Projecting the Future Budgetary Cost of AIDS Treatment in Poor Countries: A Manual for the AIDSCost Computer Programs

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Every year UNAIDS releases updated estimates of the number of people living with HIV and AIDS and the mortality impact of the epidemic, while WHO releases data on the number of people on treatment and the number needing treatment. Our dataset is a compilation of selected variables from these published sources as well as from the World Bank Development Indicators and the International Monetary Fund's estimates of economic quantities such as Gross Domestic Product and central government health expenditures. The data are in the computer format developed by the Stata statistical software corporation and are intended for use with the AIDSCost package described below, for the purpose of projecting the future budgetary cost of scaling up AIDS treatment.

[1]The authors are respectively Research Assistant and Senior Fellow at the Center for Global Development. They acknowledge the comments and "beta-testing" of Lori Bollinger, Markus Haacker, John Stover, Scott Kniaz, Danielle Kuczynski, David Roodman, and Martina Tonizzo. For programming assistance on the Stata "dialog" components, we thank, Zurab Sajaia and Misha Lokshin. Remaining errors are the responsibility of the authors. Like all software products, this one will require periodic updates both to correct bugs that have not yet come to light and to improve the utility and/or accuracy of its output. Please direct any comments or queries to the first author with a copy to the second author at the e-mail addresses: OMccarthy@CGDev.org and Mover@CGDev.org. These computer programs and the accompanying manual and data set were made possible by financial support from the Bill & Melinda Gates Foundation.

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As we write, the future of AIDS treatment in poor countries is uncertain.

With respect to financing, the rhetoric of donor commitment continues to promise accelerated recruitment of new patients and still holds out the hope of "universal access" to treatment, though some donors and governments appear to interpret this term rather more loosely than would the man in the street. Casting a shadow over this rhetorical optimism is the international financial crisis and the fact that the major donor to AIDS treatment, the newly elected American government, has yet to determine the place of AIDS treatment in its foreign assistance policy.

This paper presents two open-source programs in Stata[2] for estimating the progress and financial burden of treating the AIDS epidemic, and for comparing alternative AIDS projection scenarios. Using data compiled from UNAIDS, the WHO, the World Bank, and the IMF[3], one can project up to 2050 the accumulating number of patients under treatment, as well as the projected cost of that treatment. The projections can be made for any of the more than 100 countries included in the provided data set or for various groups of those countries. Taking advantage of the user-defined parameters, as well as myriad graphing, specification and weighting options allows the user to appreciate the sensitivity of AIDS cost projections to the multiple assumptions on which they rest.

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[2] Stata is a proprietary statistical software package that allows for the programming and dissemination of user-written updates. We choose to release AIDSCost in this form to take advantage of the wide availability of Stata as well as the transparency and public good aspects of open-source. While use of the program does require a copy of Stata, the dialog boxes included in the AIDSCost package allow beginning users to bypass the rather steep learning curve of the Stata command line and run basic projections with the guidance of this manual.

[3] UNAIDS data from the 2008 Report on the Global AIDS Epidemic, (UNAIDS, 2008). WHO Data from the 2008 and 2007 "Towards Universal Access: Scaling up priority HIV/AIDS interventions in the health sector ((WHO, UNAIDS & UNICEF, 2007). World Bank data from the 2008 WDI(World Bank, 2008), and IMF data from the 2009 World Economic Outlook (International Monetary Fund, 2009)

In this set of programs, the total cost of AIDS treatment in a given country in a given year is the product of a unit cost specific to that country and the total number of people under treatment that year. Section 1 presents our simple model for unit costs of the health care provider.[4] Section 2 shows how to use these programs to project the cost of AIDS treatment under different epidemiological assumptions. Sections 3 and 4 introduce specific AIDSCost programs for projection and scenario comparison, including information on how to use each effectively. Section 5 discusses data imputation strategies, and Section 6 concludes.

Experienced users of Stata can skip directly to Appendix 1, which provides instructions on how to use Stata's command line to download and install the AIDSCost package. Other appendices provide additional technical information, such as a list of the variables in the included dataset and a formal description of the projection model.

I. A simple model of the cost of AIDS treatment

The total cost to the provider of delivering a service such as antiretroviral treatment is determined by many variables, including the prices of the inputs, the quality of service delivered, the intensity of that service as required by the characteristics of the patients, the skill of the providers and their managers, the incentives under which they operate and the volume of patients they serve. Health economists have labored for years to estimate "cost functions" which incorporate these considerations for hospital care, for ambulatory care

[4] The patient also typically incurs various costs for treatment, including opportunity cost for his or her time, transport costs and a co-payment for either pharmaceuticals or for the service. For lack of data, this model omits consideration of costs borne by the patient.

and for various specialized services. Unfortunately at this writing a sophisticated cost function has not yet been estimated for antiretroviral therapy in resource limited settings.

In the absence of a cost function from the literature for the service we are modeling, we assume that the cost of delivery of antiretroviral therapy (ART) in developing countries will obey a very simple cost function.

$$\begin{bmatrix} Total \\ Cost\ in \\ country\ i \\ in\ year\ t \end{bmatrix} = \begin{bmatrix} Number\ of \\ Patients\ on \\ First\ Line \\ Therapy\ in \\ country\ i \\ in\ year\ t \end{bmatrix} \times \begin{bmatrix} Unit \\ Cost\ of \\ First\ Line \\ Therapy\ in \\ country\ i \end{bmatrix} + \begin{bmatrix} Number\ of \\ Patients\ on \\ Second\ Line \\ Therapy\ in \\ country\ i \\ in\ year\ t \end{bmatrix} \times \begin{bmatrix} Unit \\ Cost\ of \\ Second\ Line \\ Therapy\ in \\ country\ i \end{bmatrix} .$$

This equation assumes that there are only two discretely different types of ART in a country, "First-Line" therapy and "Second-Line" therapy. It assumes that the unit cost of each of these types of therapy is fixed over time within the same country.[5] Thus, the total cost of first line therapy in country ***i*** in year ***t*** is just the unit cost of first line therapy for that country multiplied times the number of patients receiving that type of care in that country and year. We apply the same model to the cost of Second-Line therapy. Total cost is just the sum of the two.[6]

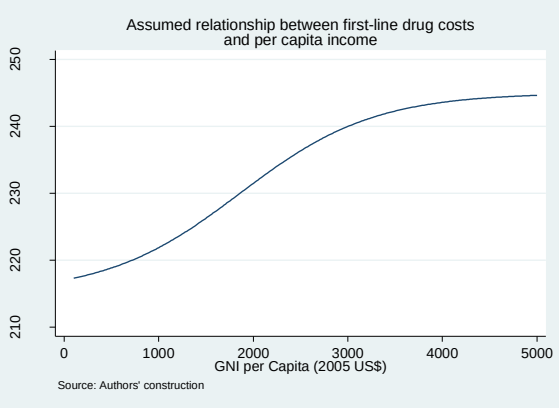
[5] Economists refer to this assumption of fixed unit costs as "constant returns to scale," because unit costs do not vary with the scale of production. Alternative possibilities include increasing and decreasing returns to scale.

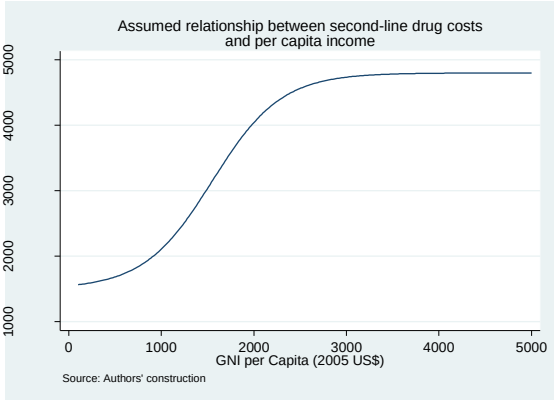
[6] If these unit costs were evaluated at the shadow prices of individual inputs and if patient costs were also included, the resulting cost projections could be considered to be the "social costs" of treatment. Since neither shadow prices nor costs borne by patients are included explicitly in the model, the projections only pertain to the budgetary or financial costs of service delivery and probably underestimate the social cost.

We model the unit cost of first- and second-line therapy as the sum of two average costs, one of ART pharmaceuticals and the other of all other costs to the provider.[7] We assume that pharmaceutical costs differ between first-and second-line therapy, but the non-pharmaceutical cost per patient year is the same for both.[8]

According to a 2007 WHO report on scaling up ART access, the weighted average price of the four most commonly used first line antiretroviral drug combinations was $219 in low income countries, and $245 in middle income countries. These values were thus taken to be the minimum and maximum of the estimated distribution of first-line drug costs, and a similar method determined the costs of second line drugs in low and middle income countries to be $1,500 and $4,800, respectively. In the absence of evidence on systematic variation of drug prices with per capita income above and below these thresholds, we treat these low and high estimates as ceilings and floors respectively. In order to predict the unit price of drugs for any individual country, we interpolate between these values using an "S-shaped" or "logistic" curve calibrated to fit between these extreme values.[9] Figure 1 shows the derived relationships between gross national income (GNI) per capita on the horizontal axis and our estimate of first line (Panel a) and second line (Panel b) drug cost on the vertical axis.

[7] We omit any consideration of costs to the patient or external costs to society of AIDS treatment. This program package is designed to project budgetary costs of program expansion, not social costs.
[8] In the provided dataset the three unit cost variables are *rxc1, rxc2* and *nonrxc*.
[9] We assume that country level ART costs vary with their gross national income per capita, between the predefined minimum and maximum stated above. These costs are the solution to a logistic function that relates a country's ART price to its GNI per capita, while restricting the value to the band between the given minimum and maximum values.





Panel a. First-line drug cost per year **Panel b. Second line drug cost per year**

Figure 1. Assumed relationships between pharmaceutical cost per patient year and the country's gross national income per capita

We followed a similar approach to estimating the non-pharmaceutical cost per patient year, where the maximum per patient average cost is assumed to be $500 and the minimum $150. Figure 2 displays the prediction equation we used to estimate the unit cost for each country.

