Electronic Supplementary Material

Cost-Effectiveness of Combining Drug and Environmental Treatments for Environmentally Transmitted Diseases*

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1 Model Description

1.1 Epidemiological Model

We assume two closed human sub-populations $i = C, A$, representing the children (C) and adult (A) populations, respectively. Let I_i denote the proportion of infected humans in population i. We incorporate into a single parameter the rate of reproduction of propagules released in the environment by population i and the fraction of propagules that reach the environment; this parameter represents the shedding rate of infectious humans and it is denoted by λ_i.

We separate the population of intermediate hosts (i.e., the freshwater snails) in two epidemiological classes: susceptible (X) and infected (W). We denote the total population of intermediate hosts as N which means that by definition $0 \leq X + W = N \leq K$ where K is the carrying capacity of the ecosystem. Following the convention in the literature on disease dynamics [1; 2; 3; 4; 5; 6; 7], we model the growth of infected intermediate hosts as

$$\dot{W} = \Big(\alpha_C \lambda_C I_C + \alpha_A \lambda_A I_A\Big) X - \Big(\delta + q_W u_W\Big) W \tag{S1}$$

where α_i represents the proportion of population i in total population, δ is the natural death rate of infected intermediate hosts, u_W is the level of environmental treatment (EnvTre), and q_W, with $0 < q_W < 1$, represents the fact that there is an upper bound on the effectiveness of EnvTre [8]. In this formulation, entry of intermediate hosts in the infectious compartment is represented by the first term of Equation (S1), and exit of intermediate hosts from the infectious compartment (i.e., death of infected intermediate hosts) is represented by the second term of Equation (S1). New infections of intermediate hosts thus rely on the relative (α_i) shedding (λ_i) of infectious humans (I_i), while the loss of infectious intermediate hosts relies on the natural death rate (δ) and the fact that we apply an imperfect (q_W) and non-selective treatment (u_W) that kills both susceptible and infected intermediate hosts.

The intermediate hosts are assumed to grow according to a logistic-type reproduction function [2; 3; 5]. Normalizing the carrying capacity K to one such that $0 \leq X + W = N \leq K = 1$, the growth of the susceptible class of intermediate hosts is

$$\dot{X} = fX\Big(1 - N\Big) - q_W u_W X - \Big(\alpha_C \lambda_C I_C + \alpha_A \lambda_A I_A\Big) X \tag{S2}$$

where f is the maximal reproduction rate. Note that density dependent mortality (or fecundity) of susceptible snails is implicitly accounted for in the nonlinear term of the logistic growth function (i.e., accounted for in the first term of Equation S2); only susceptible snails can reproduce since the parasite castrates the snails [3; 5]. Given that we model the control of intermediate hosts as non-selective, controlling the population of infected intermediate hosts also affects susceptible intermediate hosts (second term of Equation S2). Finally, the third term of Equation (S2) represents the susceptible snails becoming infected.

We focus on a case where there is contact with the disease exclusively through the environment; it infects susceptible humans at rate β_i (for $i = C, A$) through the W infected intermediate hosts living in the environmental reservoir. We assume that only children are treated via drugs, which allows us to focus on a more realistic case where only part of the human-to-environment transmission is reduced. The proportion of infected human children and adults respectively grow according to

$$\dot{I}_C = \beta_C W\Big(1 - I_C\Big) - \Big(\gamma_C + q_C u_C\Big) I_C \tag{S3a}$$

$$\dot{I}_A = \beta_A W\Big(1 - I_A\Big) - \gamma_A I_A \tag{S3b}$$

where γ_i (for $i = C, A$) is the natural rate of recovery of population i, u_C is the level of MDA treatment for children, and q_C, with $0 < q_C < 1$, represents the fact that there is an upper bound on the effectiveness of MDA controls [9; 10]. Note that because I_i represents a proportion of the population $i = C, A$, then $(1 - I_i)$ represents the proportion of susceptible individuals since there is no immunity against schistosomiasis. See figure S1 for a flow diagram of the disease transmission.

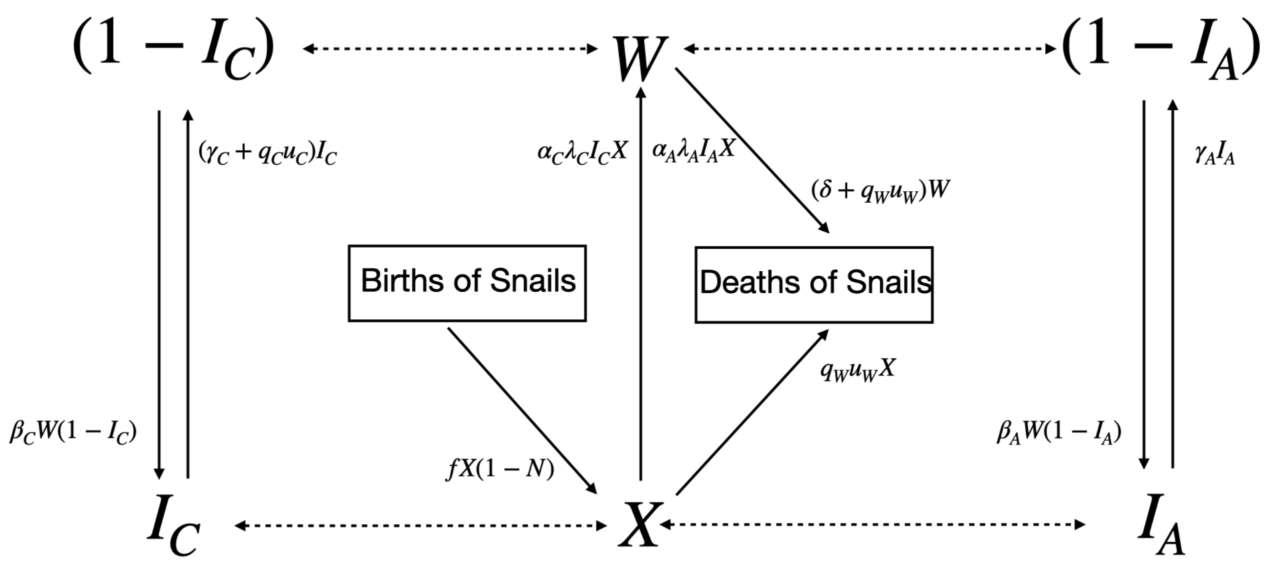

Figure S1: This figure shows a flow diagram of the disease transmission. Full lines represent flows between state variables; dashed lines represents indirect infection between susceptible humans and infected snails, and infected humans and susceptible snails.

1.2 Economic Model

Damages due to infection occur on human populations $i = C, A$. We assume that the damage function is linear and additively separable such that for each population i the damage function is given by:

$$c_i(I_i) = c_i I_i \tag{S4}$$

where c_i is the cost parameter associated with population i.

The cost of the policy is denoted by some function $c_P(u_C, u_W; \mathcal{F})$, where $\mathcal{F}$ represents a fixed transportation and management cost that is incurred each period during the planning period. We model it as being additively separable functions, such that

$$c_P(u_C, u_W; \mathcal{F}) = c_{PC}(u_C) + c_{PW}(u_W) + \mathcal{F}. \tag{S5}$$

We assume that the cost of the policy for MDA treatment, $c_{PC}(u_C)$, and the cost of the EnvTre policy, $c_{PW}(u_W)$, are increasing in the level of control. The functional form chosen for treatment of children is given by,

$$c_{PC}(u_C) = c_{PC} u_C$$

where c_{PC} is the cost parameter associated with the MDA cost function of the treatment of children; this parameter can be thought of as the cost of the drug multiplied by the number of children in the population. We assume that costs associated with control of intermediate hosts is given by the following function:

$$c_{PW}(u_W) = c_{PW} u_W$$

where c_{PW} denotes the cost parameter associated with the treatment of intermediate hosts.

We model transportation and management costs, $\mathcal{F}$, as a fixed cost in each period during the planning period regardless of whether treatment is being undertaken. There are a number of ways to consider the fixed cost. We could assume a separate and additive fixed cost for each treatment. This implies, however, that the planning agency is sending separate simultaneous shipments and teams to the village, which seems unrealistic. On the other hand, there are likely potential economies of scale across the different treatment options. For example, an agency could combine transportation of treatments to a remote village. To account for this realistic possibility, we model a single fixed cost regardless of whether children or environmental treatments are applied. We parameterize the fixed cost from the literature (see, for example, [4; 5; 11; 12; 13; 14; 15]).

2 Parameterization

2.1 Epidemiological Model

In epidemiology, the basic reproduction ratio R_0 is defined as being the expected number of secondary infection, at a disease-free equilibrium, caused by a typical infected individual over its entire infectious period [16]. In a basic model, the R_0 is given by the contact rate multiplied by the mean infectious period. In more complex heterogeneous models however, one needs to use the next-generation matrix. The dominant eigenvalue of the next-generation matrix is the basic reproduction ratio R_0 [16], which turns out to be a function of relative shedding rates of adult and children, natural recovery rates, and contact rates with the environmental reservoir. The next-generation matrix is composed of two matrices, denoted F and V, and it is equal to $-FV^{-1}$. The ij^{th} element in F represents the rate at which infected individuals in population j produce new infections in population i, and the ij^{th} element in V represents the transition rate between $(i \neq j)$, or out of $(i = j)$, infectious compartments [7]. Hence in our model,

$$F = \begin{pmatrix} 0 & 0 & \beta_C \\ 0 & 0 & \beta_A \\ 0 & 0 & 0 \end{pmatrix} \text{ and } V = \begin{pmatrix} -\gamma_C & 0 & 0 \\ 0 & -\gamma_A & 0 \\ \alpha_C \lambda_C & \alpha_A \lambda_A & -\delta \end{pmatrix}$$

where the three rows of F and V refer to the I_C, I_A, and W equations, respectively. Note that both F and V are derived under the assumption of introducing a single infected snail in an otherwise susceptible population.

Following the methodology of Diekmann *et al.* [16], the basic reproduction ratio is given by,

$$R_0 = \frac{\alpha_C \beta_C \lambda_C}{\delta \gamma_C} + \frac{\alpha_A \beta_A \lambda_A}{\delta \gamma_A}.$$

There is little evidence on how and to what extent the biological parameters in the above R_0 may differ between children and adults.[1] This evidence may be anecdotal or based on beliefs

[1] See Colley *et al.* [17] for differences in intensities of infection with age for schistosomiasis; these differences may be attributable to antiparasite immunity rather than reduced contact.

[4], and also may be highly community and occupation dependent [18]. We thus assume in our numerical simulation that all biological parameters are identical across the child and adult populations.

