RETHINKHIV

Perspective Paper

Treatment

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COPENHAGEN CONSENSUS CENTER

RUSH

FUNDING DISRUPTIVE IDEAS AGAINST HIV

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Perspective Paper

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RethinkHIV: The Project

2011 marks the 30-year anniversary since the Centers for Disease Control and Prevention introduced the world to the disease that became known as AIDS. Despite 30 years of increasing knowledge about transmission, prevention, and treatment, and current annual spending of $15 billion, every day around 7,000 people are infected with the HIV virus and two million die each year. The HIV/AIDS epidemic has had its most profound impact in sub- Saharan Africa, which accounts for 70 percent of new worldwide infections and 70 percent of HIV-related deaths, 1.8 million new infections in children each year, and has 14 million AIDS orphans.

Humanitarian organizations warn that the fight against HIV/Aids has slowed, amid a funding shortfall and donor fatigue. Yet HIV is still the biggest killer of women of reproductive age in the world, and of men aged 15-59 in sub-Saharan Africa. Time is ripe for a reassessment of current policy and expenditure.

The Rush Foundation has asked the Copenhagen Consensus Center to commission a group of leading health academics to analyze HIV policy choices and identify the most effective ways to tackle the pandemic across sub-Saharan Africa.

RethinkHIV identifies effective interventions in the fight against HIV/Aids across sub-Saharan Africa. It applies cost-benefit analysis to highlight investments and actions that can make a significant difference.

The Copenhagen Consensus Center has commissioned eighteen research papers by teams of top health economists, epidemiologists, and demographers who examine the cost-effectiveness of a range of responses to HIV/AIDS in sub- Saharan Africa under the following topics:

- Efforts to Prevent Sexual Transmission
- Efforts to Prevent Non-Sexual Transmission
- Treatment and Initiatives to Reduce the Impact of the HIV/AIDS Epidemic
- Research and Development Efforts
- Social Policy Levers
- Initiatives to Strengthen Health Systems

A panel of five eminent economists, including recipients of the Nobel Prize, convenes in the fall of 2011 to carefully consider the research and engage with the authors. The Expert Panel is tasked with answering the question:

If we successfully raised an additional US$10 billion over the next 5 years to combat HIV/AIDS in sub-Saharan Africa, how could it best be spent?

After deliberating in a closed-door meeting, the Nobel Laureate Expert Panel provides their answer, highlighting investments and actions that could be most effective avenues for additional funding. Their findings and reasoning are released in the fall of 2011, and published in full alongside all of the research in a collated volume in 2012.

RethinkHIV will generate global discussion regarding responses to HIV/AIDS in sub-Saharan Africa. To participate in a dialogue on the research and findings within sub-Saharan Africa, a Civil Society Conference and forums for youth are held following the Expert Panel meeting in late 2011.

The Civil Society Conference is a means of creating a dialogue with African civil society and to agree on a set of bold new actionable priorities with society politicians, civil society organizations, influential thought-leaders, and others within sub-Saharan Africa.

It is hoped that the project will motivate donors to direct more money to the investments and actions that are demonstrated to be most effective to curtail the pandemic in sub-Saharan Africa.

All of the research papers, and many different perspectives on priorities can be found online at the project's website:
www.rethinkhiv.com

You are invited to join the dialogue and provide your own perspective on priorities for action in Africa.

The Copenhagen Consensus Center

The Copenhagen Consensus Center is a Danish state-funded think- tank that commissions and promotes research highlighting the most effective responses to global challenges. The Center is led by author Bjorn Lomborg, named 'one of the 100 Top Global Thinkers' by Foreign Policy in 2010, 'one of the world's 75 most influential people of the 21st century' by Esquire in 2008, and 'one of the 50 people who could save the planet' by the Guardian in 2008. The Copenhagen Consensus Center is implementing the project, which follows the format of past projects such as Copenhagen Consensus 2004, Consulta de San José in 2007, Copenhagen Consensus 2008, and Copenhagen Consensus on Climate in 2009.
www.copenhagenconsensus.com

The Rush Foundation

The Rush Foundation, based in Lausanne, is dedicated to providing fast, effective funding for innovative thinking addressing the HIV/AIDS epidemic in sub-Saharan Africa. The Rush Foundation is the sponsor of the project. The Rush Foundation was launched in 2010 to fund sustainable projects in sub-Saharan Africa focused on alleviating the pandemic through innovative thinking, and to shake up the status quo in HIV thinking by spearheading thought leadership projects and debates that will help reframe HIV policy. Among other initiatives, the Rush Foundation is currently designing a grant programme with ActionAid in Africa aimed at generating new, sustainable HIV initiatives on the ground.
www.rushfoundation.org

The Papers

The body of research for RethinkHIV comprises 18 research papers. The series of papers is divided into Assessment Papers and Perspective Papers. Each Assessment Paper outlines the costs and benefits of at least three of the most promising responses, interventions, or investments to HIV/AIDS in Sub-Saharan Africa within the respective category. Each Perspective Paper reviews the assumptions and analyses made within the Assessment Paper. In this way, a range of informed perspectives are provided on the topic.

Contents

Introduction

This is one of the Perspectives Papers dealing with the Assessment Paper on Treatment by Mead Over and Geoffrey Garnett - hereafter O&G - as part of the RethinkHIV Project seeking how best to spend an extra $10 billion to combat HIV/AIDS in Sub-Saharan Africa. The purpose of the Perspectives Paper is to provide a counterbalance to the Assessment Paper by indicating areas of agreement, disagreement and discussion.

The main focus of the Assessment Paper is on ARV treatment as prevention. O&G analyze this issue by recognizing that the drugs reduce the viral load and thereby reduce the transmission of the HIV infection to others, saving lives in the process. The transmission process they model specifies an effect on yearly infections that depend on the coverage of treatment in each period of time. The greater the coverage, the lower the transmission rate, the fewer the number of infections and the greater the number of lives saved which, valued at a pre-assigned amount per life year saved, provides the benefits in the RethinkHIV project. It is the ability of the extra funds to increase coverage that enables the benefits to be obtained. How far coverage can increase the benefits due to the extra funds depends on the yearly costs of the treatment which consist of the price of the drugs and the testing and delivery costs.

O&G find that treatment as prevention can produce benefit- cost (B/C) ratios in the range 3 to 3.5 in one scenario ("zero uptake") and they are in the range 2.3 to 2.5 in the alternative scenario ("historical uptake'). In the sensitivity analysis, the B/C ratios never exceed 4. Our main contribution in this paper is to reconstruct their analysis using these ratios as benchmarks so that we can identify the types of assumption that can validate the O&G results. From there we add some new assumptions in the context of a particular type of treatment intervention not covered explicitly in the Assessment Paper.

Because the main contribution of the O&G paper is to formulate and estimate a transmission rate for HIV infection that depends on time, it constitutes an important first step towards constructing a dynamic evaluation of HIV Treatment. Given this, it seems useful to place their contribution within a more complete dynamic framework to help understand what the particular transmission mechanism specified contributes to the evaluation and to see also what is missing. The dynamic framework is presented in section 2.

In section 3 we provide a discrete time representation of the dynamic model used in section 2. This puts the evaluation of treatment into the context of an intervention for a single person receiving treatment, which performs the same function as the representative agent model in Macroeconomics. We use the discrete time representation to highlight the importance of particular data assumption and, in particular, the impact of using different discount rates. In this framework we interpret the enhanced ability of treatment to reduce infections in the O&G analysis to be an externality that magnifies the benefits that an individual receives. The existence of externalities is clearest in the case of the prevention of mother to child transmission (MTCT) and this is the intervention that will be evaluated in section 4. As we shall see, there will be two types of externality when women are treated and this is not the case when men are treated. Section 4 thus introduces an important gender consideration that is missing from the Assessment Paper.[2] Section 5 contains the discussion part of the paper and section 6 provides the summary and conclusions.

2 Pregnant women are mentioned on page 3 of the Assessment Paper, but there is no further consideration anywhere else.

Dynamic Models of the Effect of HIV Treatment on Infections

The model used in the Assessment Paper is basically an S-I (susceptible-infection) transmission system that is a staple in the epidemiological literature that has been developed by Gersovitz and Hammer (2004) for Health Economists. The dynamic framework below is a simplified version of the Gersovitz and Hammer model which is adapted to apply to HIV treatment. We call this the standard dynamic model of infections. We will not go very far with the analysis, just far enough to be able to reflect on the model presented in the Assessment Paper, which is the O&G model. Our analysis begins with the part of the standard model that explains how the flow of infections will change over time. We then present the same type of analysis as it appears in the O&G model. We then compare the two versions in terms of the number of infections that each will predict. After this we explain how the standard model analyzes interventions that will influence the flow of infections. We will show that the O&G model omits important mechanisms by which of treatment affects infections.

The standard dynamic model of infections

The starting point is a number of population identities. The population, *N*, in any country affected by HIV is the sum of those susceptive to infection, *S*, and the number of persons infected *I*:

$$N = I + S \tag{1}$$

The state variables are the infection rate (i.e., prevalence rate) and the susceptible rate defined as:

$$i = I / N \quad \text{and} \quad s = S / N \tag{2}$$

The variables change over time as follows (using dots above variables to signify time derivatives). Population increases due to the birth rate ε and decreases by the natural (not due to infection) death rate μ:

$$\dot{N} = (\varepsilon - \mu) N \tag{3}$$

Under random matching, the probability per contact of a susceptible meeting an infected person is *i*. Then $S\,i$ is the total number of susceptibles having contact with an infected person. The transmission rate per contact is β. The rate of increase of transmissions from this rate applied to the number having contact with an infected person is $\beta\,S\,i$. Thus the number of infecteds increases over time by the number of new infections less the number of people who die anyway (μ) or because of AIDS (α):

$$\dot{I} = \beta\,S\,i - (\mu + \alpha)\,N \tag{4}$$

Lastly, the number of susceptibles increases naturally from population growth and decrease as some of them get infected or die naturally:

$$\dot{S} = (\varepsilon - \mu) N - \beta\,S\,i \tag{5}$$

The O&G model of infections compared

The Assessment Paper has equations similar to (4) and (5). Since the two equations are strongly interrelated, to make our points we need only focus on one of them, which will be the susceptibles equation. O&G's version of equation (5) is their equation (3), which we reproduce here as:

$$\dot{S} = k\,\gamma\,N - \beta\,S\,i - \mu\,S \tag{6}$$

Where γ is the rate of entry 'per person' into the at risk population and *k* is the fraction of the population "at risk". For ease of comparison term by term we rewrite our equation (5) as:

$$\dot{S} = \varepsilon\,N - \beta\,S\,i - \mu\,N \tag{7}$$

There is no difference in the second terms of equations (6) and (7), but there are important differences in the first and third terms. These differences imply that the O&G model will underestimate the number of *S* and *I* and hence also underestimate the number of infections that a reduction in the transmission rate β will generate.