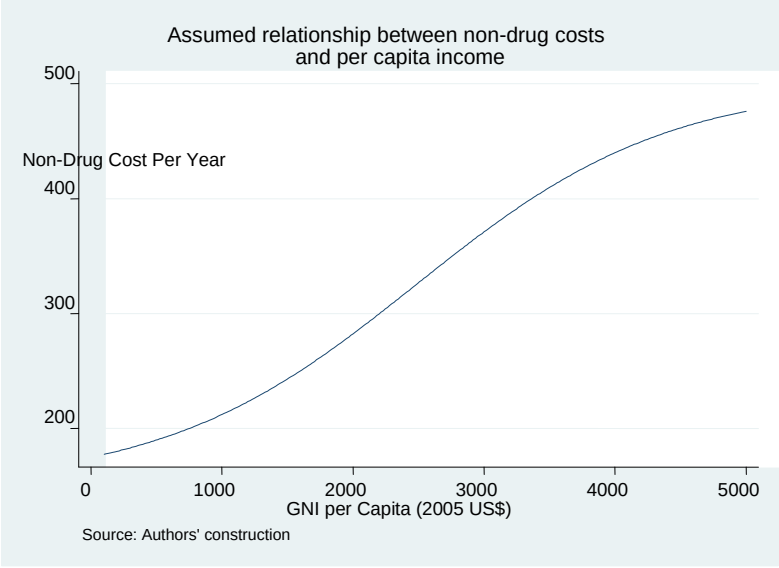


Figure 2. Assumed relationships between non-pharmaceutical cost per patient year and the country's gross national income per capita

With these estimates of unit cost, we now turn to the other part of our cost estimation, projection of the number of patients.

II. Use of the AIDSCost tools

Projecting the course of the epidemic

How many new HIV infections can we expect in the coming years? How many will be added to anti-retroviral therapy (ART)? How much will this cost? The AIDSCost program "***aidsproj***" allows users to manipulate parameters governing incidence, and ART uptake, and project the course of AIDS prevalence, incidence, deaths, costs, and ART coverage up to the year 2050. In this way, users can track the growth of the treatment "entitlement", as outlined in Over, 2008.[10]

[10] Over uses these programs to estimate the course of the AIDS epidemic and from this explores what he terms the AIDS entitlement: "The term `entitlement' applies to a government expenditure program which engenders the expectation that current beneficiaries will continue to receive funding in future years." (Over, 2008)

The graphs below show examples of ***aidsproj*** output illustrating the growth of the aids entitlement in the 15 PEPFAR focus countries, as well as the costliness of increasing treatment in the absence of prevention, as discussed in Over, 2008.

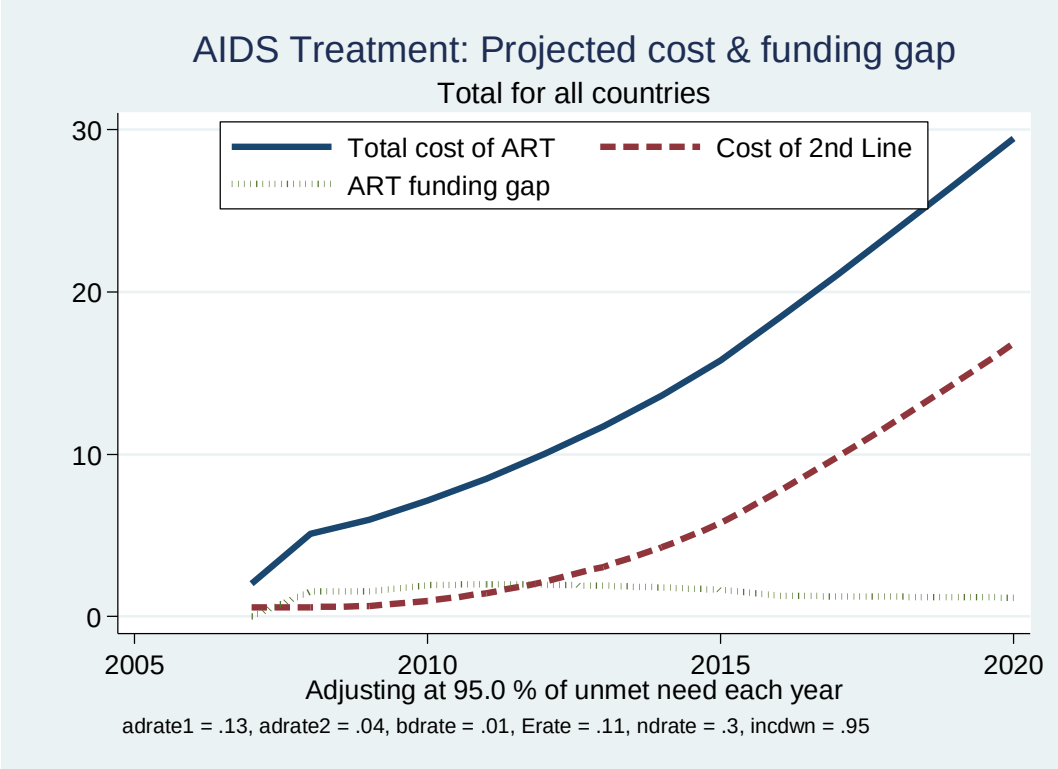


Figure 3. Projected Future AIDS treatment under the assumption of rapid ART uptake..

Figure 3 is an example of output from AIDSCost program ***aidsproj***. The variable parameters are displayed underneath the X axis. The graph shows the total cost of ART funding over the next twelve years under the assumption of rapid ART scale up. Over uses AIDSCost programs to make projections such as these to show that the U.S, through the large expansion of overseas AIDS treatment funding, has created a stock of patients dependent on the continuation of treatment funding, a dependency relationship that he calls an AIDS treatment "entitlement". Furthermore, he shows that the size of this US obligation or

"entitlement" would quickly grow if the current rate of expansion were to be maintained. He also uses this model to argue that prevention constitutes a cheaper way to manage the fiscal burden of the epidemic, but would only reduce treatment expenditures in the long run.

Comparing different projection scenarios

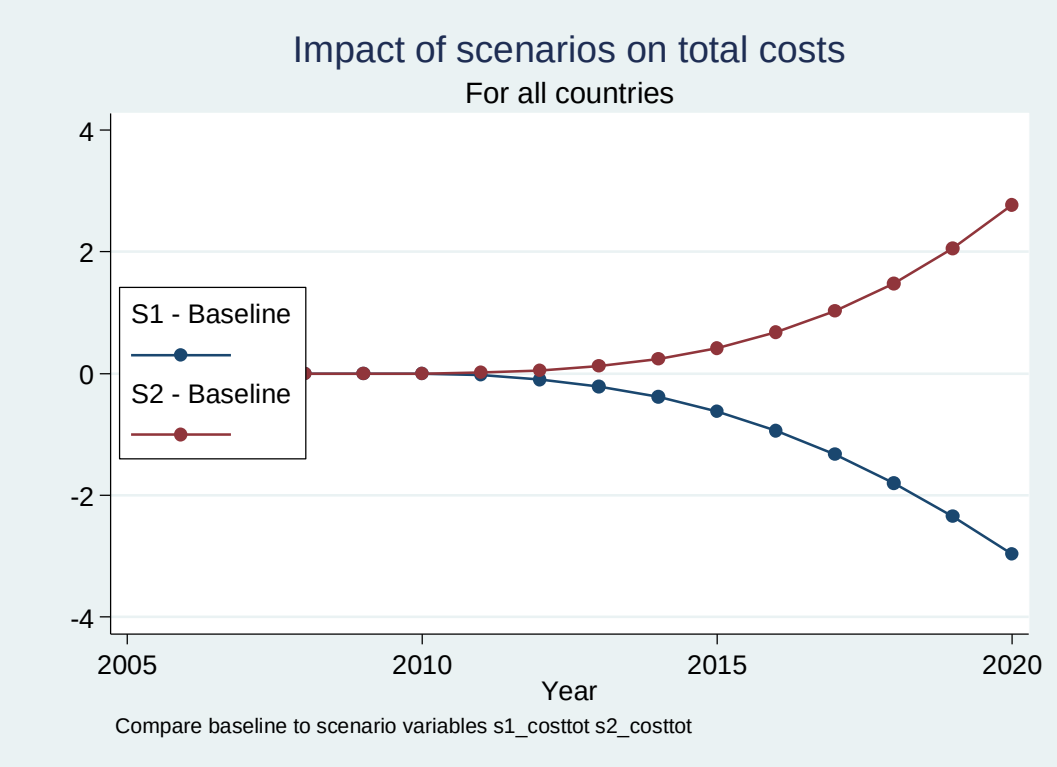


Figure 4. Difference in total costs under different assumptions of incidence

Figure 4 above is an example of output from the AIDSCost program ***aidsdif***, and shows the sensitivity of the cost estimate projection in Figure 3 to different assumptions regarding incidence. The blue line shows the difference in costs between a baseline

projection of rapid ART uptake and slowly decreasing incidence to a scenario where incidence decreases by 25% each year. While this difference-in-cost projection does not account for the cost of the intervention that lowered incidence, it is a useful comparison to the red line, which shows scenario 2. Scenario 2 here assumes incidence slowly *increases* by 5% every year[11]. One notices that the blue line stays low and eventually becomes negative as total costs decrease with incidence, whereas the red line steeply increases. ***Aidsdif*** takes the output files from ***aidsproj*** as input, so the user can make comparisons of relative costs and benefits of up to six ***aidsproj*** scenarios relative to a baseline ***aidsproj*** projection. Figure 4 represents one of several output graphing options, and there are a variety of tables that can be produced comparing costs over the projected years. ***Aidsdif*** thus allows one to see the magnitude of the additional burden of treatment as it widens over time.