There is little data available on the contact rate of humans with the pathogen, β_i, and we found no data available on the shedding rate λ_i. In our simulation the contact rate is set such that there is 1 infection per 200 water contacts,[2] and the shedding rate is set such that there is approximately 1 intermediate host infection per 555 sheds. The chosen values of β_i and λ_i were calibrated to match a basic reproduction ratio, R_0, of 3.5.[3]

The natural recovery rate in humans, γ_i, may be thought of as the life expectancy of the disease in hosts (3.3 years) [20]. Since we do not take into consideration the intensity of infection human hosts, we assume that humans, once infected, carry 70 worms [3]. The maximum reproduction rate of intermediate hosts, f, is set according to estimates of the literature [21], assuming a carrying capacity of 10,000 individuals in a water access point of 200 square meters [3]. The natural mortality rate of intermediate hosts, δ, is based on their life expectancy (2 months) [21; 22; 23], again assuming a carrying capacity of 10,000 individuals in water access point of 200 square meters [3].

2.2 Economic Model

The costs include damages (reduction in human health), treatment (MDA and EnvTre), and a fixed transportation (from a central planning agency to an endemic remote village) and management cost. All costs are discounted using a discount rate of $r = 0.04$ or 4%.

Damage related to infectious humans were calibrated such that, without intervention, infection rates of 38% in a community of 5,000 people would yield losses of 550 disability-adjusted life years (DALYs) [5]. The value of a life year was set to be approximately the median value of the GDP per capita of an African country (approximately $3,000 USD). Although we assume that costs are identical for children and adults, cost parameters—representing damages on the whole subpopulation and not just one individual—must differ if proportions of children and adults are not the same.

For the MDA cost function, we calibrated the cost function using the cost of the drug used to fight schistosomiasis [4; 5; 11; 13; 14]. The MDA cost parameters were calibrated for a 5,000 people community. Effectiveness of MDA treatment was assumed to be 80% [9; 10].

For the EnvTre cost function, we calibrated the linear term of the cost function using estimates for variable costs of snail control (e.g., chemical, personnel compensation) [5; 12; 15]. Chemical applications of molluscicide niclosamide does not systematically kill all snails; the meta-analysis of Yang *et al.* [8] finds that the death rate of snails 15 days after the spraying is approximately 88%.

Finally, the fixed cost of transportation and management is based on estimates from the literature [4; 5; 11; 12; 13; 14; 15].

[2] This is consistent with findings of the literature [3; 19].

[3] According to Sokolow *et al.* [3], the expected R_0 for schistosomiasis ranges from 1 to 7.

2.3 Parameter Levels

Table S1 summarizes the parameter values we used in our numerical simulation.

Parameters	Level	Definition
β_i	5.00×10^{-3}	Contact rate for $i = C, A$ (year^{-1}).[4]
λ_i	1.80×10^{-3}	Shedding rate for $i = C, A$ (year^{-1}).[5]
γ_i	4.30×10^{-3}	Natural recovery rate for $i = C, A$ (year^{-1}).[6]
δ	6.00×10^{-4}	Natural death rate of the disease in the environment (year^{-1}).[7]
f	1.168	Maximum reproduction rate of intermediate hosts (year^{-1}).[8]
α_1	0.4	Proportion of children in total population.[9]
α_2	0.6	Proportion of adults in total population.[9]
r	0.04	Annual discount rate.[10]
c_C	208,268	Damages related to infectious children (US Dollars).[11]
c_A	312,402	Damages related to infectious adults (US Dollars).[11]
c_{PC}	210	Cost of drug for treating children population (MDA) (US Dollars).[12]
c_{PW}	370	Cost of chemical treatment (EnvTre) (US Dollars).[13]
$\mathcal{F}$	1,500	Fixed transportation and management costs (US Dollars).[14]
q_C	0.8	Effectiveness of MDA control.[15]
q_W	0.88	Effectiveness of EnvTre control.[16]

Table S1: Parameter levels used in the base case of the numerical simulation.

[4] Calibrated to match a R_0 of 3.5. Set such that there is 1 infection per 200 water contacts (consistent with the literature) [3; 19]. See electronic supplementary material section 4.1 for a sensitivity analysis of the results when varying the contact rate relative to the shedding rate while keeping R_0 constant.

[5] Calibrated to match a R_0 of 3.5. This gives approximately 1 environmental infection per 555 shedding. See electronic supplementary material section 4.1 for a sensitivity analysis of the results when varying the contact rate relative to the shedding rate while keeping R_0 constant.

[6] Based on the life expectancy of the disease in hosts (3.3 years) [20], assuming humans carry 70 worms once infected [3].

[7] Based on the life expectancy of infected intermediate hosts (2 months) [21; 22; 23], assuming a carrying capacity of 10,000 individuals in a water access point of 200 square meters [3].

[8] Based on an instantaneous intrinsic fertility rate of snails of 0.16 per day per square meter, and assuming a carrying capacity of 10,000 individuals in a water access point of 200 square meters [3]. See electronic supplementary material section 4.7 for a sensitivity analysis of the maximum reproduction rate of intermediate hosts.

[9] Based on data from Senegal from "The World Factbook" [24]. For a sensitivity analysis of the results while varying the proportion of children in the total population, see electronic supplementary material section 4.2.

[10] See electronic supplementary material section 4.4 for a sensitivity analysis of the results while varying discount rate.

[11] Based on an estimate of the number of DALYs lost when no intervention takes place over a ten year period [5]. See electronic supplementary material section 4.5 for a sensitivity analysis of the value of a DALY.

[12] Based on the literature [4; 5; 11; 13; 14].

[13] Based on the literature [5; 12; 15].

[14] Approximate value based on the literature [4; 5; 11; 12; 13; 14; 15].

[15] Based on the literature [9; 10]. See electronic supplementary material section 4.6 for a sensitivity analysis of the effectiveness of MDA control.

[16] Based on the literature [8]. See electronic supplementary material section 4.6 for a sensitivity analysis of the effectiveness of environmental control.

3 Optimization

3.1 Boundary Conditions and Constraints

The initial and terminal conditions of the four state variables are such that:

$$W(0) \text{ is given, and } W(T) \text{ is free;} \tag{S6a}$$
$$X(0) \text{ is given, and } X(T) \text{ is free;} \tag{S6b}$$
$$I_i(0) \text{ are given, and } I_i(T) \text{ are free for } i = C, A.^{17} \tag{S6c}$$

We present results from a numerical simulation where initially all state variables are at their pre-treatment equilibria.[18] The chosen parameter values imply that before any treatment, the level of infection for both the children and adult populations has converged to approximately 38%.[19] The steady-state level of the snail population will converge to the carrying capacity (i.e. $K = 1$), while the number of infected snails will converge to 54%. These are the initial values of the state variables in our numerical simulation.

All terminal values on state variables are free. This means that the algorithm approximating the optimal control problem will optimally choose the infection prevalence in children, as well as the optimal number of infected snails at the end of the time horizon. This requirement of choosing optimal levels is however conditional on the fact that these optimal levels can be reached in the given time horizon.

State variables W, X, and I_i for $i = C, A$, are also subject to constraints that bound them from above and below. Formally, the constraints are given by:

$$0 \leq W \leq N \leq 1; \tag{S7a}$$
$$0 \leq X \leq N \leq 1; \tag{S7b}$$
$$0 \leq I_i \leq 1 \quad \text{for } i = C, A. \tag{S7c}$$

since the carrying capacity of the ecosystem where the intermediate host resides has been normalized to one, and since I_i denotes the proportion of infected individuals.

Control variables u_W and u_C are modeled in a additive way. The former acts as an increase in the death rate of the intermediate host, while the latter acts as an increase in the rate of recovery of children. Control variables are subject to:

$$0 \leq u_W \leq 1; \tag{S8a}$$
$$0 \leq u_C \leq 0.9. \tag{S8b}$$

The upper-bound of 0.9 on the MDA control variable u_C represent the fact that there is systematic noncompliance to drug treatment [27; 28; 29].

3.2 Time Horizon and Objective Function

Since we do not impose conditions on state variables at the end of the planing period, i.e., since the terminal conditions are free, the minimization of the objective guarantees that the terminal

[17] For WHO's guidelines on treatment and long-term control and eradication objectives for neglected tropical diseases see [11] and [25]; for guidelines on vector management see [26].

[18] See electronic supplementary material section 4.3 for sensitivity analyses of the results when varying initial level of infection.

[19] This is consistent with the findings of Lo *et al.* [5].

conditions are optimized conditional on being reachable in a finite number of periods, T. We assume that

$$T \text{ is given,} \tag{S9}$$

rather than being optimaly chosen. Following previous literature investigating the cost-effectiveness of schistosomiasis [2; 5; 7; 30], the finite amount of time chosen for the simulation is $T = 10$ years. We consider longer time horizon in section 4.8 of the electronic supplementary material.

We model the problem as a cost minimization. Given some non-negative discount rate r, the objective of the planner is to minimize the present discounted costs of the disease—which includes both damages and treatment costs—which is given by:

$$\min_{u_C, u_W} \int_0^T e^{-rt} \Big\{ c_C(I_C) + c_A(I_A) + c_P(u_C, u_W; \mathcal{F}) \Big\} \mathrm{d}t \tag{S10}$$
$$\text{s.t. } (S1), (S2), (S3), (S6), (S7), (S8) \text{ and } (S9).$$

where $c_i(I_i)$ for $i = C, A$ and $c_P(u_C, u_W; \mathcal{F})$ are respectively given by (S4) and (S5). Explicitly, the problem is

$$\min_{u_C, u_W} \int_0^T e^{-rt} \Big\{ c_C I_C + c_A I_A + c_{PC} u_C + c_{PW} u_W + \mathcal{F} \Big\} \mathrm{d}t \tag{S10}$$

$$\text{s.t. } \dot{W} = \Big(\alpha_C \lambda_C I_C + \alpha_A \lambda_A I_A\Big) X - \Big(\delta + q_W u_W\Big) W \tag{S1}$$

$$\dot{X} = f X \Big(1 - N\Big) - q_W u_W X - \Big(\alpha_C \lambda_C I_C + \alpha_A \lambda_A I_A\Big) X \tag{S2}$$

$$\dot{I}_C = \beta_C W \Big(1 - I_C\Big) - \Big(\gamma_C + q_C u_C\Big) I_C \tag{S3a}$$

$$\dot{I}_A = \beta_A W \Big(1 - I_A\Big) - \gamma_A I_A \tag{S3b}$$

$W(0)$ is given and $W(T)$ is free; (S6a)

$X(0)$ is given and $X(T)$ is free; (S6b)

$I_i(0)$ are given and $I_i(T)$ are free for $i = C, A$; (S6c)

$$0 \le W \le N \le 1; \tag{S7a}$$

$$0 \le X \le N \le 1; \tag{S7b}$$

$$0 \le I_i \le 1 \quad \text{for } i = C, A; \tag{S7c}$$

$$0 \le u_W \le 1; \tag{S8a*}$$

$$0 \le u_C \le 0.9; \tag{S8b*}$$

$$T \text{ is given.} \tag{S9}$$

where constraints (S8) on control variables vary depending on the treatment scenario:

Scenario	**MDA Constraints**	**EnvTre Constraints**
No Controls	$0 \le u_C \le 0$	$0 \le u_W \le 0$
MDA	$0 \le u_C \le 0.9$	$0 \le u_W \le 0$
EnvTre	$0 \le u_C \le 0$	$0 \le u_W \le 1$
MDA & EnvTre	$0 \le u_C \le 0.9$	$0 \le u_W \le 1$

Table S2: Constraints on control variables in the different treatment scenarios considered in our analysis.