A comparison of the first terms reveals that O&G for some reason want to restrict entry into the numbers of people who are going to be judged as newly "at risk" in the population. They have applied the parameters $k\gamma$ to the population *N* instead of the birth rate ε as in the standard model. There are two restrictions imposed here and both of them are questionable in the context of the treatment intervention. The standard model assumes that everyone born is susceptible to infection sometime in their lifetime and this includes those newly born. In the O&G model only the fraction *k* is at risk. Given that the number of children infected with HIV is so high in SSA, not to have $k = 1$ is very strange. Even if $k = 1$ is adopted, the second difference is that O&G want to use the rate of entry into the risk population γ rather than the birth rate ε. It is difficult to know whether γ is going to be higher than ε because a definition of an "at risk" group is not given in the Assessment Paper.

In fact an estimate of *k* is not presented anywhere in the paper either. All we get is their equation (8) which tells us how one can *deduce k* from a knowledge of other parameters. This after-the-event approach shares the same basic weakness as the World Bank's, and many other groups', strategy with HIV which seeks to target the high risk groups first. As pointed out in Brent (2010a), one often does not know which group is to be considered "high risk" *a priori*. For example, Pisani (2008) informs us that a schoolgirl in South Africa is ten times more likely to be infected with HIV than a prostitute in Beijing. In this particular case, schoolgirls are to be targeted as the "high risk" group and not prostitutes. Who would have thought that this would have been the case in advance of looking at the facts?

A comparison between the third terms of equations (6) and (7) again shows how the O&G model will underestimate the number of infections. The death rate μ is applied to *S* in O&G's equation (6), while it is applied to *N* in the standard model equation (7). Since *N* is greater than *S* by the number of *I*, see equation (1), the O&G model reduces the number of S due to the death rate than the standard model. So using equation (4) the lower value for *S* will generate a lower number of infections that can be reduced by treatment.

The standard and O&G dynamic models with interventions

We now introduce into the analysis control variables, variables under the control of the government via the expenditures that are incurred on them. In the context of the RethinkHIV project, the controls are the HIV interventions. These may be for prevention, treatment or mitigation. Control variables affect the parameters in the system, i.e., ε, μ, β and α. Typically prevention is targeted at the susceptibles and treatment to the infecteds. However, in the Assessment Paper the focus in on treatment as prevention, so in principle every parameter in the system can be affected by treatment *T*. We will assume:

$$\varepsilon = \varepsilon(T), \acute{\varepsilon} > 0 \quad (8a)$$
$$\alpha = \alpha(T), \acute{\alpha} < 0 \quad (8b)$$
$$\mu = \mu(T), \acute{\mu} = 0 \quad (8c)$$
$$\beta = \beta(T), \acute{\beta} < 0 \quad (8d)$$

In (8a) we recognize that HIV lowers the fertility rate. Therefore providing treatment will raise the fertility rate and with it the birth rate. A rise in the population will increase the number of infecteds directly, via *I*, and indirectly via the number of susceptibles *S* in (4). Equation (8b) focuses on the effect of treatment on the death rate of those living with HIV/AIDS.[3] The consequences can also be explained in terms of equation (4). The lower is α, the more people living with infections will go up in terms of *N*. Moreover, the more infecteds there are, the higher is i and the more new infections will take place via βS. This is of course the reason why HIV prevalence in the US is rising even though the rate of new infections (incidence) has been staying relatively constant. People with HIV who do not die add to the number living with HIV and, because they are still around, they can give the virus to others. Equation (8c) acknowledges the *possibility* that there could be an impact on the death rate for those not infected with HIV who take treatment, for example as a pre-exposure prophylaxis; but at this point in time there is no firm general evidence that its impact is not zero. Lastly in the list of parameters affected by treatment we come to equation (8d). Treatment reduces the transmission mechanism β and will therefore reduce the number of new infections, see equation (4), and so increase the number of lives saved.

Of the four possible effects of treatment listed in equations (8a) to (8d), only (8d) appears in the O&G model. The omission of equations (8a) and (8b) in particular reinforces our previous conclusion that the O&G model is underestimating the number of lives saved from treatment. In the previous paragraph we have explained how the number of lives saved increase due to treatment using models explaining the flow of infections. Here we just need to reinforce this conclusion by pointing out that equations (6a) and (6b) recognise the fertility effects of treatment. That is, increasing births and reducing deaths must increase the number of lives saved. Since the main contribution of the Assessment paper is to model how treatment will change the transmission mechanism $\beta(T)$, we will now examine in detail O&G's formulation of equation (8d).

The O&G model 's specification of the transmission mechanism

The O&G model's specification of the transmission mechanism and how it changes due to treatment is given in equation (10) in the Assessment Paper, which becomes our equation (9):

$$\beta_t = \beta_o \left(\tau_t / \tau_o \right) [1 - C] [1 - e] [1 + \delta h_t] \qquad (9)$$

where β_t is the transmission rate in any year *t*, β_o is the transmission rate in the base year prior to the expansion of treatment, τ_t is the treatment rate in any year *t*, τ_t is the treatment rate in the base year, *C* is the proportion by which circumcision reduces the transmission rate, *e* is the proportion by which educational and education programs reduce the transmission rate and δ is the perverse incentive effect (the "moral hazard" effect) whereby increasing coverage h_t in year *t* increases risky behaviour leading to more infections.

The easiest way to interpret the role of equation (10) is to focus on the second terms of equations (6) and (7) which are identically the same being $\beta S i$. If we ignore the first and third terms which we have already analyzed, we can replace both (6) and (7) by:

$$\dot{S} = - \beta S i \qquad (10)$$

Equation (10) just says that increasing infections lowers the number of susceptibles. In O&G's equation (9) they recognize that the effects in the square brackets lower the number of susceptibles and hence the transmission rate of HIV. Effectively they are defining an adjusted S which we will call *S'* and using this to replace equation (10) in the form:

$$\dot{S} = - \beta_t S' i \qquad (11)$$

3 Although overall effect of treatment is to increase life expectancy, for a few individuals ARVS is fatal because of its toxicity.

where

$$S' = [1 - C]\,[1 - e]\,[1 + \delta h_t]\;S \qquad (12)$$

and

$$\beta_t = \beta_o\,(\tau_t / \tau_o) \qquad (13)$$

We can therefore regard O&G's equation (9) as making a contribution by decomposing equation (11) into the two parts (12) and (13). Equation (12) reminds us that the transmission rate is reduced by treatment only after the effects of other behavioural interventions have first taken place. This is of course correct. But, O&G do not in fact make any of the adjustments implied by *S'* in (12), as they report in footnote 8 that they have set all the variables in (12) (except for S) equal to zero in their simulations. This leaves only equation (13) left to understand and assess.

In equation (13), β_t starts off equal to β_o and then changes according to τ_t / τ_o, which is the percentage change in the fraction getting treatment in any year relative to the base year. To determine the treatment fraction in any year, O&G use:

$$\tau_t = 1 - f\,g\,h_t \qquad (14)$$

As treatment coverage h_t changes over time, the extent of treatment is affected by *f*, the fraction of the transmissions that takes place in the early stage of the infection when treatment is thought not to be effective, and *g*, the overall effectiveness of the treatments when they are given after the non-responsive stage. In their simulations, O&G assume that $f = 0.7$ and $g = 0.7$. Equation (14) then reduces to: $\tau_t = 1 - 0.49\,h_t$. To illustrate their methods, O&G consider the situation where the original coverage is $h_o = 0.1$ and treatment is being scaled up so that coverage becomes $h_t = 0.5$. This means $\tau_o = 1 - 0.49\,(0.1) = 0.951$ and $\tau_t = 1 - 0.49\,(0.5) = 0.0.755$, which makes $\tau_t / \tau_o = 0.794$. The result therefore of increasing coverage by 40% is to decrease infections by 1 – 0.794, i.e., 20.6%. It is clear then from this calculation that the precise definition of τ_t is the fraction of people treated who are no longer infecting others. It represents the number of lives saved as a percentage of those infected.

In the context of this worked example, i.e., the 40% scaling up of coverage, O&G are estimating that for every 2 persons treated there will be 1 fewer persons infected. We think this is an overestimate, not because of the estimate of *g*, but rather because of the assumed value for *f*. O&G are right that a value for *g* in the upper 90% range as claimed by Cohen and Chen (2010) is not likely to be generalizable to the total population. While it true that in the population as a whole there are going to be people who are so newly infected that they will either: (a) not know their HIV status and thus not know they need treatment or (b) are so infectious that treatment will not be minimally effective in reducing transmissions, this does not mean that it is reasonable to assume that $f = 0.7$ for the purposes of the RethinkHIV Policy experiment. An extra $10 billion is not going to be able to treat everyone who could possibly need treatment. At a cost of $1,374.7 per person (my estimate, see section 3), $10 billion would cover 7.3 million people and there are over 22 million with HIV in SSA at this present time. So the 30% of people assumed untreatable for the *f* parameter is not likely to apply to the treatment scale up for RethinkHIV Policy. With f = 1, we have $\tau_t / \tau_o = 0.698$ and not 0.794. Infections would be reduced by 30.2% and not just 20.6%.

To summarize our assessment of the O&G dynamic model of infections: we think that the model that predicts 1 fewer infections for 2 persons treated is an underestimate of the lives saved by treatment scale up with the $10 billion budget as envisaged by RethinkHIV Policy. B/C ratios of around 3 that follow from the O&G estimates of lives saved are therefore likely to be too low. We reach this conclusion for four main reasons:

- The O&G model restricts the population who can be infected to those who are high risk. This ignores babies, for example, at a time when child infections are so large in SSA – there are 2.3 million currently infected.
- The number of S and I are underestimated relative to the standard model of infection flows. So a reduction in β would have a larger impact than assumed.
- The O&G model concentrates only on β_t and ignores all the other ways that treatment can impact the flow of infections, for example, by increasing fertility.
- Finally, the O&G model regards 30% to be untreatable when the treatment scale envisaged will not attempt to reach this group. We think that f =1 can be used instead of f = 0.7 and so more people can be treated effectively that is assumed.