[11] For a discussion on whether ART presence increases risky sexual behavior, see (Katz, Schwarcz, Kellogg, Klausner, Dilley, Gibson et al. 2002), (Crepaz, Hart & Marks, 2004), (Over, Revenga, Masaki, Peerapatanapokin, Gold, Tangcharoensathien et al. 2007), and (Over, Heywood, Marseille, Gupta, Hira, Nagelkerke et al. 2004)

III. Aidsproj requirements

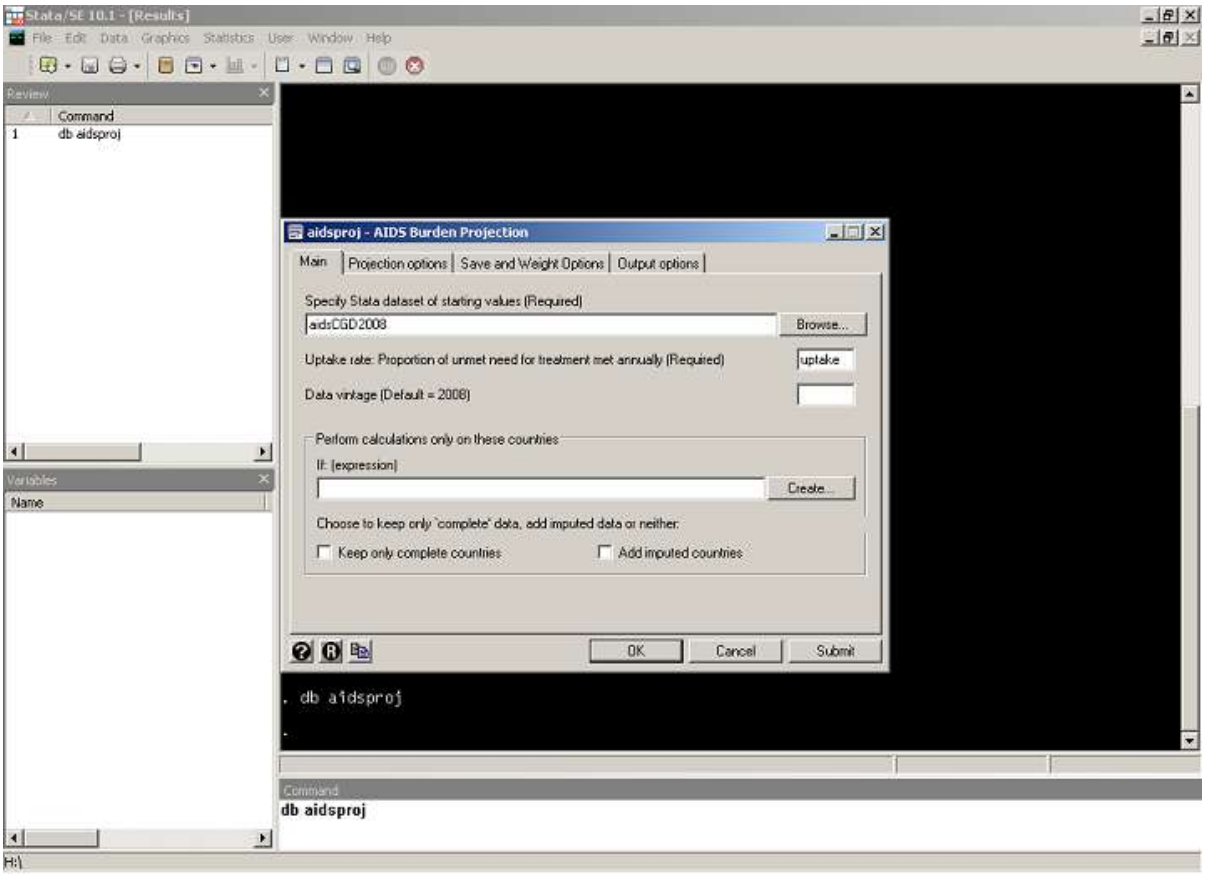


Figure 5. Screenshot of AIDSCost dialog *Aidsproj*, and the Stata command which invokes it.

Aidsproj makes projections of prevalence, incidence, deaths, need for anti-retroviral therapy, ART coverage and costs of treatment. ***Aidsproj*** uses these five key variables to make relatively simple extrapolations, whereby one can manipulate assumed parameters (shown below) to track how sensitive the progress of the epidemic (in a single country, group of countries, or the entire world) is to assumptions about uptake, death rates, ART coverage and others. Furthermore, ***aidsproj*** creates new variables that allow the user to track the total cost of treating AIDS, as well as breaking up costs into discretionary and entitlement spending.

The above screenshot displays the Stata command that produces the ***aidsproj*** dialog box, 'db aidsproj'. The filepath of the required starting dataset, "aidsCGD2008" is shown, as well as an illustration of the way to select the country-specific historical ART uptake rate, *uptake*. The 'if' section allows users to restrict projections according to the rules of normal Stata expressions. For example, the ***aidsproj*** user can restrict projection to only the PEPFAR countries by entering the word 'pepfar' into this dialog box. The check boxes for "imputed" and "complete" countries restrict the sample in specific ways, discussed below.

The only required option in the command syntax is the uptake parameter, which is the proportion of need for new enrollment in ART met each year. For example, suppose that in a certain country there are 2000 people previously enrolled in ART while an additional 1000 people need ART this year. The model assumes that none of the 2000 previously enrolled lose their entitlement.[12] ***Aidsproj***'s uptake parameter determines how many of the additional 1000 people needing treatment will be added to the treatment rolls. If ART uptake in a particular year is 85% (the country fills 85% of the gap between last year's enrollment and this year's need), the value of this uptake parameter for that year would be 0.85. The user can select this value by specifying a numerical constant for the parameter, *uptake*. In this case this same constant uptake parameter is applied to all countries in computing future projections. Alternatively, the user can exploit the provided country-specific values of *uptake*, in which case ***aidsproj*** assumes each country's future uptake will

[12] For this computation we set aside the fact that some of the hypothetical 2000 on ART the previous year will have been lost to follow-up. Although this proportion lost to follow-up is crucial for measuring the success of antiretroviral therapy, its value is unknown for any specific country in the world. For projections the user must specify a value of this proportion by choosing a values of the parameters ***adrate1, adrate2*** and ***bdrate***, but in the absence of country-specific information we prefer to assume this value is zero when we estimate country-specific uptake rates.

be as successful as it was between 2006 and 2007[13]. The ***aidsproj*** user requests the program to use this provided country-specific value for each country by typing the word "*uptake*" in the uptake option. Note that there is no default value for *uptake* in ***aidsproj***; the user must specify it. The specified uptake rate is a major determinant of the projected values of the total cost of treatment and of total AIDS related mortality.[14]

If the user sets the parameter by typing the word "*uptake*" as in Figure 5rather than entering a specific value, ***aidsproj*** assumes that each country continues to fill unmet need at the same rate that it did between 2006 and 2007. For example, between 2006 and 2007 Uganda increased its treatment enrollment by 16,464 patients, a respectable number on its own merits. However, the gap between the number enrolled the previous year and the number estimated to need treatment in 2007 was 251,464. So Uganda's rate of adjustment toward complete access to AIDS treatment of all in need was only about 7 percent. And the value of the parameter *uptake* for Uganda was 0.07.

Across all the countries in the provided data, the rate of adjustment varies from close to zero to close to 100 percent and the value of *uptake* thus varies from close to 0 to close to 1.0. From inside Stata, the user can print out the values of *uptake* for all the countries in the data set by typing:

use aidsCGD2008, clear

list cntry uptake

[13] A constructed measure of ART enrollment is used for this purpose, defined as enrollment in 2007, minus twelve times the average monthly increase in ART enrollment. The second author believes this to be a more reliable retrospective estimate of ART enrollment in 2006.

[14] *Uptake* is defined as (1-*lambda*). The parameter *lambda* comes from the partial adjustment model: $Y_t = Y_{t-1} + (1-\lambda)(Y_t^* - Y_{t-1})$, where Y_t is the number receiving treatment in year ***t*** and Y_t^* is the desired number of people receiving treatment in that year, here defined to be the total number needing treatment.

By asking Stata to produce a histogram of the variable *uptake* with the command,

histogram uptake, frequency

the user can display the distribution of the country specific adjustment parameter *uptake* . Only 23 of the countries in the dataset performed well relative to unmet need, increasing their treatment enrollment by at least 50 percent of the gap between 2007 need and last year's enrollment. (These are the countries with values of *uptake* above 0.5.) The remaining 103 countries were only able to achieve a fraction of this rate of scale-up, with 47 increasing enrollment by less than 10 percent of the gap (with values of *uptake* less than 0.1).

Using *uptake,* the starting values for the other variables and certain user-selectable parameters, the program computes a projection for each successive year. These parameters can be seen in the "Projection Options" tab of the dialog shown in Figure 6.[15] Note that all can be manipulated and the default values are as listed. The parameters enter in the projections as multipliers of preceding values of prevalence, incidence, coverage and death. Therefore, the choice of parameter values, to some degree, affects all five of the key variables, as well as the cost projections. The equations used to compute the projected values of the five key variables are shown in the Appendix 5.

[15] The second author selected the default values of these parameters based on his prior experience modeling antiretroviral therapy in India ((Over et al., 2004) and Thailand ((Revenga, Over, Masaki, Peerapatanapokin, Gold, Tangcharoensathien et al. 2006)), on conversations with John Stover and Lori Bollinger, authors of the Spectrum mode(l(Bollinger, Stover & UNAIDS, 2007), (Stover, Johnson, Zaba, Zwahelan, Dabis & Ekpini, 2008)), and with knowledgeable UNAIDS and World Bank staff. A discussion of the survival curve of AIDS patients in the context of Thailand is presented in Appendix A of (Over et al 2006). However, no one knows today what the actual value of any of these parameters will be for any country in the world. This is an important reason to release this computer program and solicit ideas from many people on the possible future values of these parameters.