3.3 Numerical Methods

We use pseudospectral collocation to solve for the optimal dynamics of treatment and infection over time (see [31; 32; 33] for applications of this technique). Specifically, we approximate the optimal control model with a non-linear programming (NLP) problem, where we assume that our controls are approximated with an n^{th} degree polynomial over a period from 0 to T (the end of the planning horizon) [34]. The algorithm ensures that the residual error of the constraints is minimized at the collocation points. The collocation points and degree of polynomial are chosen to balance speed of convergence to a solution and numerical error; we used 60 collocation points. One advantage of this approach over more typical two-point boundary value methods, such as shooting, is that we can directly incorporate in the problem the constraints on the state and control variables [35]. This feature enables us to find optimal solutions that might reside on the boundary of the control set for a period of time. A second advantage is the ability to handle larger scale dynamical systems, such as the one in this paper with four states variables and two control variables. The solution method was implemented using TOMLAB (v. 8.4) [36; 37] and the accompanying PROPT toolbox [38]. The approximate NLP is solved using general-purpose nonlinear optimization packages KNITRO, SNOPT and NPSOL. We have included the source code that utilizes the TOMLAB/PROPT software at the end of the electronic supplementary material. Readers can download a trial version of the software to rerun our analysis.

4 Sensitivity Analyses

4.1 Basic Reproduction Ratio

According to Sokolow *et al.* [3], the expected range of the basic reproduction ratio R_0 for schistosomiasis ranges from 1 to 7. In the main results, the contact rates β_i and shedding rates λ_i were calibrated such that the basic reproduction ratio R_0 would be equal to 3.5. We investigate the range given in Sokolow *et al.* [3] by varying the contact rate from 1 infection per 700 water contacts ($R_0 = 1$), to 1 infection per 100 water contacts ($R_0 = 7$), and by varying the shedding rate from 1 intermediate host infection per 1944.4 sheds ($R_0 = 1$), to 1 intermediate host infection per 277.8 sheds ($R_0 = 7$). For the majority of the range of R_0 (at least between 2 and 7), our finding on the optimal substitution away from MDA due to the environmental treatment holds qualitatively (figure S2, top two panels). For the environmental treatment, more time will be spent at the maximum level with a higher R_0, and more so if this higher R_0 is due to higher contact rates (figure S2, bottom panel).

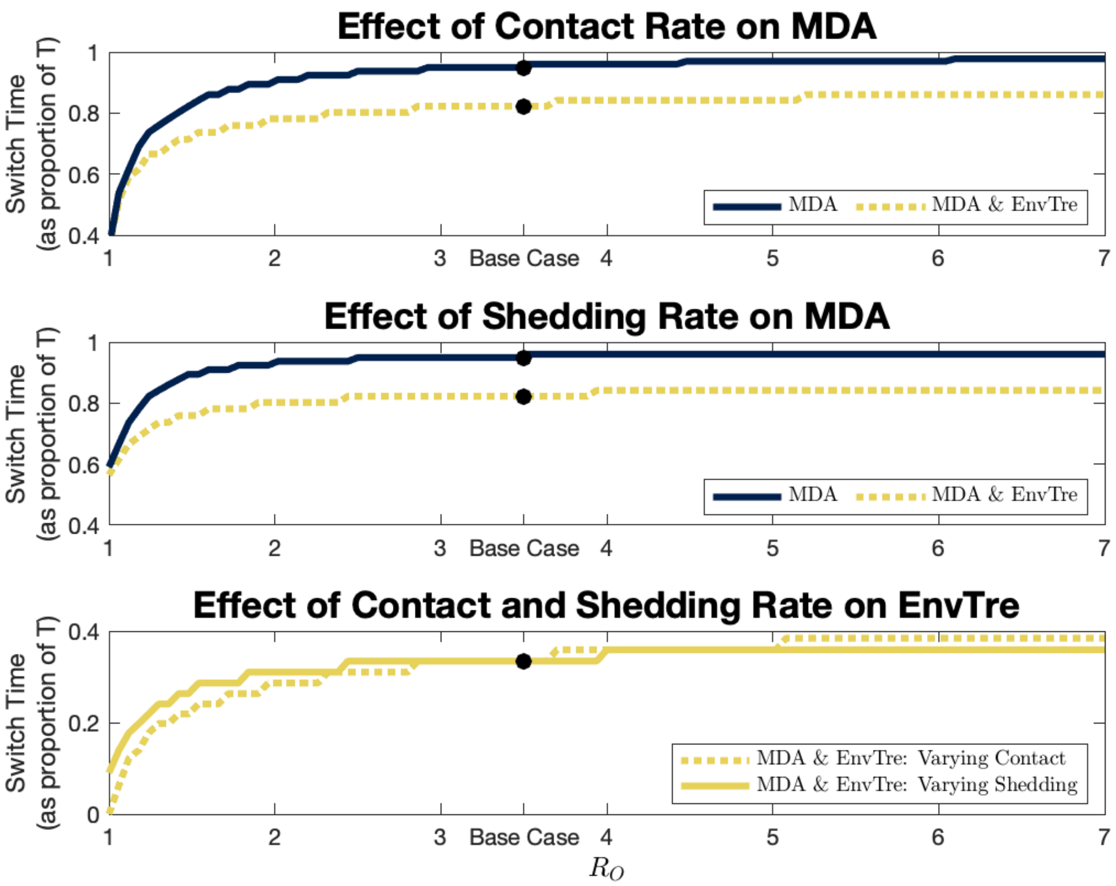

Figure S2: Proportion of total treatment time spent at the maximum level of control (MDA or EnvTre) as a function of the basic reproduction ratio, R_0—which varies either with the contact rate (β_i) or the shedding rate (λ_i). The top panel shows the effect of the contact rate on children MDA, while the center panel shows the effect of the shedding rate on children MDA. The bottom panel shows the effect of the contact and shedding rate on the environmental treatment.

The contact rates (1 infection per 200 water contacts) and shedding rates (1 intermediate host infection per 555 sheds) in the main results are consistent with the literature [3; 19], however, there are many combinations of contact and shedding rates that could yield a R_0 of 3.5, even if we keep the biological parameters identical across children and adults. Our sensitivity analyses suggest that the substitution away from MDA due to EnvTre remains the same regardless of how the contact rate is relative to the shedding rate (figure S3, top panel). Contact rates play a bigger role than shedding rates in determining the amount of time spent at maximum treatment (figure S3). As the contact rate (β_i) increase relative to the shedding rate (λ_i), and keeping R_0 constant, more time will be spent utilizing both MDA and EnvTre controls.

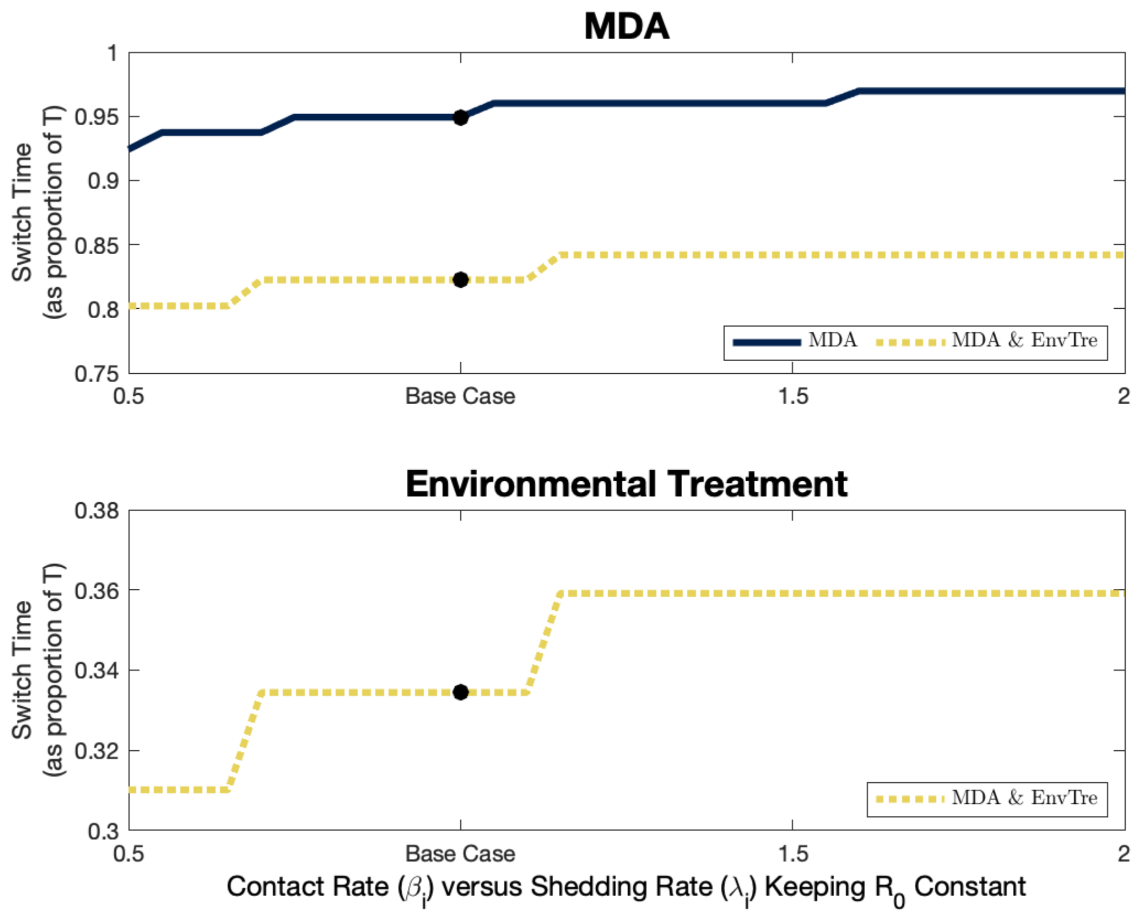

Figure S3: This figure shows the proportion of total time spent at the maximum level of MDA (i.e., $u_C = 0.9$, top panel) and the proportion of total time spent at the maximum level of EnvTre (i.e., $u_W = 1$, bottom panel) as a function of the contact rate relative to the shedding rate, keeping R_0 constant at 3.5. A value of 0.5 on the x-axis represents a case where the contact rate is half of its base case value, while the shedding rate is twice its value; a value of 2 on the x-axis is the converse.