A Discrete Time Representation of the Dynamic CBA Framework

The continuous time, infinite horizon, dynamic framework provides some basic insights into evaluating HIV treatment, but it is also useful to look at the O&G Assessment Paper through the eyes of a discrete, finite time horizon formulation. To set the stage we first work through a present value CBA calculation where the prevention benefits of treatment are excluded, which is the reference point that the Assessment Paper used when first considering its benefit-cost calculations. This calculation is a fuller version of what O&G call "naive estimates" of B/C ratios for treatment when introducing their results section. This first calculation serves to illustrate the main method that will be used in the rest of this Perspectives Paper. In the process we can highlight the role and importance of discounting. Then we extend the calculations to fit in with the O&G analysis proper which involves including the prevention benefits of treatment for others which we interpret to be the positive externalities of treatment. Throughout our focus will be on what are the assumptions necessary to obtain B/C ratios equal to 3 and when should we expect higher ratios. In this section we will stick to the O&G context where treatment is to be applied to the general population. In the next section we will analyze results that apply just for the subset of treatment that targets prevention of MTCT.

Calculating Benefits and Costs when Treatment does not Prevent Infection to Others

In this exercise, as in O&G's results using the naive estimates, the time horizon is 35 years, the drugs add 21 years of life, but these added years only appear after 14 years have elapsed. These years correspond to an initiation of ARVs when the CD4 count is greater than 350 as shown in O&G's figure 5. The average cost per person year is the $735.5 1st line treatment amount given in O&G's table 1. The yearly benefits use the upper bound $5,000 value. The calculations are shown in our table 1 below. The present value sums are shown in the last row with and without discounting.

In table 1, the undiscounted B/C ratio is 4.09 ($105,000/ $25,672.5), the B/C ratio with a 3% discount rate is 3.23 ($52,484 / $16,234) and the B/C Ratio with a 5% discount rate is 2.70 ($33,997 / $12,611). The higher the discount rate, the lower is the B/C ratio. This result is because, for ARV treatment, where the costs are immediate and the benefits appear in the future only when the extended life expectancy is gained, the discounting affects costs and benefits asymmetrically.

To see this clearly, look at years 1 and 15. In year 1 there are costs of $734 but no benefits. By year 15 when the benefits start they are no longer worth $5,000. With a 3% discount rate they are worth $3,306 and with a 5% rate they are worth only half of $5,000 (i.e., $2,525). The role of the discount factor is crucial here as it serves to lowers the current values of benefits and costs. The discount

factor attached to the second year of costs that occur in year 2 is 0.971 with the 3% rate and 0.952 with the 5% rate. So costs are not reduced by much. By contrast the present values of the second year of benefits are almost halved. The discount factor attached to the second year of benefits, which occur in year 16, is 0.661 with the 3% rate and 0.505 with the 5% rate.

The results of discounting on the B-C ratios presented in table 1 appear again in the first row of numbers in table 2. We see that these relate just to the case where treatment is initiated with a CD4 count greater than 350, giving 35 years of costs and 21 years of benefits, and where the costs are the lowest in O&G's table 1, corresponding to 2010 1st line treatment values. In rows 2-4 of table 2, with benefits throughout fixed at the upper bound $5,000 amount, we show the effects of discounting with the higher cost values presented by O&G. B/C ratios remain always above 1 (which is the cut-off value for an expenditure to be socially worthwhile) only for 1st line treatment. For 2nd line treatment, B/C ratios exceed 1 only when the lower cost figure is used and the discount rate is not above 3%. The rest of table 2 shows the results when Treatment is initiated at CD4 counts other than at greater than 350. Table 2 confirms the soundness of the O&G strategy to start the scaling up of Treatments with the group of people living with HIV/AIDS who have the lowest CD4 counts. B/C ratios are always higher the lower the CD4 count when treatment is initiated.

In the analysis that is to follow we are going to be using a special case of O&G's treatment fraction equation (14): $\tau_t = 1 - f\, g\, h_t$. Neither the transmission rate nor the coverage rate will vary by year. The fraction *f*, for the reasons explained in section 2, will be equal to 1. As we are considering a representative individual, the coverage rate is effectively going to be h = 1. As a result we are simply working with: $\tau = 1 - g$. So if a treatment is 30% effective, i.e., g = 0.3, then 70% of infections will still take place and benefits would be only 30% of the value that would exist if there were 100% effectiveness.

Calculating Benefits and Costs when Treatment does Prevent Infection to Others

The calculations appearing in tables 1 and 2 can be viewed as the CBA results for evaluating treatment that is solely for the benefit of the person who receives the drugs. In this case the medicine is targeting *primary* infection prevention. Another reason for administering ARVs is for *secondary* infection prevention, or preventing others getting infected. The O&G paper is mainly concerned with trying to capture the benefits of treatment that prevent secondary infections. This is the usual interpretation of what it means to employ the strategy of using "treatment as prevention". To move easily from our previous analysis of primary infection to incorporate also secondary prevention we will regard the prevention of infections of others as an externality of individual treatment. The prevention of others will be expressed in terms of the number of partners saved from HIV by the originally HIV infected individual getting treatment. Every partner saved provides $1,500 worth of benefits. So we just apply multiples of $5,000 to the number of partners saved to get the new benefits figures with the externality included.

The benefit figure of $5,000 that appears both in tables 1 and 2 corresponds to the case where there are 0 partners saved. For every partner saved, there is an extra $5,000 worth of benefits. This means that: for 1 partner saved the benefits are $10,000, 2 partners saved the benefits are $15,000 and so on. Costs are not affected by the addition of the secondary benefits to the calculations. To see what impact adding the prevention of secondary infections makes to our previous analysis we will start with table 1 which is summarised by the first line of table 2. Note that the objective is to end up with B/C ratios that replicates O&G's results, i.e., are close to 3.

Table 1: Benefits and Costs for 1st Line Treatment with 2012 Costs and No Externalities

Year	Costs ($)	Benefits ($)	Discount Factor at 3%	Discounted Costs ($) 3%	Discounted Benefits ($) 3%	Discount Factor at 5%	Discounted Costs ($) 5%	Discounted Benefits ($) 5%
1	734	0	1.000	734	0	1.000	734	0
2	734	0	0.971	712	0	0.952	699	0
3	734	0	0.943	691	0	0.907	665	0
4	734	0	0.915	671	0	0.864	634	0
5	734	0	0.888	652	0	0.823	603	0
6	734	0	0.863	633	0	0.784	575	0
7	734	0	0.837	614	0	0.746	547	0
8	734	0	0.813	596	0	0.711	521	0
9	734	0	0.789	579	0	0.677	496	0
10	734	0	0.766	562	0	0.645	473	0
11	734	0	0.744	546	0	0.614	450	0
12	734	0	0.722	530	0	0.585	429	0
13	734	0	0.701	514	0	0.557	408	0
14	734	0	0.681	499	0	0.530	389	0
15	734	5,000	0.661	485	3,306	0.505	370	2,525
16	734	5,000	0.642	471	3,209	0.481	353	2,404
17	734	5,000	0.623	457	3,116	0.458	336	2,291
18	734	5,000	0.605	444	3,025	0.436	320	2,181
19	734	5,000	0.587	431	2,937	0.416	305	2,078
20	734	5,000	0.570	418	2,851	0.396	290	1,979
21	734	5,000	0.554	406	2,768	0.377	276	1,884
22	734	5,000	0.538	394	2,688	0.359	263	1,795
23	734	5,000	0.522	383	2,609	0.342	251	1,709
24	734	5,000	0.507	372	2,533	0.326	239	1,628
25	734	5,000	0.492	361	2,460	0.310	227	1,550
26	734	5,000	0.478	350	2,388	0.295	217	1,477
27	734	5,000	0.464	340	2,318	0.281	206	1,406
28	734	5,000	0.450	330	2,251	0.268	196	1,339
29	734	5,000	0.437	321	2,185	0.255	187	1,275
30	734	5,000	0.424	311	2,122	0.243	178	1,215
31	734	5,000	0.412	302	2.060	0.231	170	1,157
32	734	5,000	0.400	293	2,000	0.220	162	1,102
33	734	5,000	0.388	285	1,942	0.210	154	1,049
34	734	5,000	0.377	277	1,885	0.200	147	999
35	734	5,000	0.366	268	1,830	0.190	140	952
Sum	**25,633**	**105,000**		**16,234**	**52,484**		**12,611**	**33,997**

Source: Constructed by the author using the CD4 > 350 initiation time line for benefits and costs given in figure 5 of O&G
Note: The present value (PV) for a benefit or cost in any year is the product of the current value times the discount factor where DF = $(1 + \rho)^{-t}$.

Table 2: B/C Ratios by CD4 Count Initiation and Line of Treatment with No Externalities

Intervention	Years of Benefits	Years of Costs	Annual Cost	Annual Benefit	B/C Ratio ρ = 0%	B/C Ratio ρ = 3%	B/C Ratio ρ = 5%
Initiation of Treatment: CD4 > 350							
1st Line Treatment							
2012 Costs	21	35	$ 733.5	$5,000	4.09	3.23	2.70
2050 Costs	21	35	$1,004.6	$5,000	2.99	2.36	1.97
2nd Line Treatment							
2012 Costs	21	35	$2,117.1	$5,000	1.42	1.12	0.93
2050 Costs	21	35	$2,939.7	$5,000	1.02	0.81	0.67
Initiation of Treatment: CD4 < 350 & CD4 > 275							
1st Line Treatment							
2012 Costs	27	37	$ 733.5	$5,000	4.97	4.19	3.67
2050 Costs	27	37	$1,004.6	$5,000	3.63	3.06	2.68
2nd Line Treatment							
2012 Costs	27	37	$2,117.1	$5,000	1.72	1.45	1.27
2050 Costs	27	37	$2,939.7	$5,000	1.24	1.05	0.91
Initiation of Treatment: CD4 < 200							
1st Line Treatment							
2012 Costs	37	41	$ 733.5	$5,000	6.15	5.73	5.42
2050 Costs	37	41	$1,004.6	$5,000	4.49	4.18	3.96
2nd Line Treatment							
2012 Costs	37	41	$2,117.1	$5,000	2.13	1.98	1.88
2050 Costs	37	41	$2,939.7	$5,000	1.53	1.43	1.35
Initiation of Treatment: CD4 < 100 & CD4 > 50							
1st Line Treatment							
2012 Costs	22	24	$ 733.5	$5,000	6.25	6.05	5.90
2050 Costs	22	24	$1,004.6	$5,000	4.56	4.41	4.31
2nd Line Treatment							
2012 Costs	22	24	$2,117.1	$5,000	2.16	2.09	2.04
2050 Costs	22	24	$2,939.7	$5,000	1.56	1.51	1.47
Initiation of Treatment: CD4 < 50							
1st Line Treatment							
2012 Costs	14	15	$ 733.5	$5,000	6.36	6.26	6.19
2050 Costs	14	15	$1,004.6	$5,000	4.65	4.57	4.52
2nd Line Treatment							
2012 Costs	14	15	$2,117.1	$5,000	2.20	2.17	2.15
2050 Costs	14	15	$2,939.7	$5,000	1.59	1.56	1.54