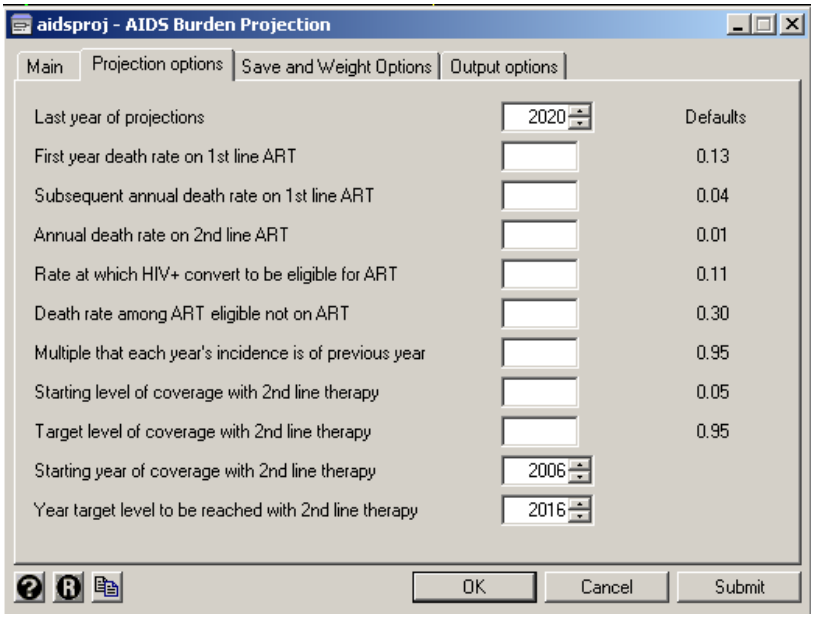


Figure 6. Screenshot of Aidsproj second tab

An option visible at the bottom of the Main tab of the ***aidsproj*** dialog affects the sample of countries included in the projection. Due to gaps in the data reported to UNAIDS, the WHO and the World Bank, some countries required simple imputations to "fill" one or more of the five key variables. Some required more daring imputations. The simple imputations were most often for missing values of *need* for ART, which can be roughly estimated from available estimates of other variables, such as prevalence, the number on treatment, etc.. The more heroic imputations can only be constructed by using a regression equation to predict the missing value. The user can choose to keep only countries where there was no imputation (by checking the "complete" box), to keep the additional countries for which a few imputations were necessary (by checking neither box) or to have ***aidsproj*** perform additional more heroic imputations in order to add a few additional countries. In total, there are 88 "complete" countries. Adding heroicly imputed countries brings the total number in the sample to 126. The default, middle path has 109 countries in the sample.

The other default options represent the authors' best guesses regarding the mortality reduction achievable with an antiretroviral therapy program which is able to retain patients as successfully as the model programs on which data is currently available. An important potential use of the AIDSCost package is to explore the implications for future fiscal burdens and mortality reductions of alternative assumptions regarding he mortality benefits of ART as represented on the second tab of the ***aidsproj*** dialog.

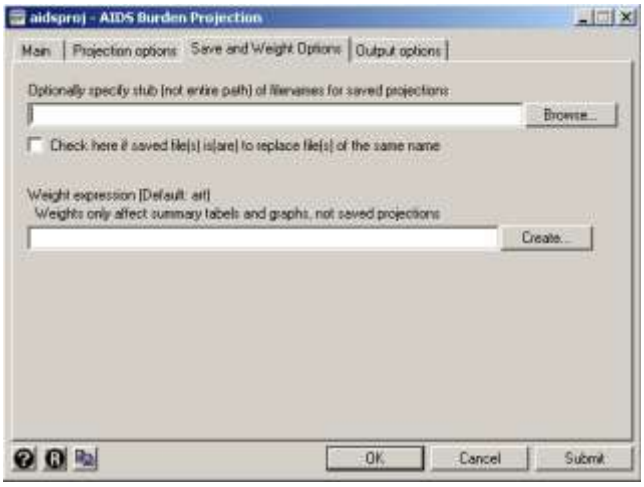


Figure 7. Aidsproj's 3rd tab.

The first box on the "Save and Weight Options" tab allows the user to specify the file stub which will save any graphs produced, as well as the final output data[16]. The user need not specify individual names for the graphs and data, as the program adds on identifying suffixes for each graph. For example, specifying the stub "projection" will produce saved graphs such as "projection_n__World.gph". "World" here, refers to one of the output options, which will be discussed below, and "n" to a graph of unmet ART need.

[16] In order to make projections, ***aidsproj*** makes substantial changes to the original source dataset "aidsCGD2008.dta". The program also produces a large amount tables and graphs, depending on how many options are specified. Saving the resulting dataset allows the user greater freedom to view tables and graphs, as well as compare projections under different assumptions. Note also that ***aidsproj*** will refuse to continue if the user specifies an already-existing file. To overwrite an existing file, use the check box on the third tab of the dialog box.

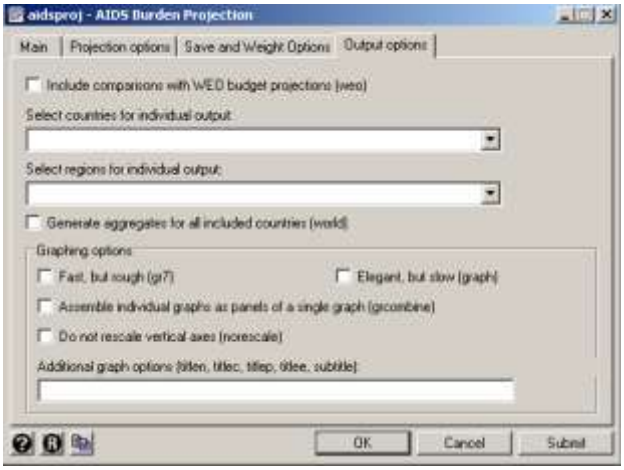


Figure 8. Aidsproj's 4th tab

The fourth tab of the ***aidsproj*** dialog allows the user to select output and graphing options. The 'weo' checkbox produces projections of ART expenditures as a percentage of various parts of national health care spending. The two drop down boxes for country and region selection are not mutually exclusive, nor all required; the user can specify individual countries along with regions, and each country or region will have its own tables and graphs. The 'world' checkbox aggregates included countries, rather than printing output for each country separately. In the absence of countries or regions specified above, it also produces aggregate output for all included countries.

The graphing options are for the most part cosmetic, but for any graphs to be produced, one of the top two graphing options must be selected. The "Elegant, but slow" check box produces standard Stata format graphs, and takes a few seconds each to produce. The faster option produces less formatted graphs, but completes in a fraction of a second. Other options allow you to add titles, combine multiple graphs into a single file, and change a default graphing option[17].

[17] Type "help rescale" from inside Stata for information on a utility program that may be useful independently of this package.

After all parameters and options are specified, execution of the ***aidsproj*** program produces a number of tables. There are epidemiological projections, which show the progression of prevalence, incidence, deaths, coverage, need for ART, and ineligibility of HIV positive people (variables *p, I , d, art, n, h,* respectively). Treatment projections display a table of unmet need, the number ineligible, number on first line ART, number on second line ART, and the total number on ART.

The cost projections table displays the costs of first and second line treatments per patient, non pharmaceutical costs per patient, total costs of first and second line treatments, and the funding gap for ART treatment. In its current incarnation, ***aidsproj*** varies unit costs across countries according to the country's income level, but holds unit costs fixed over time in any individual country. Also produced are estimates of total discretionary and non-discretionary spending, as well as the total "entitlement". Below is an example of one of the output tables, which projects aggregate total costs in thousands of US dollars for all countries, and assumes rapid uptake of ART treatment with slowly decreasing incidence:

Table 1. aidsproj cost projections.

----Cost projections (US$1,000's)----

Variables in table:

cost1st	**Cost of 1st Line ART ($1,000's)**
cost2nd	**Cost of 2nd line ART**
costtot	**Total cost of ART**
fundgap	**Funding gap for ART**

year	cost1st	cost2nd	costtot	fundgap
2007	1,480,009	543,615	2,023,624	0
2008	4,519,007	571,675	5,090,682	1,544,925
2009	5,327,353	644,889	5,972,242	1,541,316
2010	6,212,916	951,449	7,164,365	1,938,942
2011	7,065,388	1,436,933	8,502,321	1,978,530
2012	7,876,745	2,130,120	10,006,865	1,960,352
2013	8,643,579	3,060,785	11,704,364	1,896,133
2014	9,363,587	4,255,568	13,619,155	1,789,077
2015	10,035,276	5,737,711	15,772,987	1,642,419
2016	10,657,845	7,720,119	18,377,964	1,266,325
2017	11,231,059	9,830,666	21,061,725	1,244,040
2018	11,755,188	12,057,068	23,812,256	1,219,624
2019	12,230,852	14,387,357	26,618,209	1,193,478
2020	12,659,060	16,809,517	29,468,577	1,165,973
Total	119,057,864	80,137,472	199,195,336	20,381,135

While this projection only goes to 2020, ***aidsproj*** allows projections to be made up to 2050. One immediately notices the consistent billion dollar plus funding gap throughout the next decade.

IV. Requirements for *aidsdif*

The usefulness of projecting the global burden of AIDS treatment is enhanced by comparisons between alternative projection scenarios. Whereas ***aidsproj*** is a tool for projecting the global burden of AIDS treatment, ***aidsdif*** allows the user to quantitatively compare different scenarios, and see the impact of various changes in assumptions on up to six different scenarios.[18] ***Aidsdif*** displays the values of the chosen variables year-by-year,

[18] The user-friendly dialog for ***aidsdif*** allows the specification of one baseline projection and four alternative scenarios. Using Stata's command line interface, one can specify up to six alternative scenarios.

then calculates the difference in each year. The value of ***aidsdif*** is being able to calculate the dollar treatment costs and mortality benefits of different AIDS treatment policies over time, and thus calculate and display the cost-effectiveness of different interventions that are aimed at reducing one or more of the key determinants of the future cost of AIDS treatment. .

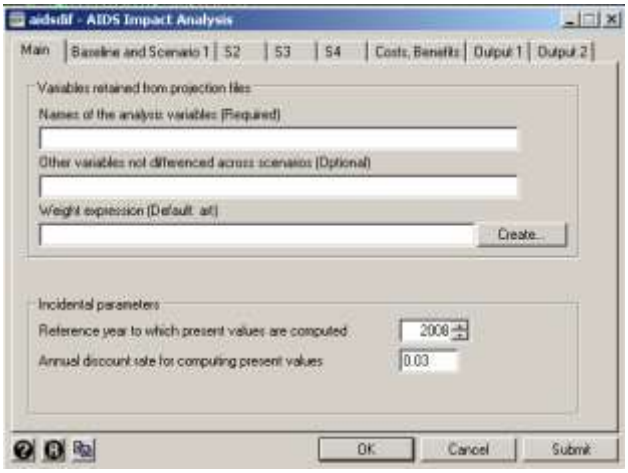


Figure 9. Aidsdif's 1st tab.