4.2 Proportion of Children in Total Population

In our simulation, the proportions of children versus adults are based on data from Senegal where 40% of the population are children (0-14 years) and 60% are adults (15 years and over). As the proportion of children in total population increases, the damage parameter associated with infectious children (c_C) increases while the one associated with infectious adults (c_A) decreases because of the way they are constructed (i.e., a constant times the respective proportion), however MDA cost parameter associated with children (c_{PC}) increases proportionally. As a result, there is no change in the amount of time spent treating children (figure S4, top panel). Furthermore, only when the proportion of children becomes low enough, and in turn the expenditures associated with child MDA, we find a discrete shift up in the amount of time spent treating the environment (figure S4, bottom panel).

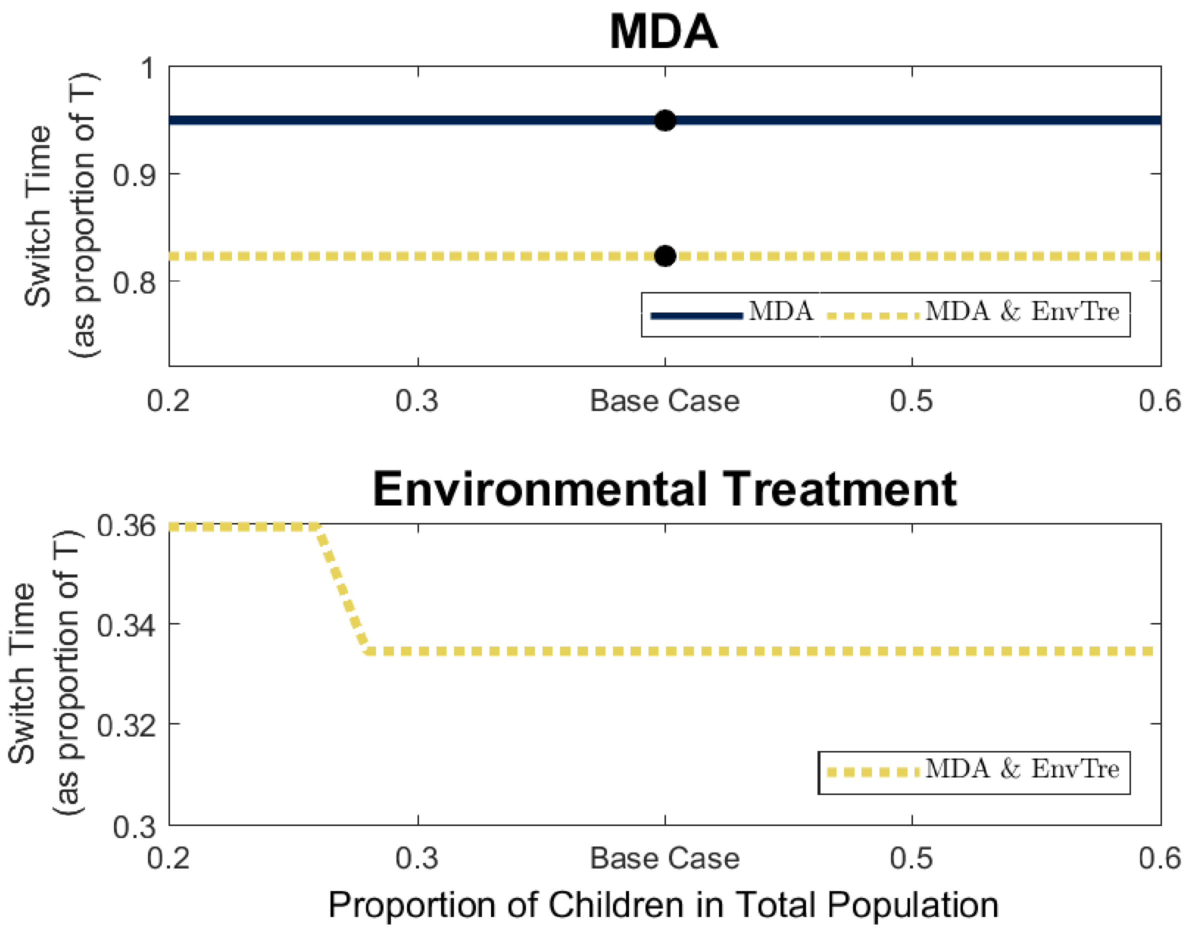

Figure S4: This figure shows the proportion of total time spent at the maximum level of MDA (i.e., $u_C = 0.9$, top panel) and the proportion of total time spent at the maximum level of EnvTre (i.e., $u_W = 1$, bottom panel) as a function of the proportion of children in the total population.

4.3 Initial Conditions

In our analysis, all state variables are at their pre-treatment, long-term, levels. By varying the initial conditions from 10% to 100% of these levels, we find that the optimal substitution away from MDA to EnvTre remains approximately the same, except when values drop below the 20% threshold (figure S5, top panel). Since moving further away from the long-term value implies a lower number of infected intermediate hosts in the environment, the switch time of EnvTre will reduce the further we are from the steady-state values (figure S5, bottom panel).

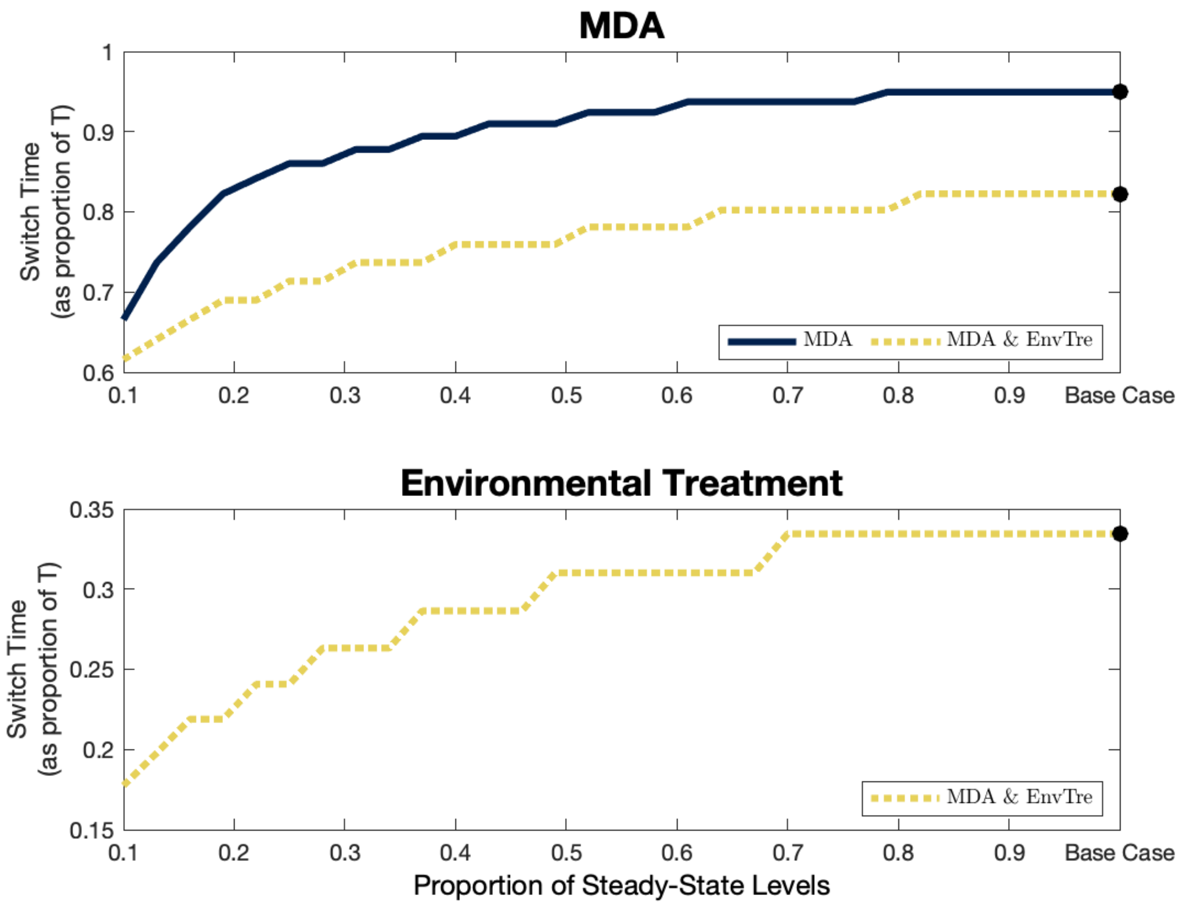

Figure S5: This figure shows the proportion of total time spent at the maximum level of MDA (i.e. $u_C = 0.9$, top panel) and the proportion of total time spent at the maximum level of EnvTre (i.e. $u_W = 1$, bottom panel) as a function of the initial conditions. Initial conditions range from 10% to 100% of the long-term values for state variables I_C, I_A, and W; the snail population size $(X + W)$ is assumed to be at its carrying capacity in all simulations.

4.4 Discount Rate

The higher the discount rate r the more weight is placed on damages, treatment, and transportation and management costs incurred early in the program. By varying the discount rate, we find that it does not vary the optimal substitution away from MDA due to EnvTre in the $r = [0, 0.2]$ range (base case, $r = 0.04$) (figure S6, top panel) Conversely, the level of EnvTre reduces as the discount rate increases indicating that EnvTre has long-term benefits that are attenuated when the discount rate increases (figure S6, bottom panel). For a discussion about discount rates for health outcomes, see [39] and [40].