To replicate any particular set of results using our framework, we need a set of benefits and costs and a time line that applies to these benefits and costs. The time line will be as in our table 1, i.e., 21 years of benefits and 35 years of costs, as this already fitted in with O&G's naive estimates. For costs we will use O&G's table 1. This has costs for first line and second line treatment for 2012 and 2050. We can use averages of the two periods to represent what is typical over the period. Mean first-line costs are $869.1 and they are $2,528.4 for the second-line drugs. Currently, only 3% of the treatments in SSA use second-line drugs. However, we can expect the share to rise over time. The Global Fund uses 5%. But if we are supposed to be working towards universal coverage we should expect the

ratio to be higher than this. Medecins Sans Frontiers in their longest running project in Khayelitsha in South Africa found that 22% percent had to switch from first-line to second-line drugs.[4] Since the experience of South African is often going to be the upper bound for what is feasible with HIV/AIDS interventions in SSA, we will take the 20% figure as being what we can expect in the future for full scale up. Taking the average for the cost of first-line treatment and adding this on to 20% of the second-line treatment average we get $1374.7 as the cost per treatment that we will be using to replicate the O&G results. Note that by working with the 20% figure are deviating from the 10% second-line treatment assumption used in the Assessment Paper.

With the timeline and the costs fixed, we now turn to the benefits. As we explained earlier, the benefit values we will be using are going to be a function of the number of partners saved, starting with $10,000 for 1 partner and going up in multiples of $5,000 as the number of assumed partners saved increases. Table 3 shows all the possibilities and results for each treatment initiation option as we consider the number of partners to range from 1 to 8. We stop at 8 partners as this is the lowest number of partners for us to approximate the B/C ratio of 20 found by O&G in their table 2, which corresponds to their case where treatment is being initiated at a CD4 count of 350 and above.

We can immediately see in our replication of the O&G results in the first section of table 3 a cause for disagreement with the O&G findings. To obtain B/C ratios of 3 we must restrict the initiation period only to those who initiate ARVs when the CD4 count is above 350. We give results for 1 and 2 partners saved. According to Oster (2009) who analyzed DHS surveys in 14 SSA countries, only about 3% of women and 12% of men have multiple partners. Most people who have multiple partners report just two partners. It is reasonable to assume therefore that 1 or 2 partners saved would be typical in SSA. With 2 partners, B/C Ratios would be in the range 3 to 7 depending on the discount rate chosen.

Table 3: B/C Ratios by CD4 Count Initiation and Line of Treatment with Externalities

No. Partners Saved	Years of Benefits	Years of Costs	Annual Cost	Annual Benefit	B/C Ratio $\rho = 0\%$	B/C Ratio $\rho = 3\%$	B/C Ratio $\rho = 5\%$
Initiation of Treatment: CD4 > 350							
2	21	35	$1,374.7	$15,000	6.55	5.18	3.14
1	21	35	$1,374.7	$10,000	4.36	3.45	2.10
Initiation of Treatment: CD4 < 350 & CD4 > 275							
2	27	37	$1,374.7	$15,000	7.96	6.71	4.64
1	27	37	$1,374.7	$10,000	5.31	4.48	3.09
Initiation of Treatment: CD4 < 200							
2	37	41	$1,374.7	$15,000	9.85	9.18	7.85
1	37	41	$1,374.7	$10,000	6.56	6.12	5.24
Initiation of Treatment: CD4 < 100 & CD4 > 50							
2	22	24	$1,374.7	$15,000	10.00	9.68	9.04
1	22	24	$1,374.7	$10,000	6.69	6.45	6.03
Initiation of Treatment: CD4 < 50							
2	14	15	$1,374.7	$15,000	10.18	10.02	9.72
1	14	15	$1,374.7	$10,000	6.79	6.68	6.48

4 The three percentages for second-line treatment coverage just cited come from The All Party Parliamentary Group on AIDS (2009), p12.

Even with just 1 partner saved, B/C ratios would in most cases exceed 3. This supports our conjecture from section 2 that the O&G model is likely to underestimate the B/C ratios of treatment. In the next section we focus just on a particular category of treatment where B/C ratios will be much higher than would be the case for treatment aimed at the population as a whole.

Mother to Child Transmission (MTCT)

The most obvious intervention that fits into the category of treatment as prevention, and not covered explicitly in the Assessment Paper, is that involved with giving ARV medications to pregnant women to prevent the transfer of HIV to their babies. According to Avert (2011a), without treatment, HIV is transferred during pregnancy, labour and delivery to 15-30 percent of babies and during breastfeeding to a further 5-20 percent of babies. In 2009 around 400,000 children became infected with HIV, mainly through MTCT, about 90% in SSA.

In terms of the time horizon analysis we have just been using, the importance of considering treatment to reduce MTCT is that it is the intervention that has the longest period of benefits (the babies expected lifetime gained by treatment) relative to the period of costs (the cost period is very short as many times a single dose is given to the mother and to the baby after delivery). So it has the potential to have the highest B/C ratio of any form of HIV/AIDS treatment.

In 2007, there were 1.3 million pregnant women who were HIV+ needing ARVs for preventing MTCT in SSA. At the time there were 446,000 pregnant women who did receive ARVS for this purpose.[5] We will use the 1.3 million figure as the number of additional persons whose treatment can be funded as part of the $10 billion that we are considering to spend as part of the RethinkHIV project. There will be three alternative MTCP programs that we will be evaluating in our CBA. They range varies from the simplest, a single dose, to a full package of services lasting 18 months. All the programs will involve other costs than the drugs themselves. For each program we will assume that the following non-drug costs are required to receive the full benefits that we will be assuming:[6]

- A screening test to learn each woman's HIV status(at a cost of $3.90 per woman)
- For each HIV+ woman, testing and counselling (at a cost of $13 per woman)
- Family planning services for prevention of unintended pregnancies (at a cost of $20 per woman per year)
- For each HIV+ woman, a CD4 screening, to determine eligibility for ARVs (at a cost of $20)
- Early infant diagnosis of HIV exposure (at a cost of $32.50)
- Cotrimoxazole prophylaxis for the postpartum treatment of infected infants (at a cost of $5).

The total of these non-drug costs is $94.4 per woman. However, the screening test to detect the HIV virus has to be carried out for all pregnant women and not just those who eventually will be found to be HIV+. So the screening is a cost that applies to all pregnant women in SSA, which we will assume to be around 20 million per year. Since our CBA of MTCT is working on an average per infected pregnant woman basis, we have to calculate how many women need to be tested per HIV+ pregnant woman. We have previously established that (adding the 446,000 number of HIV+ pregnant women who are on ARV medications to the 1.3 million needing treatment) that there are about 1.75 million pregnant women per year who are infected with HIV. Diving 20 million by 1.75 produces approximately an 11 to 1 ratio. Thus for every 1 person found infected with HIV, 10 other

5 See table 5.4 in UNAIDS (2009).
6 All of these cost figures come from Schwartländer et al. (2011).

pregnant women are required to have the screening test. At $3.90 per test, the total screening cost for other women is $39. Adding $39 to the $94.4 amount for a HIV+ woman results in a total non-drug cost of $133.4 per woman treated.

We define "full benefits" to be the life expectancy that can be expected if PMCT is 100% effective in reducing infection, i.e., one baby's life is saved for every mother treated. In all cases the full benefits from treatment will generate 0.3 of the value of a life year saved (which will continue to be $5,000) as this is the proportion of babies that would likely become infected in the absence of the intervention. So $1,500 will be the annual benefits for 100% effectiveness. The number of years of expected life expectancy to be gained from PMCT treatment depends on the life expectancy at birth with and without AIDS. Table 4, based on Velkoff and Kowal's (2007) table 2, presents estimates of the life years gained by gender if there were no AIDS in the 26 countries in SSA where HIV has had the most impact on life expectancy. The average of the males gained is 11.64 years and the average for the females was 14.8, which makes the overall average around 13 years. If a baby would have died after 2 years with AIDS, then the 13 years of life gained would begin at year 3 and end at year 15.

Table 4: Differences in Life Expectancy at Birth Without and With AIDS for Selected Sub-Saharan Countries in 2006

Country	Difference (in years) if there were No AIDS (Male)	Difference (in years) if there were No AIDS (Female)
Botswana	22.3	28.4
Burkina Faso	4.4	5.6
Burundi	7.0	9.0
Cameroon	5.5	7.2
Central African Republic	13.5	17.6
Congo	6.0	7.8
Cote d'Ivoire	6.2	9.3
Eritrea	3.9	5.3
Ethiopia	4.2	5.5
Gabon	9.4	12.0
Guinea Bissau	3.8	5.2
Kenya	8.5	10.7
Lesotho	22.7	29.5
Liberia	3.7	5.3
Malawi	13.5	17.6
Mozambique	12.5	15.0
Namibia	24.0	30.6
Nigeria	5.2	7.2
Rwanda	4.2	5.6
South Africa	20.6	28.7
Swaziland	38.9	43.1
Tanzania	7.0	9.0
Togo	5.8	7.6
Uganda	7.5	9.6
Zambia	13.3	16.6
Zimbabwe	29.1	35.7
Average Number of Years Gained	**11.6**	**14.8**

Source: Based on US Census Bureau, International Programs Center. Table 2 of Velkoff and Kowal (2007).

The 13 years of life years gained, and the $1,500 per year gained for the benefits, will apply in the same way to all three PMCT programs we will be evaluating. What differs by program will be the actual transmission rate that will be applied to the 100% effectiveness base and the drug costs of each program.[7] Note that the actual transmission rate for PMCT does not, like the general case modelled by O&G, depend a lot on human behavioural responses to the HIV epidemic in terms of condom use, circumcision, etc. We will therefore model the change in babies infected as depending solely on the *g* effectiveness parameter in the O&G model which varies by PMCT program.

The first program that we will be evaluating we will call the Nevirapine (NVP) program. This single dose drug reduces the chance of transmission by about half to 16%. With g = 0.16 instead of 0.33, the benefits per year would be reduced from the full benefit figure of $1,500 to approximately $750. Although the cost of NVP is miniscule at around five cents per dose, we have to add on the non-drug costs of $133.4 (as explained above) to produce a cost estimate of $133.45 per treatment. The B/C ratios for the Nevirapine are presented in table 5. At the 3% discount rate, the B/C ratio is 54.31 (and 67.44 without discounting and 47.44 at the 5% discount rate).