There are only a few requirements for ***aidsdif***. As is the case for ***aidsproj***, ***aidsdif*** requires some input variables in order to run. These are a cost variable and a benefit variable, which are by default assumed to be the variables total annual cost of treatment (*costtot*) and total annual AIDS deaths (d), both of which are produced in the output of ***aidsproj***. It is possible to specify other cost or benefit variables; one need only add the option or include them in the fifth tab of the ***aidsdif*** dialog. The discount rate by which future costs and benefits are calculated is a selectable parameter, as is the reference year to which future streams of costs and benefits are discounted.

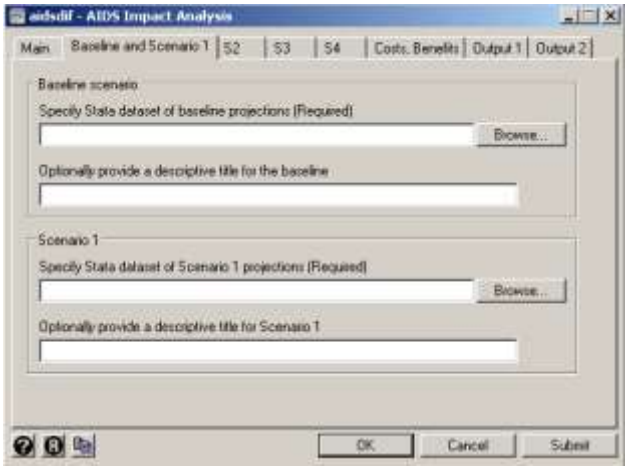


Figure 10. Aidsdif's second tab specifies the two required projection files to be compared, the baseline file and the first scenario file

The datasets of baseline and scenario projections that are required to be chosen here are where the user must decide what to analyze. The required datasets are saved output files form ***aidsproj***, so the user can test the results of different assumptions about the progress of the epidemic. For example, if users wanted to estimate the reduction in annual AIDS deaths and the increase in treatment costs associated with increased ART uptake, they could produce two ***aidsproj*** datasets, each with different values of ART uptake (*uptake*). Using the high uptake scenario as the baseline and the low uptake scenario as the comparison allows one to see the increased cost of higher ART uptake. The program also computes and displays the ratio of the incremental costs to incremental deaths, producing the estimated cost-effectiveness of the increased speed of uptake. The S2, S3, and S4 tabs allow the user to specify up to four different scenarios each of which will be compared to the specified baseline.

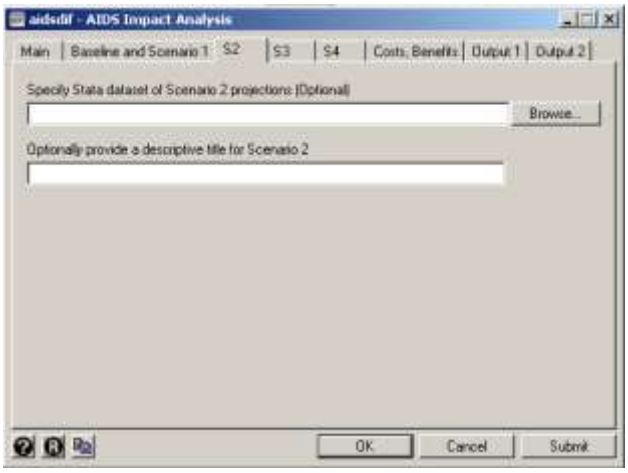


Figure 11. Aidsdif's 3rd tab.

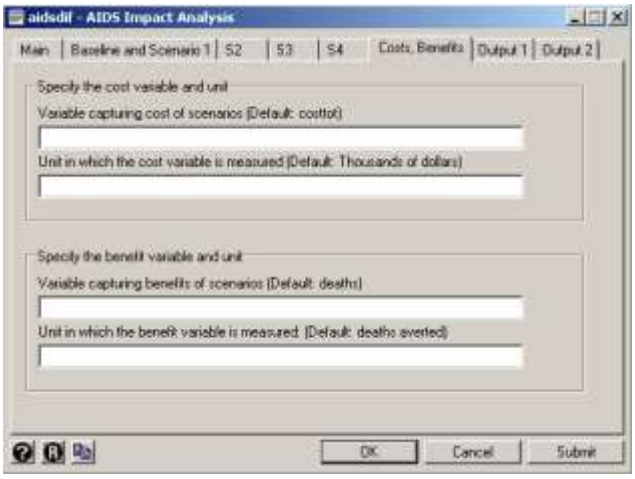


Figure 12. Aidsdif's 6th tab

The "Costs, Benefits" tab asks the user to specify cost and benefit variables in which the differences will be recorded. This paper's examples uses variables "*costtot*" and "*d*", which refer to total per-year costs of ART and total deaths, respectively, as cost and benefit variables. Note that these specific variables must be present in the datasets in for the defaults to work.

While ***aidsdif*** produces too much output to display in its entirety here, the following table illustrates the important point: This scenario can be produced by the ***aidsdif*** dialog box by filling in the three filenames as specifications for the files "Baseline", "Scenario 1" and "Scenario 2" and then checking the boxes "Generate aggregates for all included countries (world)" and "Fast but rough" on the Ouput1 tab and the box "Display differences between scenarios and baseline" on the Output2 tab[19].

Variables containing the cost-effectiveness over the projection horizon: by country

variable name	storage type	display format	value label	variable label
ce1_d	float	%9.0g		**CE of S1: Dollars per deaths averted**
ce2_d	float	%9.0g		**CE of S2: Dollars per deaths averted**

Variable	Obs	Mean	Std. Dev.	Min	Max
ce1_d	**106**	**17.8082**	**5.292968**	**12.33732**	**27.02595**
ce2_d	**105**	**16.11861**	**4.671426**	**11.33303**	**23.57562**

Averages of cost-effectiveness over the **105** countries by region:
Weighted by **art**

Variables in table:

ce1_d	**CE of S1: Dollars per deaths averted**
ce2_d	**CE of S2: Dollars per deaths averted**

rgn	ce1_d	ce2_d
EAP	**18.596**	**16.844**
	10.000	**10.000**
ECA	**23.174**	**21.007**
	17.000	**17.000**
LAC	**23.196**	**21.020**
	24.000	**24.000**
MNA	**20.431**	**18.372**
	7.000	**7.000**
SAS	**13.534**	**12.413**
	5.000	**5.000**
SSA	**16.285**	**14.879**
	43.000	**42.000**
Total	**16.882**	**15.401**
	106.000	**105.000**

Table 2. Aidsdif's cost comparisons.

The command calls three files, which are in order, the baseline, the first scenario and the second scenario. The baseline is output of ***aidsproj*** with country specific ART adjustment at

[19] Alternatively, more comfortable users can input the following command into Stata's command line, all in one row. The resulting projections are the same whether one uses the dialog or the command line.

```
aidsdif costtot d, bl("world_adjhist_inc95_08.dta")s1("world_adjhist_inc75_08.dta")
s2("world_adj95_inc95_08.dta") world gr7 grd
```

historical uptake rates and reduction in incidence of 5% each year. Scenario 1 simulates an intervention focused on prevention, reducing incidence by 25% each year. Scenario 2 simulates an intervention focused on scale up, with ART adjustment set to 95% instead of the historical value (which in this case is about 18%). Notice that ***aidsdif*** creates two variables, *ce1_d* and *ce2_d*, which are the cost-effectiveness of scenarios 1 and 2 respectively, in dollars per death averted. The program computes only AIDS treatment costs. This means that the extra treatment cost of moving from 18% to 95% uptake are included in the comparison of Scenario 2 to the baseline, but the extra costs of implementing an HIV prevention program that would reduce incidence by 25% per year instead of by only 5 % a year is not included in the comparison of Scenario 1 to the baseline.

One can see that the mean of *ce2_d* is significantly higher, with increased uptake costing nearly six dollars more per death averted than increased prevention. This is an intuitive, even obvious result; preventing one death could be cheap as providing a condom, whereas putting one more infected person on treatment commits whoever pays for treatment to years, if not decades of costly monthly expenditures. There is also a table that shows the difference in means and samples broken down by region. The output not displayed here shows year-by-year differences in deaths, costs, and any other variable one cares to include, and shows the total costs incurred or avoided. Using ***aidsproj*** and ***aidsdif*** in conjunction this way allows for a transparent and easily adjustable method for the evaluation of the impacts of various changes in assumptions.

V. Data Imputation Strategy

In order to make projections of future cost burdens from published data, it is necessary to address two missing data problems: (1) UNAIDS did not publish their estimates of country-specific HIV incidence for past years, so we must impute those numbers in order to guess future incidence; (2) some countries are missing data on only one or two key variables, which the user may prefer that we impute from other variables known for that country.

UNAIDS publishes estimates of total incidence within a region, but eschews publication of the estimates of country-specific HIV incidence because such estimates are unreliable, much more so than prevalence estimates for the same year and country. But using the following equation, it is possible to approximate the AIDS annual incidence numbers that are implicit in the UNAIDS prevalence estimates

$$i_t = plwh_t - plwh_{t-1} + aids_death_t$$

where the variables *plwh* and *aids_deaths* come from UNAIDS data[20]. The estimates of incidence so obtained are plausible on average, but their variation from year to year in the same country is often erratic and implausible, especially for countries with low numbers of incident cases. It is likely that this exaggerated year-to-year variation is an artifact of UNAIDS' rounding of the variables *plwh* and *aids_deaths* to the closest 100 or 1,000. So our strategy is to smooth the annual incidence numbers obtained from the above process and use the baseline-year value from that smoothing process (e.g. the 2007 smoothed value for vintage 2008 data) as a basis for projecting future incidence. When aggregated by region,

[20] Ideally one would want to add to the right-hand-side the number of non-AIDS deaths among people living with AIDS. However, this figure is unknown and is in any case likely to be small as a proportion of total deaths among people living with AIDS.

these incidence estimates closely match UNAIDS' estimates for the same regions.