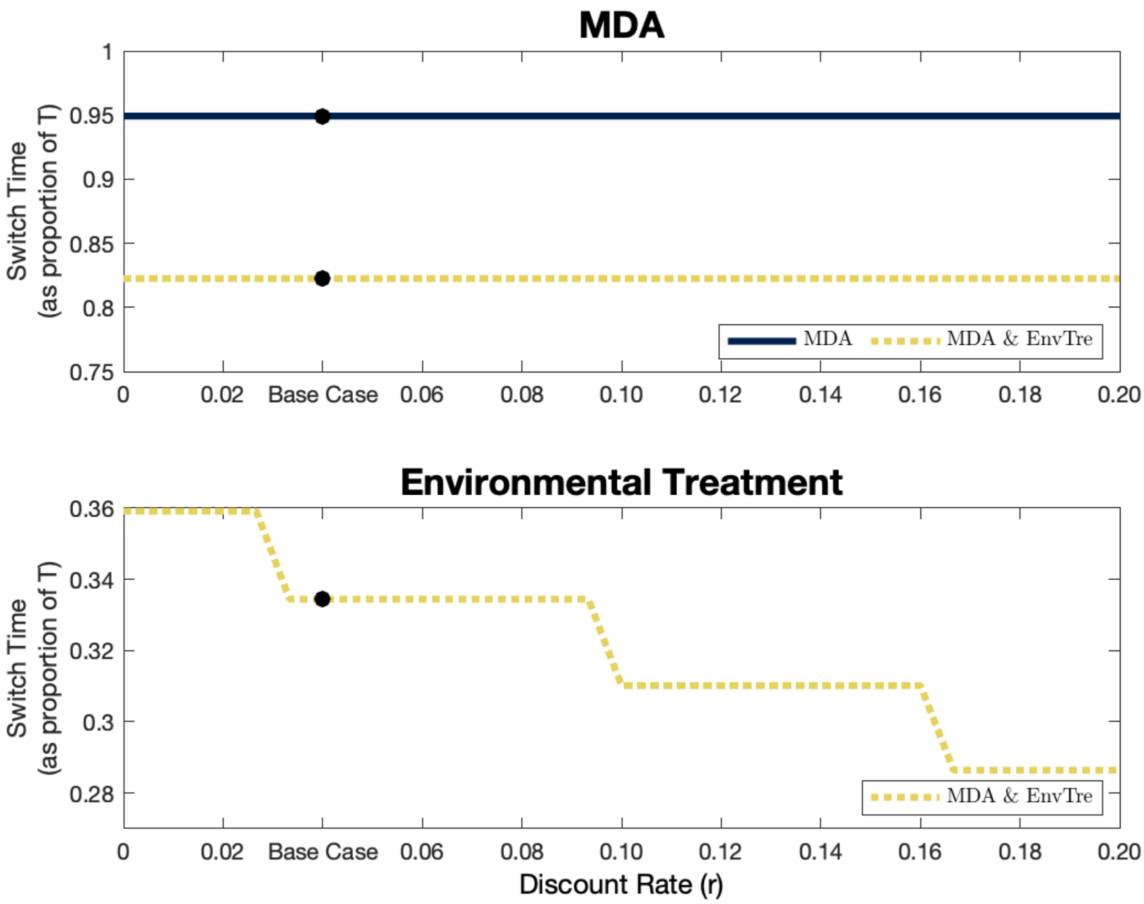

Figure S6: This figure shows the proportion of total time spent at the maximum level of MDA (i.e. $u_C = 0.9$, top panel) and the proportion of total time spent at the maximum level of EnvTre (i.e. $u_W = 1$, bottom panel) as a function of the discount rate.

4.5 Value of a DALY

The value of a DALY was set to be approximately the median GDP per capita of an African country. Intuitively, the switch time for both MDA (figure S7, top panel) and EnvTre (figure S7, bottom panel) will increase as the value of a DALY increases. Because, everything else equal, damages are relatively more important than treatment costs if the value of a DALY increases, more treatment will occur. The substitution from MDA to EnvTre will decrease as the value of a DALY increases since the effect of EnvTre is only indirect compared to MDA that directly, and immediately, reduces disease burden.

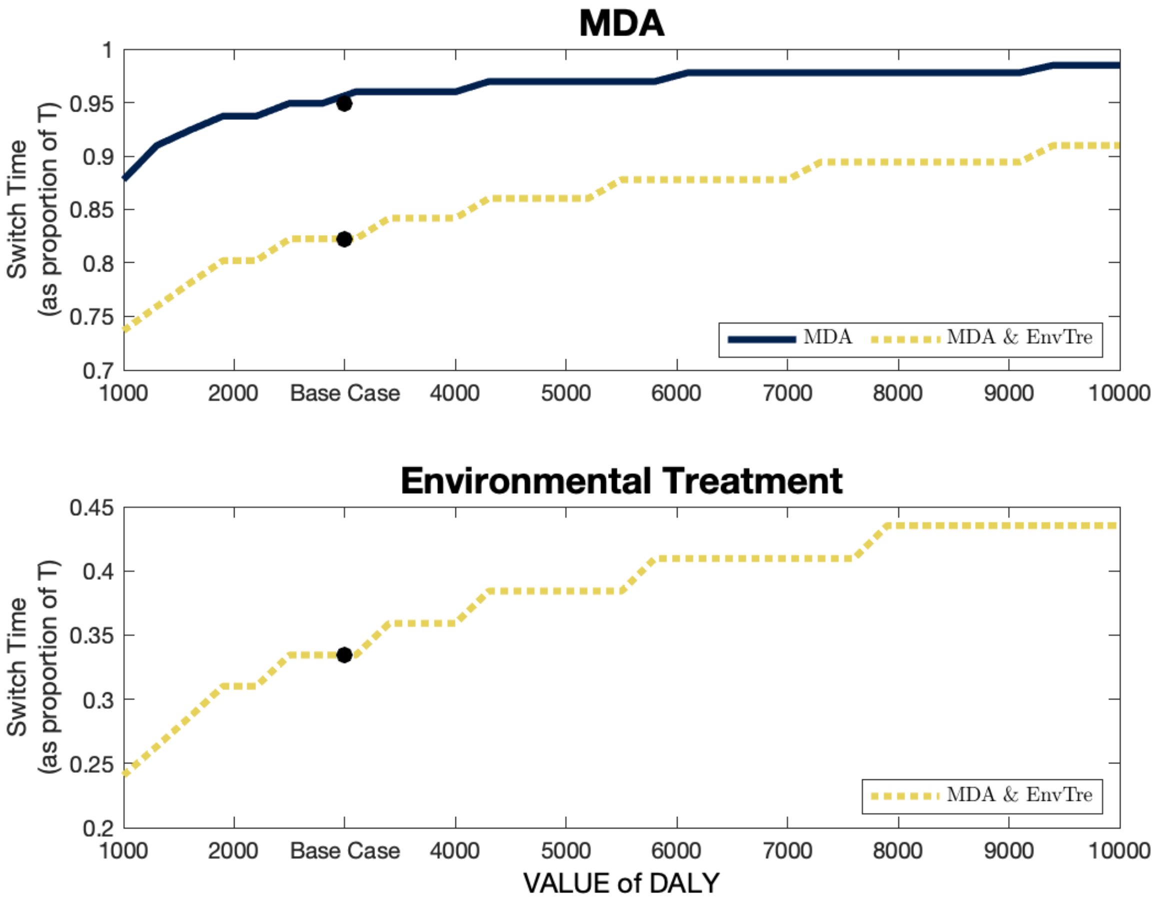

Figure S7: This figure shows the proportion of total time spent at the maximum level of MDA (i.e. $u_C = 0.9$, top panel) and the proportion of total time spent at the maximum level of EnvTre (i.e. $u_W = 1$, bottom panel) as a function of the value of DALYs.

4.6 Effectiveness of Controls

MDA and EnvTre have a limited effectiveness. In these sensitivity analyses, we investigate how our results would be affected by a worsened or improved effectiveness. We find that if the effectiveness of MDA improves, the substitution away from MDA due to EnvTre would increase (figure S8, top panel) since a higher MDA effectiveness would reduce the optimal amount of time needed to reduce disease burden in humans. Though one could expect an improved effectiveness to have the same effect on both the MDA and MDA & EnvTre cases, the effect is more pronounced in the latter because the reinfection of humans is lower when EnvTre is utilized. Effectiveness of MDA has no impact on the optimal amount of EnvTre (figure S8, bottom panel). As for the effectiveness of EnvTre, it has no effect on the substitution away from MDA due to EnvTre (figure S9, top panel), and an improved effectiveness in EnvTre control would reduce the optimal amount of EnvTre treatment (figure S9, bottom panel).

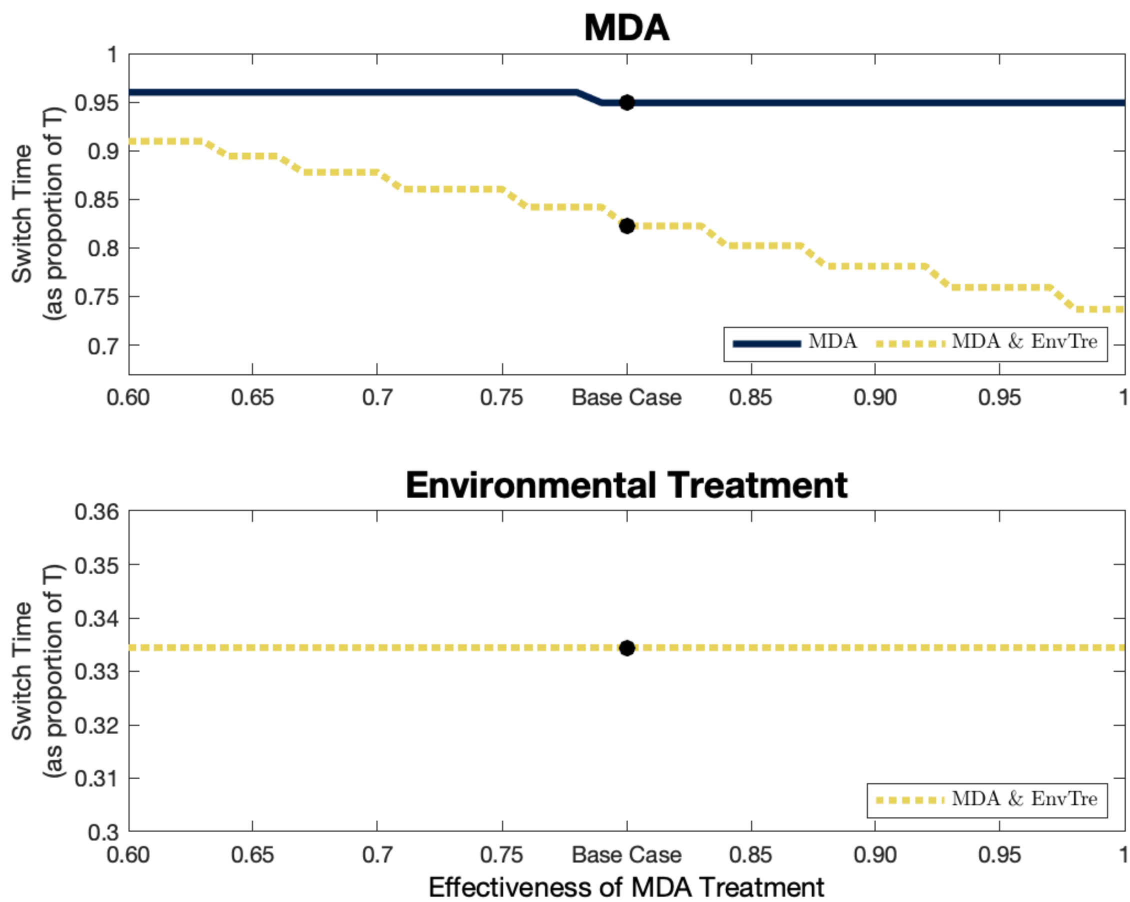

Figure S8: This figure shows the proportion of total time spent at the maximum level of MDA (i.e. $u_C = 0.9$, top panel) and the proportion of total time spent at the maximum level of EnvTre (i.e. $u_W = 1$, bottom panel) as a function of the effectiveness of MDA control.

