 and 2006. Table 6 shows that only with the interruption of the vector transmission, the deaths due to Chagas in children under 5 years of age could be brought down to zero.

Table 6
Forecast of the number of Chagas deaths among children under 5 years of age

Years	Number of expected deaths		
	Without intervention	Spraying and blood transfusion strategies	Spraying, blood transfusion and treatment of children under 5 years old
1998	2882	2882	2882
1999	2952	2827	2202
2000	3022	2649	1511
2001	3095	2308	774
2002	3169	1765	0
2003	3245	1129	0
2004	3323	592	0
2005	3403	203	0

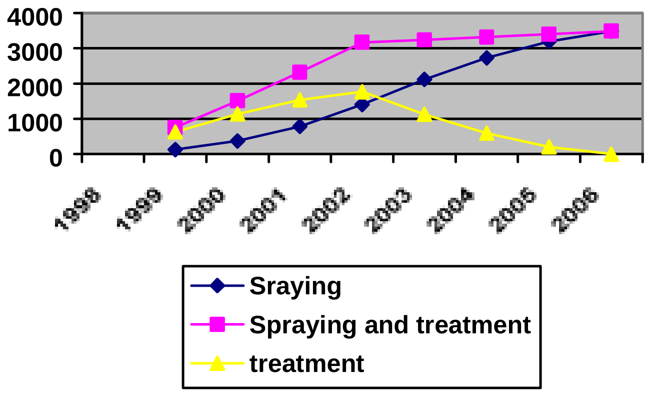
If treatment was added, the number of Chagas child deaths would be reduced to zero in 2002. In other words, as indicated in tables 6 and 7, spraying would allow to avoid a total of 14.200 child deaths. If treatment of young children was added to the program, more than 21 thousand of them could escape death due to this disease.

Table 7
Number of Chagas deaths among children under 5 years of age avoided by spraying, control of blood transfusion and treatment

Años	Number of Deaths Avoided		
	by spraying and control of blood transfusions	by spraying, control of blood transfusions and treatment	net effect of treatment on deaths avoided
1998	-	-	-
1999	125	750	627
2000	373	1.511	1.138
2001	787	2.321	1.534
2002	1.404	3.169	1.765
2003	2.116	3.245	1.129
2004	2.731	3.323	592
2005	3.200	3.403	203
2006	3.485	3.485	-
Total	**14.221**	**21.207**	**6.986**

Figure 3 graphs the evolution of the scenarios reported in table 7. It can be seen that the impact of treatment on the deaths reduction is just in short run (6 years after the start of the program). After 2006 there is no additional effect of treatment on the reduction of deaths, since there would be no more potentially infected children, thanks to the vector eradication.

Figure 3
Annual Number of Chagas Deaths Avoided
among children under 5 years of age in Bolivia, 1998-2006



V. Final considerations

This paper shows some practical applications of indirect estimates of mortality and morbidity due to some transmissible diseases. Despite the serious limitations of the pertinent statistical information in Bolivia and other countries where these diseases are important, the analysis shows the feasibility of obtaining some reasonable estimates, by use of all the information available, however imperfect and fragmentary it may be. Despite the data problems, the estimates provide useful inputs to prepare diagnostics and to quantify the requirements and impacts of intervention programs. In the case of Bolivia, we had to combine different data sources and to apply with care fairly simple estimation methods.

As regards the main substantive analysis, we found that Chagas, malaria and tuberculosis impose a heavy public health burden in Bolivia, as well as an economic strain, specially the first and third pathologies. Together, they account for annual production losses of more than US$560 million dollars in 1998 (7.2% of GDP). The loss due to Chagas is estimated to be US$334 million (4.3% of GDP); that of tuberculosis US$197 million (2.5% of the GDP) and malaria with little bit less than US$33 million (0.4% of GDP).

The Chagas program in Bolivia, financed by the IDB, is expected to avoid the infection of 1.8 million children of the cohort aged 0 and 5 years in 1998, by interrupting the vector and blood infection. The program can also, if implemented according to plan, avoid the death of 14 thousand to 21 thousand children under 5 years of age by 2006, depending on the number of implemented interventions.

The reported impacts are obviously subject to uncertainty, given that our results are based on a relatively small set of assumptions about the epidemiology of each disease, as well as the official population projections by age at the national level. Introducing additional assumptions and complexity in the estimation and projection model would add richness to the analysis, although not necessarily more precision to the estimated values, given the fragility of the primary information on which they are based. The present estimates could perhaps serve as a starting point for more elaborated cost-effectiveness and cost-benefit analyses, which would require to pay greater attention to the economic aspects that play in each type of evaluation, as well as the epidemiological dynamics of each disease.

Annex 1. Examples of cost/benefit evaluations of Chagas programs

A recent paper by Akhavan (1997) suggests that Chagas programs have very low cost and large benefits per year of life saved (according to distinct forms of measurement) vis-à-vis their costs. Specifically, Akhavan concludes that the Chagas program in Brazil which started in 1975, has avoided the loss of 2 million years of healthy life, 41% due to avoided deaths and 59% to avoided disability. It represents a cost equivalent to US$ 260 per year of healthy life gained and a cost/benefit ratio of 1:6.

Previous evaluations in Bolivia by Cárdenas (1997) showed much higher costs than the estimates obtained during the IDB program preparation. Her figures indicate that the cost of the previously existing, smaller scale Chagas program had been US$ 1,620 per death in the case of the interruption of vector transmission; US$ 6,312 per examination for the Chagas parasite in blood donations; US$ 1,325 for treatment of children under 5 years of age, and US$ 3,009 in the treatment of congenital Chagas among children.

The differences between Cárdenas estimates and the IDB study (1998) are related basically to the cost per year of life gained. The value estimated by Cárdenas is US$ 362 whereas the IDB study arrives to a much smaller value of US$ 3,79 per year of life gained. The differences can be attributed to: (a) to the fact that Cárdenas only considered the years of life lost avoided by the reduction of deaths, and did not take into account the gains due to reduced disability, which we have shown are very important; b) the costs found by Cárdenas refer to a program performance less efficient that the present program intends to be; and (c) Cárdenas estimates refer to all the Chagas patients, while the IDB covered only the group under 5 years of age, a targeting that also provides better opportunities for greater effectiveness.

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