Table 5: B/C Ratios for Three Prevention of MTCT Programs

Intervention	Years of Benefits	Years of Costs	Annual Cost	Annual Benefit	B/C Ratio ρ = 0%	B/C Ratio ρ = 3%	B/C Ratio ρ = 5%
Nevirapine Program	13	1	$133.45	$ 750	67.44	54.31	47.44
Zidovudine Program	13	1	$157.40	$1,350	102.92	82.89	72.40
WHO Program	13	2	$243.00	$1,500	37.04	30.27	26.69

The second program we will call the Zidovudine (ZDV or AZT) program. This program used to be the WHO recommended regimen and involves the following combination: Zidovudine from six months gestation, a single dose of Nevirapine at birth and a week of Zidovudine and Lamivudine after delivery. This combination is obviously more difficult to administer and costlier than the single dose of Nevirapine. The drug costs are $24, and with the $133.4 of non-drug costs, the total is $157.4 as opposed to the $133.45 with Nevirapine. But it is also more effective than NVP. The number of babies who get infected after the ZDV combination is 10%, which means that it is 90% effective and g = 0.03 instead of 0.33. Multiplying the full benefit value of $1,500 by 0.9 gives a $1,350 figure for the benefits per year for this program. Table 5 shows that even though the costs are higher than for the Nevirapine program, the benefits are higher still, so the B/C ratio is greater at 82.89 with the 3% discount rate (and 102.92 without discounting and 72.40 at the 5% discount rate).

Lastly we will evaluate what we will call the WHO program as this is the regimen that fits in with the latest 2010 WHO guidelines. These guidelines are targeted at the 60% of women who are not yet recommended for treatment for themselves as their CD4 count exceeds 350. For the 40% of women who take ARVs for themselves, we will assume that they will follow the Zidovudine program with its costs.[8]

7 The estimates of the actual treatment effectiveness and the costs for the first two MTCP programs examined below are taken from The All Party Parliamentary Group on AIDS (2009), p11.

8 When we assumed that Nevirapine was the program for the 40% of women who were already on treatment instead of the Zidovudine program, which we assumed in the text, there was only a difference of $10 in the costs, so the B/C ratios did not change by much.

For the 60% of the women who are not yet on ARVS, there are two options, A and B. Option A involves a dual prophylaxis and option B has a triple prophylaxis. Of the 60%, the split is 36% on option A and 24% on option B. Option B costs more than option A. Schwartländer et al. (2011) has estimated the weighted average of the two options (using the percentage splits as the weights) to be $705 per woman. This cost includes drugs and non-drugs. The drug regimen lasts 18 months as it includes 12 months of breastfeeding as recommended by the WHO. We will regard 2/3 of the costs ($470) to incur in the first year and 1/3 ($235) to occur in the second year. Putting all of the costs together involves a weighted average calculation. We take 0.4 of the $157.45 (which is the cost of the Zidovudine program) and add this to 0.6 of the $705 WHO program costs involving options A and B to obtain $486. Of this, $345 occurs in the first year and $141 (i.e., 0.6 of $235) in the second year. Given that the Zidovudine program already has 90% effectiveness and the WHO program is investing in a comprehensive set of additional drugs and services to enhance effectiveness, it is reasonable to assume 100% effectiveness and set g = 0, which means that the full benefits per year of $1,500 would apply. Because the costs are so much higher than for the Zidovudine program, and the benefits are only slightly larger, table 5 shows that the B/C ratios are lower than for the Zidovudine program. The B/C ratio is 30.27 with the 3% discount rate (and 37.04 without discounting and 26.69 at the 5% discount rate).

To summarise our CBA of MTCT programs. The Zidovudine program had the highest B/C ratios and at 82.89 with the 3% discount rate is likely to have the highest ratio of all RethinkHIV interventions that are under evaluation for the RethinkHIV project.[9] Certainly, as far as the treatment inventions as a whole are concerned, as reflected by the B/C ratios coming from the O&G study, PMCT should be given the highest priority. Our B/C ratios are for individual treatments. If the Zidovudine program can be scaled up to all of the 1.3 million pregnant mothers in 2007 keeping the ratios intact, PMCT would cost $250.6 million and save around 270,000 lives.[10]

This cost of $250.6 million to save 270,000 babies' lives by treating 1.3 million pregnant women is per year. We need to consider now scaling up so that every pregnant woman is treated. If we assume that there are going to be no new infections, as envisaged in the UNAIDS Treatment 2.0 initiative, then we are planning to treat all women currently living with HIV.[11] In Sub-Saharan Africa in 2009 there were 12.1 million such women (and 2.3 million children infected with HIV, or 1.725 million babies if we continue to assume that three-quarters of children infected become infected as babies). Assuming that the cost per woman treated is the same as for the 1.3 million that we have just considered, i.e., $157.4 per woman, then the total cost would be $1.9 billion to save 1.725 million lives, nearly 20% of the RethinkHIV Project's $10 billion targeted budget. Realistically, though, there will be some additional women who will become newly infected, so elimination of MTCT using just treatment will cost more than $1.9 billion.

Treatment versus Family Planning to prevent MTCT

So far we have carried out the CBA as if the only ways to reduce or eliminate MTCT is to give pregnant mothers ARVs or to stop women getting infected in the first place (called primary prevention). The ratio of women living with HIV/AIDs to the number of babies with HIV/AIDS, which was 7 to 1 in 2009, need not be a constant. An alternative strategy is to prevent the number of unwanted pregnancies that women living with HIV/AIDS have by investing and intervening thorough family planning (FP).

9 Strictly, if PMCT is to be evaluated as a separate program and not part of a $12 billion package, then the size of the net-benefits would be appropriate CBA criterion. However, the rankings by net-benefits mirror that of the B/C ratios for the PMCT programs.
10 **This assumes that about three-quarters of the 400,000 children affected with HIV in 2007 became infected as babies and that 90%** of them would not have been infected under the Zidovudine program.
11 **These numbers come from Avert (2011b).**

A central concept in the literature on the prevention of MTCT via FP is that of *unmet need* for contraception. Mahy et al. (2010) describe this as a common measure of access to FP and define it as: "the proportion of sexually active, fecund women in a union who wish to stop or postpone childbearing and are not currently using contraception. The measure can be interpreted as the increase in contraceptive prevalence rates if all women were able to fulfil their preferences." The extent of unmet need in 24 of the countries with the largest numbers of HIV+ pregnant women in a union in 2009 is shown in table 6. The table also shows the percentage of women using contraception and the percentage that would be using contraception in 2015 if the unmet need were satisfied.

Table 6: Unmet Need for Family Planning (FP) in the top 24 countries in SSA in 2009

Country	No. HIV+ women delivering in 2009	% women using contraception in 2009	% women reporting unmet need for FP in 2009	% women meeting unmet need in 2015
Nigeria	210,000	20	20	41
South Africa	210,000	62	14	76
Mozambique	97,000	26	18	44
Uganda	88,000	27	41	67
Tanzania	84,000	34	22	56
Kenya	81,000	41	25	65
Zambia	68,000	35	27	61
Malawi	59,000	37	28	65
Zimbabwe	50,000	61	13	74
DR Congo	36,000	27	24	52
Cameroon	34,000	35	20	55
Ethiopia	30,000	22	34	56
Cote d'Ivoire	20,000	31	28	58
Chad	16,000	11	21	32
Burundi	14,000	19	29	49
Lesotho	14,000	45	31	76
Ghana	13,000	31	35	67
Sudan	14,000	44	26	70
Botswana	13,000	63	27	90
Rwanda	11,000	23	38	61
Swaziland	9,300	54	24	78
Namibia	7,700	57	7	63
Burkina Faso	6,500	19	29	48
Average	**51,543**	**36**	**25**	**61**

Source: Based on Mahy et al. (2010), table 1.

We see in table 6 that 25% of pregnancies would not have occurred if women had the contraception that they wanted. This means that 25% of MTCT in 2009 would have been averted with FP. Since the reduction in MTCT from ARVs was estimated by Mahy et al. to be 24% between 2000 and 2009 from these same countries, it would seem that FP would be more effective than ARVS in reducing MTCT.

To see how these effectiveness outcomes convert to cost-effectiveness outcomes, we need to factor in the costs. For ARVs we will use the cost figure for the WHO option A strategy described in our MTCT CBA given earlier, which was identified separately to be $237 by Schwartländer et al. (2011). This same study also put the cost of FP at $20 per woman. So with slightly greater effectiveness and much lower costs than ARVs, FP would be the more cost-effective intervention. This was the conclusion by almost every study in the literature of the comparison between these two interventions, see for example, Sweat et al. (2004), Reynolds et al. (2006) and Hladik et al. (2009).

However, even though FP is judged to more *cost-effective* than *ARVs*, this is not at all the same thing as saying that FP is more *socially beneficial* from a CBA perspective of MTCT. Note that the outcome variable that is used to compare FP with ARVS in the context of MTCT in the cost-effectiveness literature is the number of infant infections averted. When ARVs are involved, the reduction in number of infant infections is lives saved and so fits exactly with the RethinkHIV policy guidelines. A life year saved can be valued at $5,000 (or $1,500 per 0.3 of a life year saved) to form the benefits and with a comparison with the costs the B/C ratio can be formed. This is not the case with FP. The reductions in the number of infections that take the form of babies that are not born cannot be regarded as "life year saved" even though they are life years saved from HIV. The easiest way to see this is to look back at table 5 which summarized our B/C results for three MTCP programs based on ARVs. The treatments provided 13 years of added life expectancy on top of the two years that the infected baby otherwise would have had. On the other hand with an infection averted by a baby not being born due to FP there is no positive number of life years to consider. So there can be no benefits. There can only be costs with FP MTCT evaluations.

One could argue that mothers are better off by not having an unwanted pregnancy and not having an unwanted child. To quote Mahy et al. (2010): "by eliminating unmet need for family planning, women living with HIV would have the children they want when they want them." This then would be a benefit to be quantified by a CBA. For this purpose the willingness-to-pay (WTP) for contraception could be used as a proxy measure of the benefits. But, the point is that WTP is not the CBA framework for benefit estimation in the RethinkHIV policy guidelines. This simply relies on life years saved that is valued at $5,000 per year. Averting unwanted babies by FP does not supply added baby life years.

Treatment for all HIV+ women versus treating just pregnant women.