Missing data was a problem in nearly all the key variables to some degree, so a variety of imputation strategies were used, reflecting the level of uncertainty about true estimates. For example, UNAIDS does not always report point estimates of AIDS prevalence in specific countries, but does indeed calculate them and use them in their total regional and global estimates (UNAIDS annual report 2008). They do provide a range, for which we used the midpoint. This seems to be a close approximation to UNAIDS own unreported estimates. It should also be noted that countries with large amounts of missing data were often small and largely unaffected by the AIDS epidemic. Rather than essentially invent data for them, these countries were dropped, with no great effect on total estimates. In fact, the end result of our imputations are estimates of global prevalence, deaths and incidence which largely match the numbers quoted by UNAIDS.

For most other important variables with missing values, but no range of likely estimates, predicted values from OLS regressions were used for imputations. The functional form of the regressions depended on which variables were being imputed. Imputed values for deaths were the predicted values of regressing deaths in year 't' on deaths in the previous year, prevalence in 2002, and ART coverage. These regressions had excellent fit, between .96 and .99 adjusted r squared.

When possible, values of the number needing antiretroviral therapy were estimated as the predicted value of a log-linear OLS regression of need on prevalence. In cases where our estimate of a country's need is less than the number on ART, need was calculated to be

the number on ART divided by the percent coverage of ART. In cases where percent coverage was missing from the WHO data, coverage was assumed to be 95%.

VI. Conclusions

By publishing this program on the internet, we solicit explorations of the possible impact of various donor policy choices on both the costs of the programs and on AIDS mortality. Using a copy of Stata and the ***aidsproj*** program, the user can project the future fiscal burden of AIDS treatment in any individual country or selection of countries under either optimistic or pessimistic scenarios. Using the ***aidsdif*** program, the user can then compare alternative scenarios to a chosen baseline.

Supposing that donors respect the "entitlement" of existing AIDS patients, as this computer program assumes, leaves room for donors to allow the degradation of adherence support services and to slow or even halt the uptake of new patients. These possibilities can be simulated in the ***aidsproj*** model by increasing the value of any or all of the parameters ***uptake, adrate1, adrate2, bdrate***. Donors could also conserve limited financial resources for treatment by spending less money recruiting among those who need treatment (modeled by reducing the parameter ***erate***) or by halting or slowing the expansion of access to second line therapy (modeled by moving the parameter ***strtyr*** to a date beyond the projection horizon of by lengthening the period of adoption through the choice of a much later value of ***trgtyr***. Donors might also choose to cut back on prevention expenditures, or on their efforts to optimize the efficiency of prevention expenditures,

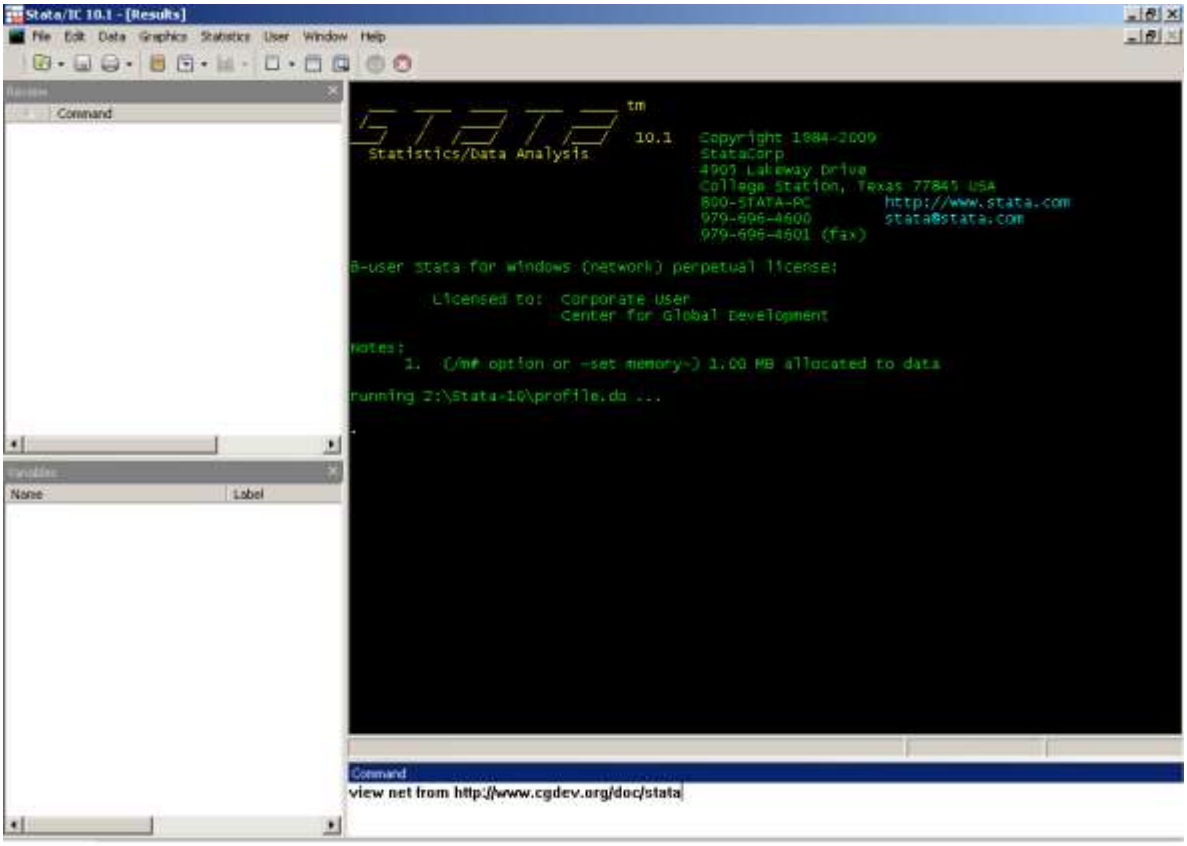
enabling the future incidence rate to increase instead of continuing to decrease as we have assumed it will (controlled by the parameter ***incmult***).

As is the case for all computer programs, ***aidsproj*** and ***aidsdif*** are works in progress. We hope that users will exercise them and report to us on their experience, both positive and negative. We will periodically update the program, both to correct less than felicitous "features" (commonly known as "bugs") and to expand the programs capability. We also welcome comparisons between this program and its competitors, such as Spectrum and ASSA2003[21], which were recently compared to one another by Nattrass [22]. We believe that a fuller understanding of the implications of ART scale-up and of alternative policies to manage its growing cost can best be achieved through the free competition of alternative projections. We hope that the publication of this paper and the accompanying programs is a step in that direction.

[21] Documentation for Spectrum and ASSA2003 can be found here, and here, respectively.
[22] (Natrass, 2007)

Appendix 1: How to Download and Install AIDSCost

Once the user has installed Stata on his or her computer and opened the program, the screen will be divided into four windows like this.



Aidsproj and its associated files are available for download through Stata's command line, as are all other user-written Stata commands. In the Stata "Command" window, type the following line exactly as it appears here:

view net from http://www.cgdev.org/doc/stata

Then press "Enter". At this point the text code that was typed will appear in the upper left window, called the "Review" window and the Stata Viewer will open and display some text with links appearing as the blue letters, **MO** and **DR**. Next, click on the link for **MO** (Mead

Over). To access the download files for ***AIDSCost***, click on the "**AIDS**" link. Then click on "**AIDSCost**" to see the files that will be downloaded. The package includes the code for two programs, "***aidsproj***" and "***aidsdif***", along with associated help files. It also includes another program "rescale" which is necessary for certain graphing options in aidsproj, though not for projections. The download file also contains the input data needed for 'aidsproj' to run (aidsCGD2008.dta). Note that you need to download the programs and the data separately, by clicking on the "net install aidscost" and "net get aidscost" blue text links, respectively. There is no additional data needed for "***aidsdif***", as it runs using the output data of "***aidsproj***".

Additionally, the user can also download a Stata "profile", which will add the aidsproj and aidsdif dialog boxes to Stata's menu[23]. This profile creates a subheading under "User" called "AIDS analysis". Through these subheadings, the user can always access the dialogs as opposed to using the command line. It is important to note that if the user already has a Stata profile, the download will fail. However, one can accomplish the same goal by adding three lines of code to their profile, as shown in the appendix. If the user does not want to add these subheadings to their menu or profile, the dialogs for the two programs can always be accessed via the "**db**" command (e.g, "**db aidsproj**").

Once these commands have been installed in the user's copy of Stata, documentation is available inside Stata by typing "help aidscost" or "help aidsdif".

[23] These dialog boxes are graphical representations of the commands **aidsproj** uses to make projections. Selecting a particular option in the dialog through a checkbox is equivalent to specifying that option in the command line. No functionality is lost in using the dialog box, but the graphical interface might be easier for a Stata novice to use.