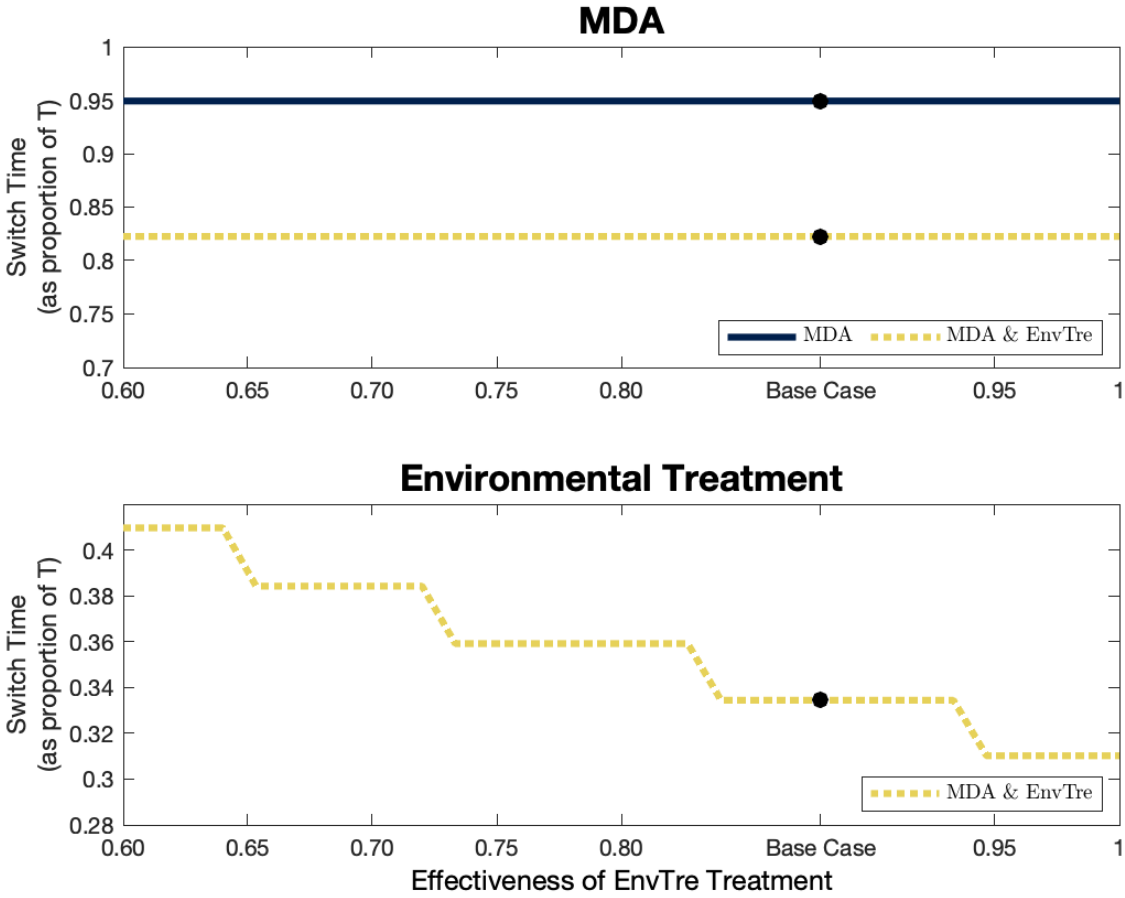

Figure S9: This figure shows the proportion of total time spent at the maximum level of MDA (i.e. $u_C = 0.9$, top panel) and the proportion of total time spent at the maximum level of EnvTre (i.e. $u_W = 1$, bottom panel) as a function of the effectiveness of EnvTre.

4.7 Growth Rate of Intermediate Hosts

We find that a variation of 50 percent around our base growth rate of intermediate hosts does not change our results (figure S10). The values considered in our sensitivity analysis did not vary our results because the growth rate remains several orders of magnitude higher than the natural death rate of snails. Only when the growth rate is of the same order of magnitude as the death rate do we find measurable changes; when growth rate drops below the death rate, it follows that treatment will reduce drastically.

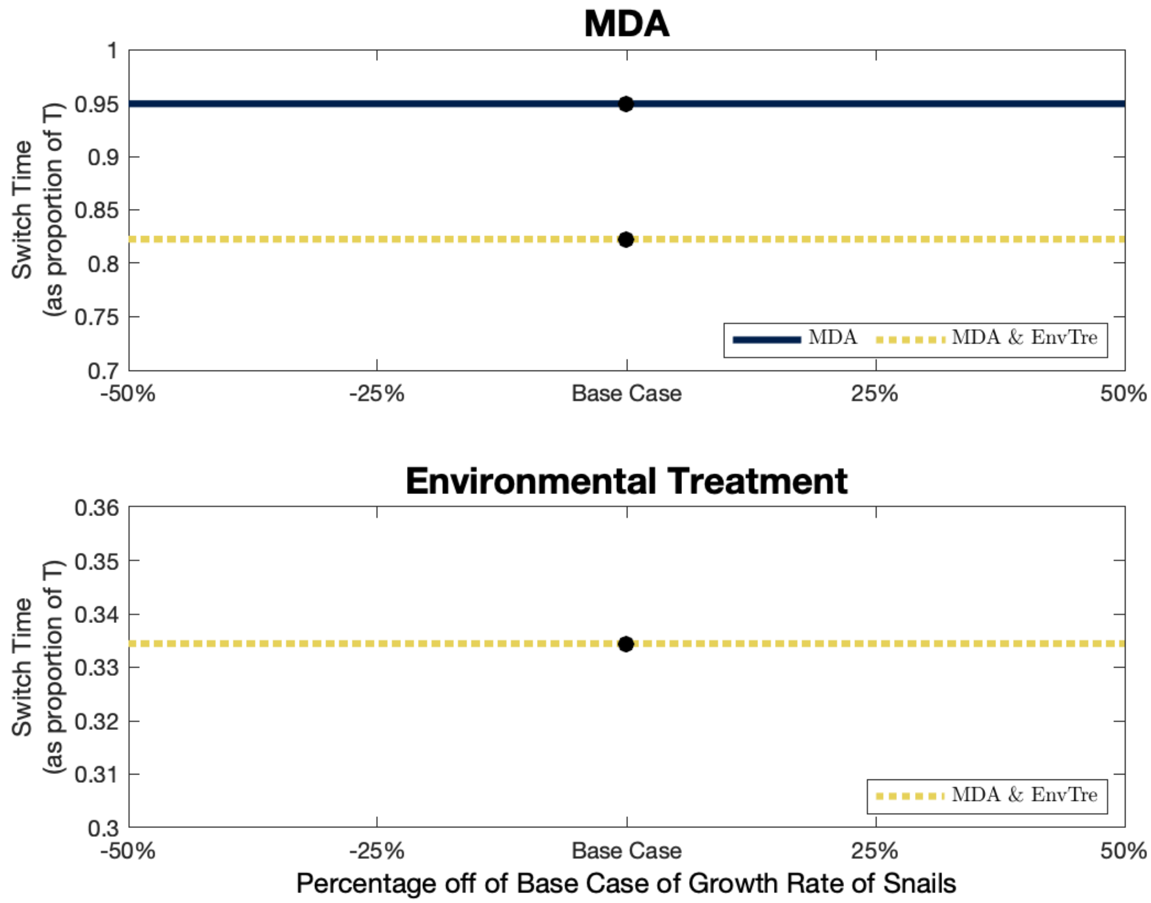

Figure S10: This figure shows the proportion of total time spent at the maximum level of MDA (i.e. $u_C = 0.9$, top panel) and the proportion of total time spent at the maximum level of EnvTre (i.e. $u_W = 1$, bottom panel) as a function of the growth rate of snails.

4.8 Time Horizon

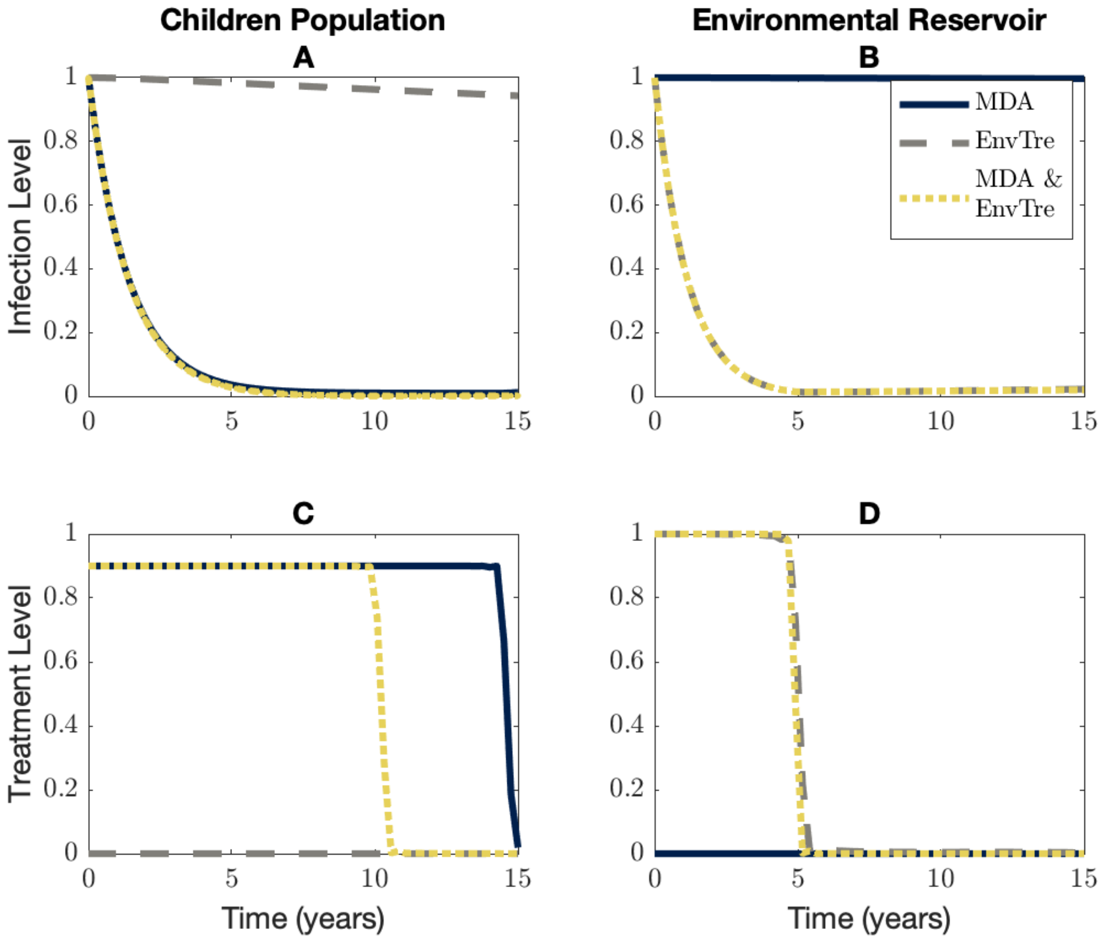

Figure S11: This figure shows the change over time of the infection prevalence in the child population (panel A), the infection prevalence in the intermediate host population (panel B), the optimal path of drug treatment (panel C) and the optimal path of environmental treatment (panel D) for when $T = 15$ years. Infection prevalence is expressed as a proportion of its respective pre-treatment, long-term, value.