An alternative way of preventing MTCT using ARVS is to give them to infected women prior to their becoming pregnant. If HIV+ women are already on ARVs they will not have to be given treatment later when they become pregnant. This alternative fits in closely with the rest of this chapter as we have already evaluated treatment in the context of no externalities (tables 1 and 2) and then again when there are externalities (table 3). We have also evaluated ARVs just in the context of MTCT (table 5). The case we are dealing with combines the different types of analysis in a particular way. From the point of view of giving the mother ARVs on an ongoing basis, rather than just prior to birth, the prevention of MTCT is an externality that will raise B/C ratios like any other positive externality. Because the ARVs will prevent MTCT for every baby that is born, the externalities will be greater the more children the woman has.

We will start with the calculations that were presented in table 1. This was assumed to apply to anyone on HIV treatment and looked at the effect simply on the person themselves. Now we apply them to a woman who is affected. As there was nothing gender specific in table 1, we can still

apply these results to any woman who is infected. The only difference to our calculations in terms of table 1 is that we are not going to consider a series of different prices of treatment. We will just go with the first-line and 20% second-line treatment average costs that we used in table 3 (i.e., $1,374.7). Now we introduce the possibility of child-birth. As in table 1, and in the top parts of tables 2 and 3, we are going to use the time horizon that corresponds with the initiation of ARVS when the CD4 count is greater than 350. This generates 21 years of benefits and 35 years of costs. The costs will not vary by year.

The benefits on the other hand will vary a lot by year. In table 1 the benefits are zero for the first 14 years and equal to $5,000. This will be changed as we will add the benefits that exist because of avoiding having a HIV infected baby. Following the time horizon used in table 5, for each baby there will be two years of no additional benefits (the baby was expected to live two years anyway) and then 13 years of benefits. We assume full effectiveness in which case the $1500 figure applies. But because only 0.33 of babies would have become infected, this translates to $1,500 benefits per child per year. We will assume that women have babies at two year intervals starting form year 1. So there will be a series of additional two year zero and 13 year $1,500 benefit cycles. We will make a set of calculations when there are 0, 1, 2, 3 and 4 children to see what difference the number of children makes to the B/C ratios. For reference we present table 7 which shows the 4-baby upper bound case, so that one can readily see all the assumptions that are now being made different from table 1. The first baby is assumed to be born in year 1, the second baby in year 3, the third baby in year 5 and the fourth baby in year 7. The benefits peak in year 15 because this is the first year that the mother's personal benefits of $5,000 appear and there is $6,000 of benefits from the 4 babies. Once the effects of child-birth are over, in year 21, benefits revert back to table 1 levels.

The *total* benefits of $109,302 and the total costs of $30,025 (or $3,123 annual benefits and $1374.4 annual costs) at the 3% discount rate form a B/C ratio of 3.59, or 3.41 at the 5% rate, and these results appears in the first row of table 8. As the number of children a woman has decrease, so does the B/C ratios. The case of zero children is important as this provides the benchmark for the evaluation. It is the B/C ratio that would apply if a man were the ARVs rather than a woman. The rest of table 8 includes adding the number of partners saved by treatment, one or two, as in the calculations in table 3. The full external benefits then of giving HIV+ pregnant women treatment is that their children and their partners will not be infected. For males the external benefits are restricted just to their sex partners. We see in table 8 that for the case that we consider to be the maximum, where there are two partners and four children, the B/C ratio at the 3% rate is 6.93 and it is 6.18 at the 5% rate. Overall, the B/C ratios for women are double that for men if there are zero partners saved; the ratios are 50% higher if there is going to be one partner saved; and the ratios are a third higher when there are two partners saved.

Table 7: Benefits and Costs when Pregnant Women are themselves Treated and also Prevent MTCT to 4 Children

Year	Costs ($)	Benefits ($)	Discount Factor at 3%	Discounted Costs ($) 3%	Discounted Benefits ($) 3%	Discount Factor at 5%	Discounted Costs ($) 5%	Discounted Benefits ($) 5%
1	1374.7	0	1.000	1,375	0	1.000	1,335	0
2	1374.7	0	0.971	1,335	0	0.952	1,309	0
3	1374.7	1,500	0.943	1,296	1,414	0.907	1,247	1,361
4	1374.7	1,500	0.915	1,258	1,373	0.864	1,188	1,296
5	1374.7	3,000	0.888	1,221	2,665	0.823	1,131	2,468
6	1374.7	3,000	0.863	1,186	2,588	0.784	1,077	2,351
7	1374.7	4,500	0.837	1,151	3,769	0.746	1,026	3,358
8	1374.7	4,500	0.813	1,118	3,659	0.711	977	3,198
9	1374.7	6,000	0.789	1,085	4,736	0.677	930	4,061
10	1374.7	6,000	0.766	1,054	4,599	0.645	886	3,868
11	1374.7	6,000	0.744	1,023	4,465	0.614	844	3,683
12	1374.7	6,000	0.722	993	4,335	0.585	804	3,508
13	1374.7	6,000	0.701	964	4,208	0.557	765	3,341
14	1374.7	6,000	0.681	936	4,086	0.530	729	3,182
15	1374.7	11,000	0.661	909	7,272	0.505	694	5,556
16	1374.7	9,500	0.642	882	6,098	0.481	661	4,570
17	1374.7	9,500	0.623	857	5,920	0.458	630	4,352
18	1374.7	8,000	0.605	832	4,840	0.436	600	3,490
19	1374.7	8,000	0.587	807	4,699	0.416	571	3,324
20	1374.7	6,500	0.570	784	3,707	0.396	544	2,572
21	1374.7	6,500	0.554	761	3,599	0.377	518	2,450
22	1374.7	5,000	0.538	739	2,688	0.359	493	1,795
23	1374.7	5,000	0.522	717	2,609	0.342	470	1,709
24	1374.7	5,000	0.507	697	2,533	0.326	448	1,628
25	1374.7	5,000	0.492	676	2,460	0.310	426	1,550
26	1374.7	5,000	0.478	657	2,388	0.295	406	1,477
27	1374.7	5,000	0.464	637	2,318	0.281	387	1,406
28	1374.7	5,000	0.450	619	2,251	0.268	368	1,339
29	1374.7	5,000	0.437	601	2,185	0.255	351	1,275
30	1374.7	5,000	0.424	583	2,122	0.243	334	1,215
31	1374.7	5,000	0.412	566	2.060	0.231	318	1,157
32	1374.7	5,000	0.400	550	2,000	0.220	303	1,102
33	1374.7	5,000	0.388	534	1,942	0.210	289	1,049
34	1374.7	5,000	0.377	518	1,885	0.200	275	999
35	1374.7	5,000	0.366	503	1,830	0.190	262	952
Sum	**48,115**	**183,000**		**30,425**	**109,302**		**23,635**	**33,997**

Source: Constructed by the author using the CD4 > 350 initiation time line for benefits and costs when there are zero babies.

Table 8: B/C Ratios for Treating the Pregnant Mothers Themselves with Varying Number of Children

Number of Children	Number of Partners	Years of Benefits	Years of Costs	Annual Cost	Annual Benefit	B/C Ratio ρ = 3%	B/C Ratio ρ = 5%
4	0	33	35	$1,374.4	$3,123	3.59	3.41
3	0	33	35	$1,374.4	$2,752	3.17	2.99
2	0	33	35	$1,374.4	$2,359	2.71	2.52
1	0	33	35	$1,374.4	$1,942	2.23	2.01
0	0	33	35	$1,374.4	$1,405	1.73	1.44
4	1	33	35	$1,374.4	$4,528	5.21	4.74
3	1	33	35	$1,374.4	$4,157	4.78	4.32
2	1	33	35	$1,374.4	$3,764	4.33	3.85
1	1	33	35	$1,374.4	$3,347	3.85	3.34
0	1	33	35	$1,374.4	$2,810	3.45	2.88
4	2	33	35	$1,374.4	$6,028	6.93	6.18
3	2	33	35	$1,374.4	$5,657	6.51	5.76
2	2	33	35	$1,374.4	$5,169	5.95	5.18
1	2	33	35	$1,374.4	$4,847	5.57	4.78
0	2	33	35	$1,374.4	$4,499	5.18	4.32

Source: Constructed by the author
Note: The annual benefits vary by year, so the figures in this column are the average benefits undiscounted over the 35 years.

Discussion

We give some thought here to whether the benefits should be $1,000 or $5,000 per life saved and to the role of discounting and how it can affect outcomes for treatment programs. Lastly, we deal with the need to give priorities to treatments that target females.

Choosing $1,000 or $5,000 as the Value of a Life Year

We can use some CBA studies of interventions in Tanzania to provide some perspective on helping us decide the appropriate value to place on the outcome of a treatment intervention. The RethinkHIV project's guidelines refer to $1,000 being appropriate for a poorer SA country and $5,000 for a richer country. Using income as the benchmark is consistent with the Human Capital (HC) approach for valuing benefits in CBA, which values a life according to the present value of a person's lifetime earnings.

Although this approach is very often used for CBAs in the Health Care field, it is not best practice. Some people earn little (women in SSA) and some nothing at all (the unemployed, the elderly and the infirm). In general we can regard the HC as providing a lower value for valuing benefits. When this benefit methodology was used to value female education as a way of preventing HIV transmission in Tanzania, [12] it valued a female's life to be worth $8,907, when it would have been worth in the millions in the US. However, this low valuation did not mean that the CBA was predestined to find that investing in female education in Tanzania would not be worthwhile. The B/C ratio was in fact in the range 1.3 to 2.9, so the investment was highly beneficial. This result came about because, even though the benefits were low using the human capital approach in a poor country, the costs were also very low in such a country. Seven years of primary education cost only $213.

12 See Brent (2009a)

The point that is being made here is that if the benefits are being measured in the context of low incomes and the costs are also being measured in the context of low incomes, then the CBA outcome need not be distorted by the use of the HC approach. But when, as with treatment that we considering in the Perspectives paper, which is measuring benefits in local terms and measuring drug costs in the context of rich developed countries, then using the HC approach to value benefits is not going to be appropriate.

Best practice in CBA is to use the Willingness to Pay (WTP) approach. This is consistent with the welfare economic base behind most normative economic policy in the West.[13] This benefit methodology can be applied to intervention commodities, such as the provision of condoms in Tanzania, where a CBA found B/C ratios in the range 1.3 to 1.7 at the existing subsidized price[14], or it can be applied directly to the value of a life saved from Voluntary Counseling and Testing using the Value of a Statistical Life (VSL) approach[15], which obtained B/C ratios above 3 for both individual and dual testing scaled up to the population as a whole.