Appendix 2: Countries requiring imputations

Countries requiring innocuous imputations:

Bangladesh	Georgia	Mauritius
Barbados	Gambia	Philippines
Comoros	Equatorial Guinea	Romania
Czech Republic	India	Suriname
Egypt	Kenya	Trinidad and Tobago
Estonia	Sri Lanka	Democratic Republic of the Congo

Countries requiring heroic imputations:

Albania	Libyan Arab Jamahiriya
Bulgaria	Maldives
Bosnia and Herzegovina	The former Yugoslav Republic of Macedonia
Bhutan	Mongolia
Fiji	Oman
Croatia	Slovakia
Hungary	Syrian Arab Republic
Jordan	Turkey
	Yemen

Countries dropped before imputation

	Virgin Islands (U.S.)	Bermuda	Solomon Islands
Israel	Iceland	Norway	Marshall Islands
Greenland	United Kingdom	Antigua and Barbuda	Tonga
Andorra	Cayman Islands	Faeroe Islands	Vanuatu
French Polynesia	Netherlands	Ireland	Palau
Northern Mariana Islands	Luxembourg	Qatar	Micronesia, Fed. Sts.
Slovenia	Monaco	United Arab Emirates	Korea, Dem. Rep.
Macao, China	Finland	Cyprus	American Samoa
Japan	Belgium	Hong Kong, China	Kiribati
Brunei Darussalam	Greece	New Caledonia	Samoa
San Marino	Germany	Australia	Serbia
France	Isle of Man	Singapore	Montenegro
United States	Spain	Bahamas, The	Dominica
Aruba	Canada	Bahrain	St. Vincent and the Grenadines
New Zealand	Switzerland	Puerto Rico	Grenada
Korea, Rep.	Channel Islands	Malta	St. Kitts and Nevis
Liechtenstein	Guam	Austria	Cuba
Netherlands Antilles	Denmark	Sweden	St. Lucia
Kuwait	Portugal	Italy	West Bank and Gaza
Cape Verde	Sao Tome and Principe	Somalia	Iraq
			Seychelles

Appendix 3: Description of Variables

```
Contains data from N:\Health\Data\AIDS_proj\Vintage_2008\aids_cgd_2008.dta
  obs:           127                          Subset of aidsbrf2008 for projection purposes
 vars:            94                          24 Apr 2009 11:19
 size:        60,706 (99.9% of memory free)    (_dta has notes)
```

variable name	storage type	display format	value label	variable label
cntry	str24	%24s		World Bank Country Name
country	str41	%41s		WHO Country Name
code	int	%8.0g	code	World Bank country code
ccode	str3	%9s		World Bank country code
nation	str19	%19s		Country label
region	str4	%9s		WHO region
rgn	byte	%9.0g	rgn	WB's Region Code, 2007
pepfar	byte	%9.0g		
complete	byte	%10.0g	complete	
lambda	float	%9.0g		Country specific adjustment parameter
p2007	long	%10.0g		2007 plwh
a2007	long	%12.0g		Estimated number of people on ART, December 2007
n2007	long	%12.0g		* Estimated number of people needing ART - UNAIDS/WHO methodology, 2007
i2007	long	%9.0g		* Incidence of new HIV cases in 2007
d2007	long	%9.0g		
rxc12007	int	%9.0g		Estimated 1st line cost per patient
rxc22007	int	%12.0g		Estimated 2nd line cost per patient
nonrxc2007	int	%12.0g		Estimated non-ARV cost per patient
cggdp2004	float	%9.0g		Central government expenditures plus net lending as % GDP
cggdp2005	float	%9.1fc		Central government expenditures plus net lending as % GDP
cggdp2006	float	%9.0g		Central government expenditures plus net lending as % GDP
cggdp2007	float	%9.0g		Central government expenditures plus net lending as % GDP
cggdp2008	float	%9.0g		Central government expenditures plus net lending as % GDP
cggdp2009	float	%9.0g		Central government expenditures plus net lending as % GDP
cggdp2010	float	%9.0g		Central government expenditures plus net lending as % GDP
cggdp2011	float	%9.0g		Central government expenditures plus net lending as % GDP
cggdp2012	float	%9.0g		Central government expenditures plus net lending as % GDP
cggdp2000	float	%9.0g		Central government expenditures plus net lending as % GDP
cggdp2001	float	%9.0g		Central government expenditures plus net lending as % GDP
cggdp2002	float	%9.0g		Central government expenditures plus net lending as % GDP
cggdp2003	float	%9.0g		Central government expenditures plus net lending as % GDP
cggdp2013	float	%9.0g		Central government expenditures plus net lending as % GDP
gdpuskp2004	float	%9.0g		GDP in 2005 US $
gdpuskp2005	float	%9.0g		GDP in 2005 US $
gdpuskp2006	float	%9.0g		GDP in 2005 US $
gdpuskp2007	float	%9.0g		GDP in 2005 US $
gdpuskp2008	float	%9.0g		GDP in 2005 US $
gdpuskp2009	float	%9.0g		GDP in 2005 US $
gdpuskp2010	float	%9.0g		GDP in 2005 US $
gdpuskp2011	float	%9.0g		GDP in 2005 US $
gdpuskp2012	float	%9.0g		GDP in 2005 US $
gdpusk2000	float	%9.0g		GDP, current US prices
gdpusk2001	float	%9.0g		GDP, current US prices
gdpusk2002	float	%9.0g		GDP, current US prices
gdpusk2003	float	%9.0g		GDP, current US prices
gdpusk2004	float	%9.0g		GDP, current US prices
gdpusk2005	float	%9.0g		GDP, current US prices
gdpusk2006	float	%9.0g		GDP, current US prices
gdpusk2007	float	%9.0g		GDP, current US prices
gdpusk2008	float	%9.0g		GDP, current US prices
gdpusk2009	float	%9.0g		GDP, current US prices
gdpusk2010	float	%9.0g		GDP, current US prices
gdpusk2011	float	%9.0g		GDP, current US prices
gdpusk2012	float	%9.0g		GDP, current US prices
gdpusk2013	float	%9.0g		GDP, current US prices
gdp_k_n_c	str17	%17s		GDP constant prices, currency
gdp_k_n_u	str8	%9s		GDP constant prices, unit
gdp_k_n_2000	float	%9.0g		GDP, constant prices, national currency
gdp_k_n_2001	float	%9.0g		GDP, constant prices, national currency
gdp_k_n_2002	float	%9.0g		GDP, constant prices, national currency
gdp_k_n_2003	float	%9.0g		GDP, constant prices, national currency
gdp_k_n_2004	float	%9.0g		GDP, constant prices, national currency
gdp_k_n_2005	float	%9.0g		GDP, constant prices, national currency
gdp_k_n_2006	float	%9.0g		GDP, constant prices, national currency
gdp_k_n_2007	float	%9.0g		GDP, constant prices, national currency
gdp_k_n_2008	float	%9.0g		GDP, constant prices, national currency
gdp_k_n_2009	float	%9.0g		GDP, constant prices, national currency
gdp_k_n_2010	float	%9.0g		GDP, constant prices, national currency
gdp_k_n_2011	float	%9.0g		GDP, constant prices, national currency
gdp_k_n_2012	float	%9.0g		GDP, constant prices, national currency
gdp_k_n_2013	float	%9.0g		GDP, constant prices, national currency
gdp_c_us_c	str10	%10s		GDP, current US prices, unit
gdp_c_us_u	str8	%9s		
gdp_c_n_c	str17	%17s		GDP, current prices, currency
gdp_c_n_u	str8	%9s		GDP, current prices, unit
gdp_c_n_2000	float	%9.0g		GDP, current prices, national currency
gdp_c_n_2001	float	%9.0g		GDP, current prices, national currency
gdp_c_n_2002	float	%9.0g		GDP, current prices, national currency
gdp_c_n_2003	float	%9.0g		GDP, current prices, national currency
gdp_c_n_2004	float	%9.0g		GDP, current prices, national currency
gdp_c_n_2005	float	%9.0g		GDP, current prices, national currency
gdp_c_n_2006	float	%9.0g		GDP, current prices, national currency
gdp_c_n_2007	float	%9.0g		GDP, current prices, national currency
gdp_c_n_2008	float	%9.0g		GDP, current prices, national currency
gdp_c_n_2009	float	%9.0g		GDP, current prices, national currency
gdp_c_n_2010	float	%9.0g		GDP, current prices, national currency
gdp_c_n_2011	float	%9.0g		GDP, current prices, national currency
gdp_c_n_2012	float	%9.0g		GDP, current prices, national currency
gdp_c_n_2013	float	%9.0g		GDP, current prices, national currency
hepctgdp2005	float	%9.0g		Health expenditure, total (% of GDP)
pubhepctgdp2005	float	%9.1fc		Health expenditure, public (% of GDP)
pubhepcttot2005	float	%9.0g		
outhepctpr~2005	float	%9.0g		Out-of-pocket health expenditure (% of private expenditure on health)
exthepcttot2005	float	%9.0g		External resources for health (% of total expenditure on health)

* indicated variables have notes

Appendix 4: Adding "aidsproj" and "aidsdif" subheadings to the User Menu in Stata

If the user already has a Stata profile, they can still add the dialog boxes to new subheadings in the User menu. The user need only add the following lines anywhere in their profile:

```
*Adds aidsproj dialog to the User menu
window menu append submenu "stUser" "&AIDS Analysis"
window menu append item "AIDS Analysis" "Projected AIDS cases, costs (&aidsproj)"
"db aidsproj"
window menu append item "AIDS Analysis" "Impact and CE analysis (&aidsdif)" "db
aidsdif"
```

Appendix 5: Parameter Definitions and the structure of the AIDSProj projection model.

The ***aidsproj*** projection model is defined by a set of recursive difference equations which generate the current year's value of a variable as a function of last year's values of that variable, one or more parameters[24] and possibly one or more other variables. The notation Δ is used to denote the difference between the current year's value and the last year's value. All variables on the right-hand-side are specific to year *t*-1.

Estimates of future country-by-country HIV incidence (defined as the number of new HIV infections per year) are essential for predicting AIDS treatment cost more than five years in the future. However, estimating incidence is challenging even for the past. UNAIDS estimated incidence for every country in the datasets we use here, but the agency did not publish the incidence data because the statisticians believe that it is insufficiently reliable. So we have been forced to estimate each country's recent HIV incidence based on UNAIDS' published trends in HIV prevalence and mortality by country. Our estimates of base-year incidence for each country are included in the provided data set as the variable, *i*.

Once we have an estimated incidence figure for our base year for each country, a user modifiable parameter, ***incmult***, determines the multiple that each year's incidence in that country will be of the previous year's incidence. The equation is:

$$i_t = \boldsymbol{incmult} * i_{t-1}$$

[24] We use the term "variable" to refer to a value that changes over time as well as over countries and the term "parameter" to refer to values that are fixed either over time or over countries.