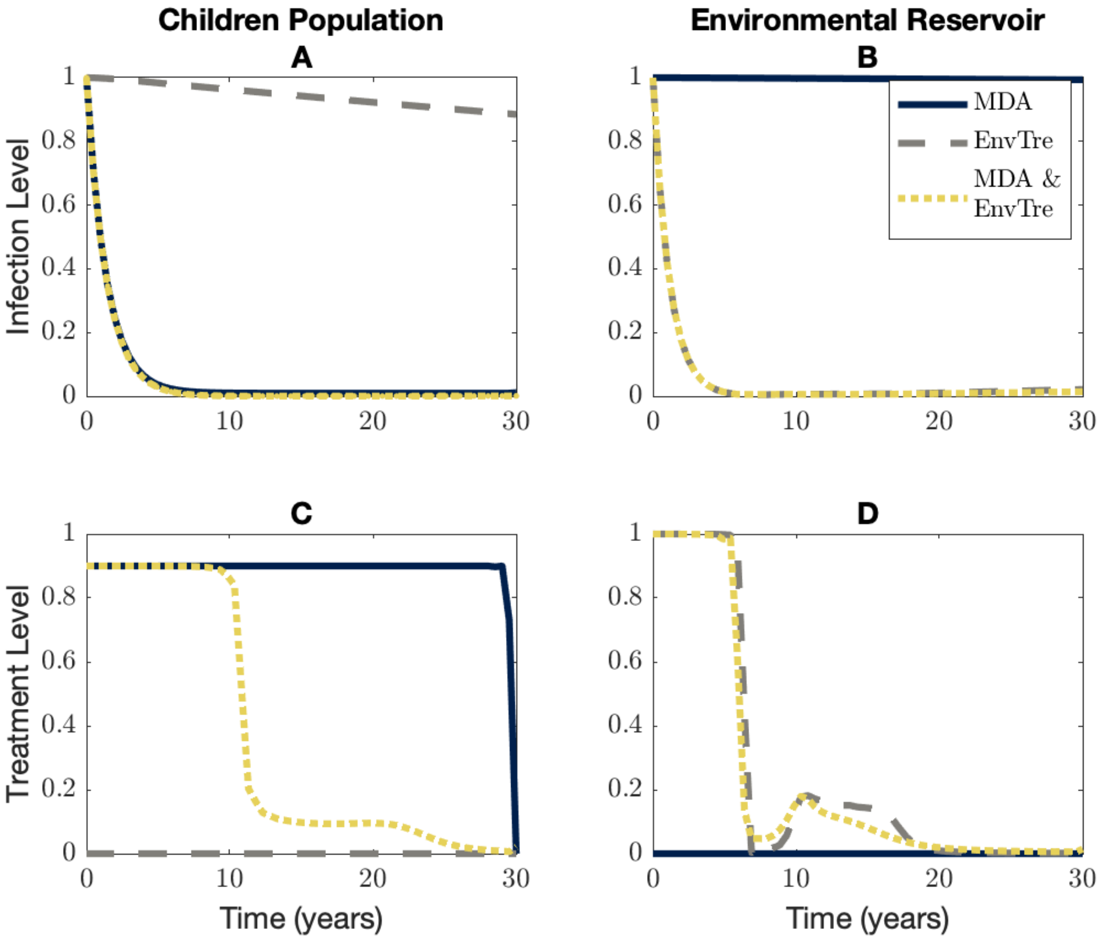

Figure S12: This figure shows the change over time of the infection prevalence in the child population (panel A), the infection prevalence in the intermediate host population (panel B), the optimal path of drug treatment (panel C) and the optimal path of environmental treatment (panel D) for when $T = 30$ years. Infection prevalence is expressed as a proportion of its respective pre-treatment, long-term, value.

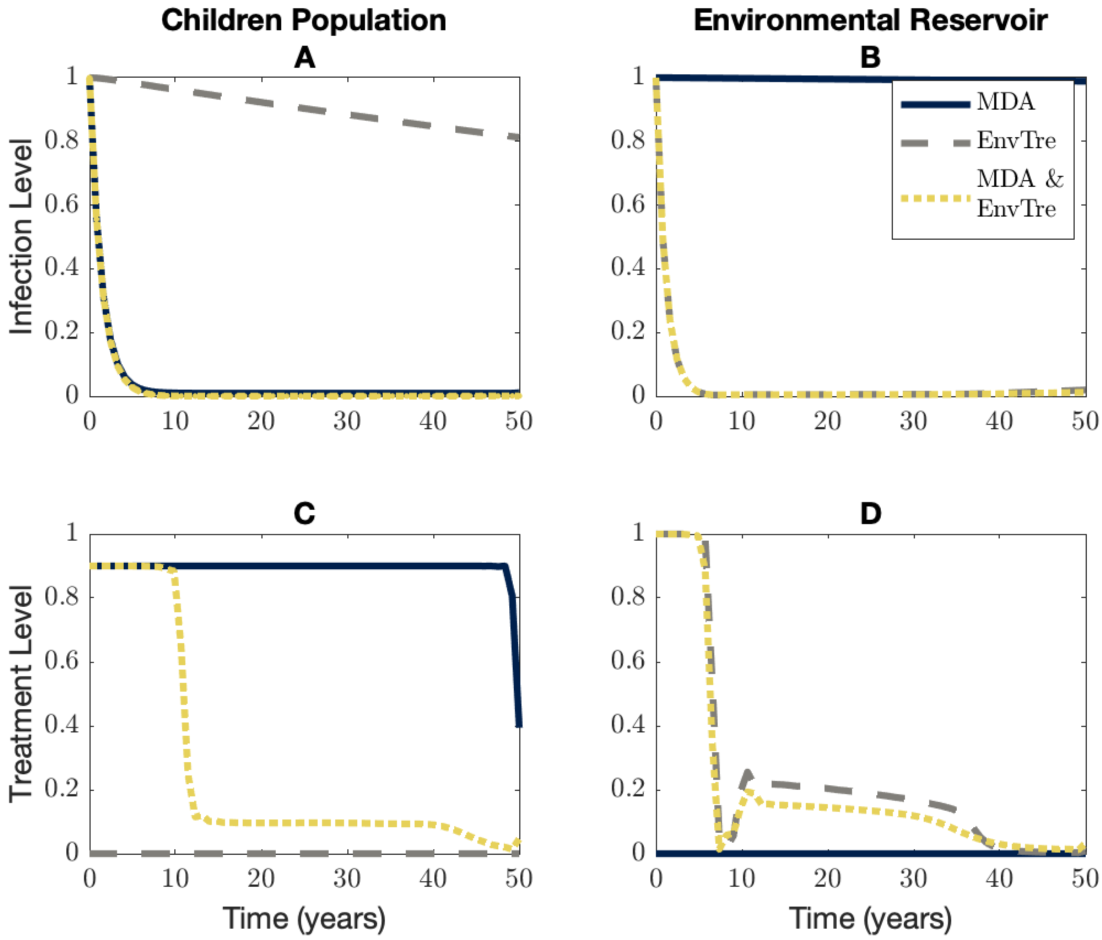

Figure S13: This figure shows the change over time of the infection prevalence in the child population (panel A), the infection prevalence in the intermediate host population (panel B), the optimal path of drug treatment (panel C) and the optimal path of environmental treatment (panel D) for when $T = 50$ years. Infection prevalence is expressed as a proportion of its respective pre-treatment, long-term, value.

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Table of Contents

Cost_Effectiveness_Main.m

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%
%
%  Cost-Effectiveness of Combining Drug and Environmental Treatments
%                  for Environmentally Transmitted Diseases
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%

% François M. Castonguay*, Susanne H. Sokolow, Giulio A. De Leo, and
 James N. Sanchirico
%
% *Corresponding author. Email: fcastonguay@ucdavis.edu
%_______________________________________________________________________________
%_______________________________________________________________________________
%_______________________________________________________________________________


% Close existing figures
```

1

```
close all;

% Calling parameter values from file "Cost_Effectiveness_Parameters.m"
% See parameter decription in SI
[betaC,betaA,lambdaC,lambdaA,gammaC,gammaA,delta,f,K,cC,cA,cPC,cPW,r,qC,qW,params,
 = Cost_Effectiveness_Parameters();

% Number of time periods
T=10; %(in years)

% Different Treatment Cases
CASE=[1; 2; 3; 4]; %1=No Controls, 2=Child MDA, 3=EnvTre, 4=Chil MDA &
 EnvTre

%Number of collocation points
Nset=60;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%
%%%%%     Solving for Steady state to find initial conditions     %%%
%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%

% Here we give 101 different initial conditions to the system to find
% different potential steady-states
SS=zeros(101,4);
i=0:0.01:1;
for k=1:length(i)

[SS(k,:)]=Cost_Effectiveness_SteadyState(i(k), i(k), i(k), 0.9,
 alphaC, alphaA, betaC, betaA, lambdaC, lambdaA, gammaC, gammaA,
 delta, f);

end
clear i k

% The system converges to only one interior equilibrium which is
 selected
% by arbitrarly choosing one of the solutions, here SS(32,:)

Initial_Conditions= [SS(32,1),SS(32,2),SS(32,3),SS(32,4)];
SS=[SS(32,1),SS(32,2),SS(32,3),SS(32,4)]';


%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%
%%%%%%%%%%%%%% If first run, one needs to use GUESS=[] %%%%%%%%%%%%%%
%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%

GUESS=[];
```

```
%Note that when GUESS=[] (i.e., when GUESS "is empty"), initial
 conditions
%are given as a guess for state variables, and a level of zero is
 given as
%a guess on control variables

% If one is using previous results as GUESS for new solving
%GUESS=Dynamics.Dynamics.Results;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%
%%%%%% Note: Need to replace "false" with "true" to get different
 results %
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%

% Note: Figure 1 did not use any Matlab

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%
%%%%%%%%%%%%   First, one needs to run baseline results   %%%%%%%%%%%
%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%