Note that the value of a life saved using the VSL approach in Tanzania was $38,900, over four times the value used for a life saved using the Human Capital approach. For CBAs in Developed countries, there is a rule of thumb that the WTP approach gives estimates that are three times that of the HC approach.[16] This relationship would probably be higher for developing counties, in which case if $1,000 is the HC valuation, then $5,000 would probably be a reasonable estimate using the WTP approach. For this reason we have used only the $5,000 benefit figure and not the $1,000 amount in all our calculations.

It is useful to compare this $5,000 figure with the value that was obtained using the Revealed Preference approach to carry out the value of a life year (strictly, a Disability Adjusted Life Year DALY as envisaged by the RethinkHIV project's guidelines).[17] The RP approach assumes that behaviour reveals preferences. In this case the assumption is that the more that a decision-maker values something, the more that the person will spend money in obtaining it. Brent (2010b) did a statistical analysis of the spending decisions by the Global Fund when giving grants to African counties for HIV interventions and they implicitly valued a DALY at $10,000 when AIDS or Malaria or TB was contributing to the DALY, and it was $6,000 when any other disease was contributing to the DALY. The standard DALY value of $6,000 is close to the $5,000 figure that were are using. Since the AIDS DALY is worth more than this according to the Global Fund's preferences, we can be sure that our $5,000 is not too high.

As a final *post script* on this discussion, it is necessary to point out that ignoring WTP and using a fixed value to apply to numbers of lives saved to estimate the benefits, as suggested by the RethinkHIV project's guidelines, will not always work. As we realized when carrying out a comparison of treatment with family planning in the context of MTCT in section 4, not every intervention explicitly can be reduced to saving lives. It may be that lives are not saved, but lives (albeit with HIV infection) are simply not being created. In this case, one has to directly find out what a woman is WTP for FP and use this to measure the benefits.

13 For an exposition of CBA that utilizes this welfare economic base, see Brent (2006).
14 See Brent (2009b).
15 See Schelling (1968).
16 See Brent (2003), chapter 11.
17 We will refer again to the role of DALYs for evaluating treatment in the Summary and Conclusions section.

Evaluating Treatment as Prevention and the Role of Discounting

Having a dynamic perspective of CBA enables one to have a deeper understanding of the essential similarities and differences between treatment and prevention in terms of carrying out a CBA of health care interventions. In any intervention numbers are important. Prevention usually involves a large number of people taking a precautionary action that involves costs in exchange for a fewer number of persons receiving the benefits in terms on avoiding the adverse effects of an illness or disease. In the case of HIV/AIDS prevention the costs involves potentially everyone getting tested or taking condoms in order that some of them do not get infected with the virus. Numbers are also important for HIV treatment, but it is in terms of numbers of years and not numbers of persons. For any one person on treatment, a larger number of years have to be devoted to incurring the costs of medications than the years of extra life expectancy that is generated by the drugs. This was the central feature that drove the calculations presented in this Discussion Paper.

Linked to the number of years that are involved with the costs is whether the intervention is a one-time or continuous activity. In many CBAs outside the health care field (for example building a bridge or school) there is large upfront cost taking place in the first period and the evaluation task is to convert a future stream of benefits to be comparable to the current costs (i.e., the present value of the benefits must be calculated). In our evaluation of MTCT we considered both cases, one where treatment was just during the birth of the baby, and again when treatment was given to mothers even prior to the pregnancy when they were being treated in their own right.

It is the context of differing numbers of years of benefits and costs, and whether costs are a one-time or continuous expense, that the impact of discounting for the evaluation of treatment can be understood. As we saw in table 1 and repeated in the first row of table 2, the fact that benefits come in year 15 and are therefore heavily discounted while the costs are experienced in all years, means that discounting is going to have a large impact when initiation is with a CD4 count of greater than 35. In the first segment in table 2, we see that the B/C ratio is greater than 1 only if there is no discounting in the last rows with 2012. This was true when there were 21 years of benefits and 35 years of costs. In the middle segment, where benefits are for 37 years and follow more closely the 41 years of costs, the impact of discounting is very small. With 2050 costs, the B/C ratio is 1.56 with no discounting and very close to the 1.43 and 1.35 with 3% and 5% discounting respectively. When we reach the fifth and final segment of table 2, discounting has almost no impact in affecting B/C ratios. When it comes to considering the evaluation of treatment that is initiated with a CD4 count < 50, the RethinkHIV experts need not agonize over whether 3%, which is current practice for health care evaluations, or whether 5%, which used to be the rate most often used, is the appropriate discount rate. These generalizations hold also for table 3 where externalities are also included.

In the evaluation of MTCP programs, there is (are) only one (or two) years of costs and these are incurred in the beginning year(s). Discounting will not impact costs. But, the benefits flowing over 13 years are greatly affected by the choice of discount rate. Fortunately the best MTCT program has enormously high value B/C ratios even at the 5% rate, i.e., it is 72.40, so again the RethinkHIV experts do not need to agonize over whether to give the highest priority to MTCT programs on the basis of which discount rate to use.

Women and HIV in SSA

A glaring omission from the Assessment Paper is any allowance for equity considerations,

whether they be related to individual, regional or gender inequalities. We will just focus on gender inequality.

Worldwide, 52% of adults living with HIV in low and middle income countries are women, while 58% of those receiving treatment are women. So outside of SSA, the ratio of women to men receiving treatment is in line with gender HIV prevalence.[18] But In SSA 60% of the HIV infections involve females. It is likely that in SSA the women's share is not in line with prevalence; especially as some treatment programs require co-payments for costs of diagnosis, treatment or care, or need to know the insurance status of patients. Women have fewer resources and are less likely to have insurance than men and would therefore be at a disadvantage. In addition, sometimes requirements are made for those initiating treatment that they disclose their status to at least one person. Such criteria may limit access to care and treatment for women because of fear of violence from partners[19].

However, even if 60% of ARVs do go to women in SSA, an argument could be made that the share should be even higher. MTCT is very high in most countries and in many countries MTCT government programs allegedly give priority to the prevention of MTCT transmission, yet there were an estimated 370,000 children who contracted HIV during the perinatal and breastfeeding period, most of them in SSA. In addition, there were 90,000 AIDS-related deaths among children in SSA in 2009.[20] The clearest sign that prevention of MTCT must have been inadequate is the CBA results we found in section 4 of this Perspectives paper. If B/C ratios of 70 to 100 can be obtained for the prevention of MTCT then this direct evidence that resources must have been used for lower priority interventions in the past.

In this Perspectives Paper we have come up with an externalities argument why females should always be given priority over males in the allocation of ARV treatments. Women have children while men do not. While it costs the same to give treatment to women as men, there will always be more persons who do not get infected and hence higher benefits from treating women, if the number of sex partners is the same. While there is evidence that males do have more partners than females in SSA, the difference is very small. In section 4 we referred to the study by Oster (2009) which reported that men only have 9 percentage points more partners than females, which would not make up for the advantage of a female having just one child whose live would be saved.

Summary and Conclusions

The Assessment Paper on Treatment finds, see figure 11, that if an extra $10 billion is spent on expanding ARV provision, then the benefit-cost ratio generated by this intervention would be in the range 2 to 3. This would mean that additional benefits would be $20 to $30 billion, which makes HIV treatment a highly socially worthwhile investment. The strategy that achieved this outcome would be to expand treatment first to those with CD4 counts less than 50 and work up the CD4 initiation list until the budget was exhausted.

The dynamic model of infections that was used by Over and Garnett to produce the estimated number of lives saved by treatment was similar in structure to the standard epidemiological model, but it did have some important differences that suggest that the Assessment Paper underestimated the true benefits of treatment – see section 2 of this Perspectives Paper. For example, the Assessment

18 See WHO (2009).
19 Again, see WHO (2009).
20 See UNAIDS (2010).

Paper model did not allow for fertility effects of treatment. If there would have been more people infected than was predicted, then there would be more lives that could have been saved when increased treatment coverage takes place.

In our simplified version of the dynamic model, which focused on a representative individual on treatment and allowed for different treatment effectiveness by considering varying amounts of partners whose lives would be saved from treatment, we were able to replicate the Assessment Paper's findings only under very restrictive circumstances - see table 3 in this Perspectives Paper. First of all there would have to be only 1 sex partner. If someone had any other partner than their spouse or regulator partner then B/C ratios less than 3 could not be obtained. Secondly, the discount rate would have to be 5% and not 3%. And finally, the CD4 count at initiation would have to be less than 350.

A useful way of summarizing our table 3 is to recognize that scaling up treatment would involve starting with the CD4 <50 group and then moving up the list of five groups until one reached the CD4 > 350 group. Since all five groups' results would be a part of this process and should be included, one can take the average of the five group B/C ratios to obtain the overall result. With 1 partner the average B/C ratio is 5.44 at the 3% discount rate and 4.59 at the 5% discount rate, and with 2 partners the average B/C ratio is 8.15 at the 3% discount rate and 6.88 at the 5% discount rate.

If the number of lives saved is underestimated in the Assessment paper, the benefits are going to be underestimated. The numerator part of the B/C ratio will be low. To know whether the ratio as a whole will be too low, we also need to consider whether the costs in the denominator of the ratio have been appropriately estimated. O&G come up with a figure of $1,034 as the average treatment cost per year - see their figure 3. They obtain this figure on the assumption that there will be economies of scale with treatment, i.e., a 10% increase in scale will lead to a 3% reduction in average cost. They refer to cross-section data in figure 3 to support their claim that economies of scale exist. But, there are two main reasons for doubting that there will be falling average costs with treatment scale up. The cross section analysis is not relevant and treatment side-effects are not recognized.

Firstly, health care facilities in SSA are mainly in the urban areas where population densities are high. Rural areas are underserved. To expand treatment in SSA will involve going into the rural areas where transport costs will inhibit uptake. These transport costs including the opportunity cost of time need to be factored into the average cost estimates. Assume that half of a typical SSA country lives in rural areas. The cross section data analyzed in figure 3 has countries expanding treatment so that costs approximate the experience of South Africa that had 971,556 persons on ARVS out of a population of 2,600,000 that needed treated according to WHO 2010 guidelines. We are assuming therefore that the costs that South Africa is experiencing are mainly urban treatment costs. Now take the case of Swaziland who has 47,241 on ARVs and 80,000 are needed. The thought experiment in the Assessment paper is that Swaziland moving towards 80,000 will be like moving towards South Africa's near million on ARVs. But the reality is that all of Swaziland's expansion will involve going into the rural areas where average costs are much higher than in the urban areas.[21]

The second problem with the Assessment's costs assumption is that is that it ignores the fact that ARV treatment has enormous adverse side effects that reduces people's tolerance and hence adherence to treatment. Treatment 2.0 points out that 38 countries out of 52 counties surveyed by

21 The ARV figures in this paragraph are from UNAIDS (2009).

the WHO had started replacing d4T (a staple of first-line treatments) with a less toxic option. The point simply is that as scaling up takes place more people will need to be treated with second-line (and third-line) drugs that are much more expensive (double the cost according to the Assessment Paper). This means that it is very unrealistic for the Assessment Paper to assume that only 10% of the people on treatment will be on second-line drugs when there is going to be such a large scale up. In our CBA calculations we attempted to partially correct for the underestimation of costs in the Assessment Paper by replacing their $1,034 figure with our $1,375 estimate which is a third-higher. We obtained this amount by assuming 20% of treatment will use second-line drugs. As we pointed out in section 3, when we were explaining the justification for the numbers determining the B/C ratios in table 3, some programs in South Africa already treat 20% of the infections with second-line drugs.