Defining *h* as the stock of people who have HIV but do not yet need treatment and *i* as the flow of new infections per time period, the change in *h* is given by:

$$\Delta h = i - (\boldsymbol{erate} * h)$$

where ***erate*** is the parameter defined as the proportion of people in group *h* who convert to needing treatment. The change in the unmet need for treatment, *un*, is defined as the new people who need treatment less those who are either recruited to first line antiretroviral therapy or die:

$$\Delta un = (\boldsymbol{erate} * h) - \left((1 - \boldsymbol{lambda}^{25}) * un\right) - (\boldsymbol{lambda} * \boldsymbol{ndrate} * un)$$

At the end of one year, everyone who is in their first year of first-line therapy either moves to second-line therapy or dies. So the change in those on first-line therapy is the flow of new additions to that group less the outflow of everyone who was on first-line therapy the previous year.

$$\Delta a1 = \left((1 - \boldsymbol{lambda}) * un\right) - a1$$

Note that the second term in the above equation can be decomposed into those who flow into post-first-year first-line ART and those who die as follows:

$$a1 = \left((1 - \boldsymbol{adrate}) * a1\right) + (\boldsymbol{adrate} * a1)$$

where ***adrate*** is a parameter capturing the death rate during the first year of first line therapy, a year when treatment failure can be high especially if people are recruited when their CD4 counts are very low. The equation which projects the change in post-first-year first-line therapy, *a2,* takes as inputs an increase equal to the flow of survivors from the first year and a decrease equal to the rate at which people fail first-line therapy and therefore become eligible for second-line therapy.

$$\Delta a2 = \left((1 - \boldsymbol{adrate}) * a1\right) - (\boldsymbol{adrate2} * a2)$$

Again the second term above can be decomposed to allow for the fact that most countries have not yet provided access to second-line therapy to everyone who needs it. Representing the country's coverage of second-line therapy by the variable cvrg2, give the following decomposition:

$$\boldsymbol{adrate2} * a2 = (\boldsymbol{adrate2} * (1 - cvrg2) * a2) + (\boldsymbol{adrate2} * cvrg2 * a2)$$

[25] See footnote 14 above for a discussion of *lambda.*

The second piece of the above decomposition then becomes the flow which increments the stock of people on second-line therapy, b. Decrements to b are caused by the death rate of people on second-line therapy, ***bdrate***.

$$\Delta b = (\boldsymbol{adrate2} * cvrg2 * a2) - (\boldsymbol{bdrate} * b)$$

The rest of the model keeps track of indicators such as the total number of people on ART[26],

$$art = a1 + a2 + b$$

the total need for ART,

$$n = un + a1 + a2 + b$$

the total number of people living with HIV/AIDS,

$$p = h + un + a1 + a2 + b$$

and annual number of deaths, d, which is defined as the sum of the deaths from all of the above equations like this:

$$\begin{aligned} d = {} & (\boldsymbol{ndrate} * \boldsymbol{lambda} * un) && \text{(deaths of those waiting for treatment)} \\ & +(\boldsymbol{adrate} * a1) && \text{(deaths during 1st year of first-line ART)} \\ & +(\boldsymbol{adrate2} * (1 - cvrg2) * a2) && \text{(deaths during 2+ years of first-line ART)} \\ & +(\boldsymbol{bdrate} * b) && \text{(deaths during 2nd line ART)} \end{aligned}$$

The value for coverage of 2nd line ART is linearly interpolated between a starting coverage rate, ***strtcov2***, in a starting year for second-line coverage, ***strtyr***, and a target coverage rate, ***trgtcov2***, in a target year, ***trgtyr***. We assume that $\boldsymbol{trgtcov2} > \boldsymbol{strtcov2}$ and $\boldsymbol{trgtyr} > \boldsymbol{strtyr}$. The interpolation formula is:

$$cvrg2 = \boldsymbol{strtcov2} + \frac{(\boldsymbol{trgtcov2} - \boldsymbol{strtcov2})}{(\boldsymbol{trgtyr} - \boldsymbol{strtyr})} * (t - \boldsymbol{strtyr})$$

For years before the starting year and after the target year, we assume:

$$cvrg2 = \begin{cases} \boldsymbol{trgcov2}, & t \geq \boldsymbol{trgtyr} \\ \boldsymbol{strtcov2}, & t \leq \boldsymbol{strtyr} \end{cases}$$

[26] For the identities and the rest of the definitions described below, the implicit time subscript is *t* on both the left and the right hand side of the equation.

The projected cost of ART is measured in thousands of constant US dollars circa 2006/7 and given by the following linear cost functions for first line therapy:

$$cost1st \;\; = ((rxc1 \; + \; nonrxc) \; * \; (a1 \; + \; a2) \;) \; / \; 1000$$

and for second-line therapy

$$cost2nd \;\; = ((rxc2 \; + \; nonrxc) \; * \; b) \; / \; 1000$$

The funding gap is the estimated cost in any given year of treating those with unmet need for first-line therapy plus those who need but do not gain access to second-line therapy.

$$fundgap = \frac{((rxc1 \; + \; nonrxc) \; * \; un \; + \; (rxc2 \; + \; nonrxc) \; * \; \boldsymbol{adrate2} \; * \; (1 \; - \; cvrg2) \; * \; a2)}{1000}$$

In these cost equations, the unit cost variables *rxc1, rxc2, nonrxc* represent country specific estimates of the annual unit costs of first line medications, second-line medications and non-pharmaceutical costs. In the current version of *aidsproj*, these values are not amenable to manipulation by the user. Estimates of these unit costs for each country are contained in the provided dataset, *aidscgd2008.dta* .

In this paper the concept of "entitlement" is defined to be the cost in year *t* (in thousands of constant circa 2006/7 US dollars) of treating all those who began treatment in a prior year. The model computes this cost by the equation:

$$titletot \; = \; \left(\frac{\left((rxc1 \; + \; nonrxc) * \; (a1 \; + \; a2 \; - \; (1 - \boldsymbol{lambda}) * \; un \;) \right)}{1000} \right) + \; cost2nd$$

where $(1 - \boldsymbol{lambda})$ is the proportion of unmet need that is recruited into first-line therapy each year. The cost of treating newly recruited patients is termed "discretionary" and projected with the equation:

$$disctot \; = \; costtot \; - \; titletot$$

The percentages of entitled and discretionary spending as a percentage of total spending are defined as:

$$titlepct \; = \; 100 * \left(\frac{titletot}{costtot} \right)$$

$$discpct \; = \; 100 * \left(\frac{disctot}{costtot} \right)$$

Overall coverage is defined as

$$cvrgpct \;=\; 100 * \left(\frac{art}{un + art}\right)$$

If the user selects the World Economic Outlook projections, the projected future total cost of ART, *costtot*, can be expressed as a percentage of a variety of macroeconomic aggregates. Fopr example the equation for ART expenditure as a percent of total national health spending is:

$$aidspcthe \;=\; \left(\frac{costtot}{hepctgdp * gdpuskp * 100}\right)$$

where *hepctgdp* is estimated health expenditure as a percent of GDP and *gdpuskp* is projected GDP and constant prices. The equation for ART expenditure as a percent of public health spending is:

$$aidspctpub \;=\; \left(\frac{costtot}{pubhepctgdp * gdpuskp * 100}\right)$$

The equation for ART expenditure as a percent of private health spending is:

$$aidspctprv \;=\; \left(\frac{costtot}{(hepctgdp - pubhepctgdp) * gdpuskp * 100}\right)$$

The equation for ART expenditure as a percent of out-of-pocket health spending is:

$$aidspctoop \;=\; \left(\frac{costtot}{oophepctpriv * (hepctgdp - pubhepctgdp) * gdpuskp}\right)$$

The equation for ART expenditure as a percent of central government spending is:

$$aidspctcg \;=\; \left(\frac{costtot}{cggdp * gdpuskp * 100}\right)$$

Because the ***aidsproj*** is open source, anyone with a bit of programming experience can open it and modify these equations. If you make a version of aidsproj called, for example, aidsproj2 which modifies these equations but changes nothing else, you can use ***aidsdif*** to help you compare the effects of your changes. We would be interested to see the result of any such experiences you conduct.

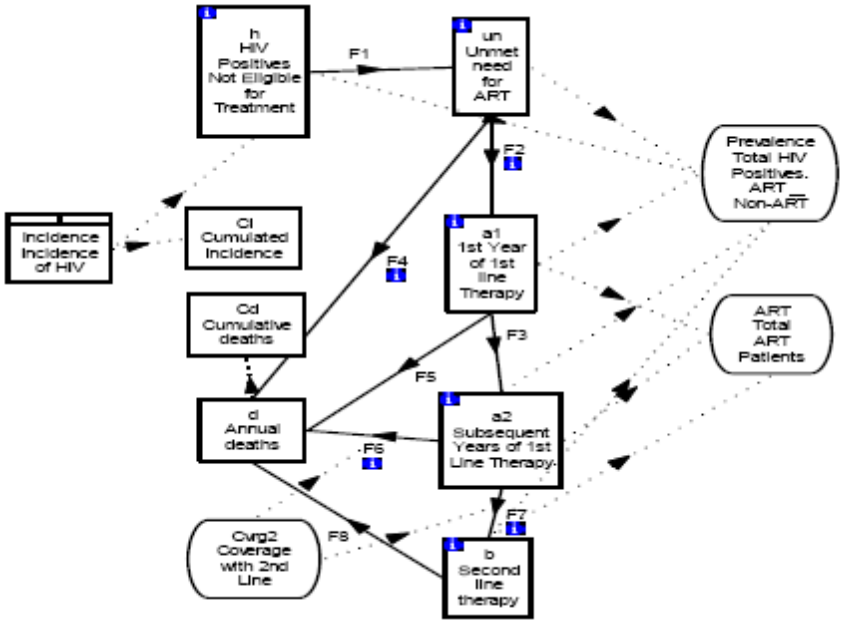


Figure 13. Structure of the AIDSProj projection model. Flow diagram for predicting the future growth of AIDS treatment costs (Source: Author's construction using ModelMaker software.)

Parameter	Definiton	Default Value
horizon	Specifies the last year to which projections are computed.	2020. Max is 2050
adrate1	First year death rate on 1st line ART.	0.13
adrate2	Subsequent death rate on 1st line ART	.04
bdrate	Annual death rate on 2nd line ART.	0.01
erate	Rate at which HIV+ convert to be eligible for ART.	0.11
edrate	Death rate among ART eligible not on ART.	0.3
incmult	Multiple that each year's incidence is of previous year.	0.05
strtcov2	Starting level of coverage with 2nd line therapy.	0.05
trgtcov2	Target level of coverage with 2nd line therapy.	0.95
strtyr	Target level of coverage with 2nd line therapy.	2006
trgtyr	Year target level to be reached with 2nd line therapy.	2016
vintage	Vintage of data.	2008

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