To summarize so far: we suggest that the estimates in our table 3 are more reliable on both the benefits and costs sides, and so the B/C ratios we found in the range 5 to 8 are better predictors of outcomes than the 2 to 3 range in the Assessment Paper.

Up to this point we have been assuming that *all* of the $10 billion is to be spent on treatment. We will now consider the results we found when only a part of the funds was going to be spent on treatment. In the presence of a budget constraint the correct CBA procedure is to calculate the B/C ratios for all types of intervention, i.e., prevention, treatment and mitigation, and to rank them from highest to lowest. Then one starts funding with the interventions with the highest B/C ratio and then work down the list until the total budget is exhausted.[22] We have argued in section 4 of this Perspectives Paper that MCTC is likely to have the highest B/C ratios of any treatment program because it will give the largest number of years of benefits (additional life expectancy) for the least number of years of costs (in most cases just one year of costs). In fact, it is highly likely that the B/C ratios for MTCT will be the largest for any type of intervention that the RethinkHIV Initiative will be considering. B/C ratios for three alternative prevention of MTCT listed in table 5 are in the range of 27 to 103. For the best alternative MTCT via a Zidovudine program, the B/C ratios are in the range 72 to 103. A strong case can be made that if $2 billion of the $10 billion is devoted to treating 12.1 women currently pregnant and likely to be in the future, then this will save 1.25 million babies lives and generate around $200 billion of benefits.

Prevention of MTCT is concerned with saving the lives of the children of the pregnant mothers. If one is also concerned with treating the mothers themselves, then the evaluation framework changes considerably to be a mix of the analyses in tables 3 and 5. The results are shown in our table 8. Costs need to be incurred in every year for the person treated. In table 7 we see that (undiscounted) costs over the woman's lifetime amount to $25,633. So treating 11.6 million women would far exceed the $10 million budget. In fact, it would not be feasible to fund the 1.6 million women who are currently pregnant and are infected with HIV. Instead there could be only 390,122 people treated with the funds available.

So the question is: who should be the 390,122 people that receive treatment for the $10 billion? The answer is clear according to table 8. The benefits of treatment depend on the size of the externalities, which is determined by the number of partners and children who are not infected because the drugs prevent the transmission of the virus to them. Men, like women, can have sex partners, but cannot have children. So the externalities are larger for women for a given number of

22 For a proof that this is the correct CBA procedure when there is a budget constraint see Brent (1998), chapter 2.

partners. The male treatment B/C ratios correspond to the three rows in table 8 where there are no children. We see that for no partners, the B/C ratio for women with 4 children are double that for males when the discount rate is 3%.[23] For 1 partner, which is the norm in SSA, the B/C ratio is 26% higher if a female has 2 children and has treatment, and is 51% higher if a female has 4 children and has treatment. The answer then is that treatment should first be given to females.

The fact that there is no analysis of treatment by gender in the Assessment Paper is a major omission. The transmission rate from males to females is three times that from females to males,[24] yet the transmission coefficient β_t has no gender component in equation (9). It would have been a simple matter to have disaggregated the *S* and the *I* in equations (6) and (7) and used a β three times larger when attached to the female term $S_f i_f$.

The other major omission from the Assessment Paper that affects all their results is that they did not follow the RethinkHIV project's guidelines and convert their outcome measure of lives saved to Disability Life Years DALYs. This omission probably affects the results for treatment much more than it would any of the other interventions that the RethinkHIV experts are considering. Antiretroviral drugs have enormous adverse side-effects due to their toxicity. For example, they lead to Lipodystrophy and impotence in males. Whether one is using DALYs, or their inverse Quality Adjusted Life Years QALYs, these side effects greatly reduce the quality of a life year saved *even if* we assume that people do not stop taking their medications because of their existence (which we know does take place). In a CBA of ARVs for elder adults in New York City, Brent (2011a, 2011b) found that the medications reduced the quality of life by 27% for those who were not depressed. Multiplying all benefits in O&G's paper by 27% would greatly reduce all their B/C ratios, by approximately a quarter.

This would also be the case with our tables 3 and 8. Females and males alike would have their quality of life greatly reduced by treatment. However, this would *not* be the case with our evaluation of the prevention of MTCT in section 4 and our results given in table 5. Prevention for a pregnant woman is a one-off intervention in this context. When successful, neither the mother nor the baby has to take ARV medications in the future, so neither of them will have their quality of life reduced. This reinforces our main recommendation in this perspectives Paper that the first $2 billion of the additional funding should be devoted to the prevention of MTCT as this treatment intervention is likely to have the highest B/C ratio of any intervention.

23 Obviously, for women to have children, they must have had sex partners in the past. So the table with 0 partners is to be understood as the number of partners a woman will have in the future, who will after treatment by the woman, will not be infected.
24 See Stillwaggon (2006).

References

Avert (2011a): Preventing Mother-to-Child Transmission of HIV (PMTCT). Downloaded from http://www.avert.org/mother-child.htm (accessed 9/9/2011).

Avert (2011b): Sub-Saharan Africa HIV & AIDS Statistics. Downloaded from http://www.avert.org/africa-hiv-aids-statistics.htm (accessed 9/9/2011).

Brent, R.J. (2011): "The Effects of HIV Medications on the Quality of Life of Older Adults in New York City." *Health Economics* (forthcoming).

Brent, R.J. (2010a): Setting Priorities for HIV/AIDS: A Cost-Benefit Approach. Edward Elgar Publishing Limited, Cheltenham, UK.

Brent, R.J. (2010b): "An Implicit Price of a DALY for Use in a Cost-Benefit Analysis of ARVs." *Applied Economics*, 43, 1413-1421.

Brent, R.J. (2010c): "A Social Cost-Benefit Criterion for Evaluating Voluntary Counseling and Testing with an Application to Tanzania." *Health Economics*, 19, 154-172.

Brent, R.J. (2009a): "A Cost-Benefit Analysis of Female Primary Education as a Means of Reducing HIV-AIDS in Tanzania." *Applied Economics*, 41, No. 14, 1731-1743.

Brent, R.J. (2009b): "A Cost-Benefit Analysis of a Condom Social Marketing Program in Tanzania." *Applied Economics*, 41, 497-509.

Brent, R.J. (2006): *Applied Cost-Benefit Analysis*. Second edition. Edward Elgar, Cheltenham, UK.

Brent, R.J. (2003): *Cost-Benefit Analysis and Health Care Evaluations*. Edward Elgar, Cheltenham.

Brent, R.J. (1998): *Cost-Benefit Analysis for Developing Countries*. Edward Elgar Publishing Limited, Cheltenham, UK.

Brent, R.J., Brennan, M. And Karpiak, S.E. (2011): "Using a Happiness Index to Measure the Benefits for a Cost-benefit Analysis of Antiretrovirals for Older Adults with HIV in New York City." *Fordham University*, New York.

Gersovitz, M. and Hammer, J.H. (2004): The Economic Control of Infectious Diseases. *The Economic Journal*, 114: 1-27.

Hladik W., Stover J., Esiru G. et al. (2009): The Contribution of Family Planning towards the Prevention of Vertical HIV Transmission in Uganda. *PLoS One*, 4, Issue 11, e7691.

Mahy M., Stover, J., Kiragu, K. et al. (2010): What Will it Take to Achieve Virtual elimination of Mother-to-Child Transmission of HIV? An Assessment of Current Progress. *Sexually Transmitted Infections*, 86 (Suppl 2), ii48-ii55.

Oster, E. (2009): "HIV and Sexual Behavior Change: Why not Africa? University of Chicago and NBER, June 2009.

Pisani, E. (2008): The Wisdom of Whores: Bureaucrats, Brothels and the Business of AIDS. New York: W.W.Norton & Company.

Reynolds, H.W., Janowitz, B., Homan, R. et al. (2006): The Value of Contraception to Prevent Perinatal HIV Transmission. *Sexually Transmitted Diseases*, 33, 350-356.

Schelling, T.C. (1968): "The Life You Save May Be Your Own." In S.B. Chase Jr. (ed.), *Problems in Public Expenditure Analysis*, Washington DC: Brookings institution, 127-161.

Schwartländer B., Stover J., Hallet, T. et al. (2011): "Towards an Improved Investment Approach for an Effective Response to HIV/AIDS. The Lancet, DOI:10.1016/S0140-6736(11)60702-2. There is online supplemental material (26/05/2011) for this article that is referred to in our paper.

Stillwaggon, E. (2006): *AIDS and the Ecology of Poverty*, New York: Oxford University Press.

Sweat, M.D., O'Reily, K.R., Schmid, G.P. et al. (2004): Cost-effectiveness of Nevirapine to Prevent Mother-to-Child Transmission in eight African Countries." *AIDS*, 18, 1661-1671.

UNAIDS (2009): Towards Universal Access: Scaling Up Priority HIV/AIDS Interventions in the Health Sector. Progress Report 2009.

UNAIDS (2010). Report on the Global AIDS Epidemic 2010.

The All Party Parliamentary Group on AIDS (2009): The Treatment Timebomb. Report of the Inquiry of The All Parliamentary Group on AIDS into Long-term Access to HIV Medicines in the Developing World, July.

Velkoff, V.A. and Kowal, P.R. (2007): *Population Aging in Sub-Saharan Africa: Demographic Dimensions 2006*, U.S. Census Bureau, Current Population Reports, P95/07-1, U.S. Government Printing Office, Washington, DC.

WHO (2009): Integrating Gender into HIV/AIDS Programmes in the health sector: Tool to Improve Responsiveness to Women's Needs.

WHO (2010): Antiretroviral Drugs for Treating Pregnant Women and Preventing HIV Infection in Infants: Towards Universal Access. Geneva.

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