%Make sure that Baseline Results are  "true" for the first run; this
 is
% gives us the baseline swich times used in later figures.
```

Figure 2 and Table 1: Baseline Results

```
if true
  [Table1,
 Dynamics]=Cost_Effectiveness_ResultProcessing(Initial_Conditions,T,Nset,alphaC,al

  %Table 1 in the paper is given by Table1.Table.Table


   % j = number of sets of initial conditions; here we try only one,
 i.e., the steady state
    j=1;
    figure
    subplot(221)

 plot(Dynamics.Dynamics(j).Results(2).time,Dynamics.Dynamics(j).Results(2).Ic./
SS(1),'k-','color',S,'LineWidth',3); hold on

 plot(Dynamics.Dynamics(j).Results(3).time,Dynamics.Dynamics(j).Results(3).Ic./
SS(1),'k--','color',W,'LineWidth',3); hold on
```

3

```
 plot(Dynamics.Dynamics(j).Results(4).time,Dynamics.Dynamics(j).Results(4).Ic./
SS(1),'k:.','color',SW,'LineWidth',3); hold on
    title({'Children
 Population','A'},'Interpreter','tex','FontSize',16)
    ylabel({'Infection Level'},'Interpreter','tex')
    axis([0 T 0 1])
    ax = gca;
    ax.FontSize = 12;
    box(gca,'on');
    set(gca,'TickLabelInterpreter','latex')

    subplot(222)

 p1=plot(Dynamics.Dynamics(j).Results(2).time,Dynamics.Dynamics(j).Results(2).W./
SS(3),'k-','color',S,'LineWidth',3); hold on

 p2=plot(Dynamics.Dynamics(j).Results(3).time,Dynamics.Dynamics(j).Results(3).W./
SS(3),'k--','color',W,'LineWidth',3); hold on

 p3=plot(Dynamics.Dynamics(j).Results(4).time,Dynamics.Dynamics(j).Results(4).W./
SS(3),'k:','color',SW,'LineWidth',3); hold on
    title({'Environmental
 Reservoir','B'},'Interpreter','tex','FontSize',16)
    axis([0 T 0 1])
    ax = gca;
    ax.FontSize = 12;
    box(gca,'on');
    h_leg=legend([p1 p2 p3],{'MDA','EnvTre',['MDA \&'
 newline 'EnvTre']},'Interpreter','latex','Orientation','vertical');
    HeightScaleFactor = 1.5;
    NewHeight = h_leg.Position(4) * HeightScaleFactor;
    h_leg.Position(2) = h_leg.Position(2) - (NewHeight -
 h_leg.Position(4));
    h_leg.Position(4) = NewHeight;
    set(gca,'TickLabelInterpreter','latex')

    subplot(223)

 plot(Dynamics.Dynamics(j).Results(2).time,Dynamics.Dynamics(j).Results(2).uC,'k-'
 hold on

 plot(Dynamics.Dynamics(j).Results(3).time,Dynamics.Dynamics(j).Results(3).uC,'k--
 hold on

 plot(Dynamics.Dynamics(j).Results(4).time,Dynamics.Dynamics(j).Results(4).uC,'k:'
 hold on
    title('C','Interpreter','tex','FontSize',16)
    xlabel('Time (years)','Interpreter','tex')
    ylabel({'Treatment Level'},'Interpreter','tex')
    axis([0 T 0 1])
    ax = gca;
    ax.FontSize = 12;
    box(gca,'on');
```

4

```
    set(gca,'TickLabelInterpreter','latex')

    subplot(224)

 p2=plot(Dynamics.Dynamics(j).Results(2).time,Dynamics.Dynamics(j).Results(2).uW,'
 hold on %

 p4=plot(Dynamics.Dynamics(j).Results(3).time,Dynamics.Dynamics(j).Results(3).uW,'
 hold on %

 p5=plot(Dynamics.Dynamics(j).Results(4).time,Dynamics.Dynamics(j).Results(4).uW,'
 hold on %
    title('D','Interpreter','tex','FontSize',16)
    xlabel('Time (years)','Interpreter','tex')
    axis([0 T 0 1])
    ax = gca;
    ax.FontSize = 12;
    box(gca,'on');
    set(gca,'TickLabelInterpreter','latex')

    %Uncomment to save figures
    %saveas(gcf,'StatesControls2x2.png'); hold off


%Finding Baseline Switch Times
if true
SwitchSBDT=
 (Dynamics.Dynamics(j).Results(2).time(max(find(round(Dynamics.Dynamics(j).Results
T;
SwitchSBDT_withEnvTre=
 (Dynamics.Dynamics(j).Results(4).time(max(find(round(Dynamics.Dynamics(j).Results
T;
SwitchEnvTre=
 (Dynamics.Dynamics(j).Results(3).time(max(find(round(Dynamics.Dynamics(j).Results
T;
SwitchEnvTre_withSBDT=
 (Dynamics.Dynamics(j).Results(4).time(max(find(round(Dynamics.Dynamics(j).Results
T;
end



end
```

Figure 3: Effect of the EnvTre cost parameter on Switch Time

```
if false


%%%Varying cost parameter associated with EnvTre from 0 to 20,000 by
 using:
```

5

```
%11 steps: Quick peek of results (takes about 40 seconds to solve)
CPW=linspace(0,20000,11);
%%%Note that "baseline points" will not necessarily align due to
%%%interpolation error when using a small number of steps

%Figure 3 is in 101 steps
%CPW=linspace(0,20000,101);

x0ic=Initial_Conditions';

CASE=4;

SA_CPW=zeros(Nset+1,length(CPW),3);

    for i=1:length(CPW)

    params.cPW=CPW(i);
    cPW=params.cPW;

            [solution, ts, Ics, Ias, Ws, Ns, uCs, uWs, mda, EnvTre,
 NPV,damages_Children, damages_Adults, transportation, Results] = ...

 Cost_Effectiveness_ModelOptimization(T,Nset,x0ic,alphaC,alphaA,betaC,betaA,lambda

                 fitApprox = fittype('pchipinterp');
                 gMDA1=fit(ts,exp(-r.*ts).*mda,fitApprox);

                    SA_CPW(:,i,1)=uCs;
                    SA_CPW(:,i,2)=ts;
                    SA_CPW(:,i,3)=uWs;
    end

      switchPoint1=zeros(1,length(CPW));
      switchTime1=zeros(1,length(CPW));
      switchPoint2=zeros(1,length(CPW));
      switchTime2=zeros(1,length(CPW));
    for i=1:length(CPW)
             switchPoint1(i)=max(find(round(SA_CPW(:,i,1),1)==0.9));
              switchTime1(i)=SA_CPW(switchPoint1(i),i,2)

        if isempty(max(find(round(SA_CPW(:,i,3),1)==1)))==1
            switchPoint2(i)=0;
            switchTime2(i)=0;
        elseif isempty(max(find(round(SA_CPW(:,i,3),1)==1)))==0
            switchPoint2(i)=max(find(round(SA_CPW(:,i,3),1)==1));
            switchTime2(i)=SA_CPW(switchPoint2(i),i,2)
        end
    end


%%%%%%% Code for Figure  %%%%%%%%%%%
    if true
    cPWSwitch=CPW;
```

6

```
    figure
    subplot(211)
    box(gca,'on');

 p1=plot(cPWSwitch,SwitchSBDT*linspace(1,1,length(CPW)),'k-','color',S,'LineWidth'
 hold on
    p2=plot(cPWSwitch,switchTime1./T,'k:','color',SW,'LineWidth',3);
 hold on %,'color',SW
    title("Effect of WASH Cost on
 SBDT",'Interpreter','tex','FontSize',16)
    ylabel({'Switch Time'; '(as proportion of
 T)'},'Interpreter','tex')
    ax1 = gca; % current axes
    ax1.XColor = 'k';
    ax1.YColor = 'k';
    drawbrace( [2e+04 SwitchSBDT],[1.54e+04
 SwitchSBDT],15,'Color','k')% 0.9493
    text(1.67e+04,0.91, 'Same as','FontSize',12,'FontWeight','bold')
    text(1.65e+04,0.895, ' no WASH','FontSize',12,'FontWeight','bold')
    p4=plot([370 370],[SwitchSBDT_withEnvTre
 SwitchSBDT_withEnvTre],'k.','LineWidth',1,'MarkerSize',25);
    text(800,SwitchSBDT_withEnvTre, '\leftarrow Base
 Case','FontSize',12,'FontWeight','bold')
    axis([0 20000 0.8 0.96])
    legend([p1 p2],{'MDA','MDA \&
 EnvTre'},'Interpreter','latex','location','southeast','Orientation','horizontal')


   subplot(212)
    box(gca,'on');
    %set(gca,'LineWidth',2);
    p1=plot(cPWSwitch,switchTime2./T,'k:','color',SW,'LineWidth',3);
 hold on
    %p1=plot(c4Switch,switchTime2onlyWASH./
T,'k--','color',W,'LineWidth',3); hold on
    title("Effect of WASH Cost on
 WASH",'Interpreter','tex','FontSize',16)
    xlabel('EnvTre Cost Parameter','Interpreter','tex')
    ylabel({'Switch Time'; '(as proportion of
 T)'},'Interpreter','tex')
    drawbrace([1.54e+04 0], [2e+04 0],15,'Color','k')%,'LineWidth',1)
    text(1.63e+04,0.5, 'EnvTre has','FontSize',12,'FontWeight','bold')
    text(1.65e+04,0.4, 'no effect','FontSize',12,'FontWeight','bold')
    text(1.65e+04,0.3, 'on SBDT','FontSize',12,'FontWeight','bold')
    p4=plot([370 370],[SwitchEnvTre
 SwitchEnvTre],'k.','LineWidth',1,'MarkerSize',25);
    text(800,SwitchEnvTre, '\leftarrow Base
 Case','FontSize',12,'FontWeight','bold')
    axis([0 20000 0 1])
    legend([p1],{'MDA \&
 EnvTre'},'Interpreter','latex','location','northeast','Orientation','horizontal')
```

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```
  % saveas(gcf,'SAc4_2.png'); hold off
 end

end
```

Figure 4: Effect of the time horizon on MDA Switch Time

```
if false


% We vary the time horizon T from a factor of T=10 years to T=50 years
 in:

% Quick peek: 6 steps
capT=linspace(10,50,6); %Takes about 2:08 minutes to solve

%41 steps for Figure 5
%capT=linspace(10,50,41);

x0ic=Initial_Conditions';
SA_capT=zeros(Nset+1,length(capT),5);



    for i=1:length(capT)


        for CASE=4

                T=capT(i);

              [solution, ts, Ics, Ias, Ws, Ns, uCs, uWs, mda, EnvTre,
 NPV,damages_Children, damages_Adults, transportation, Results] = ...

 Cost_Effectiveness_ModelOptimization(T,Nset,x0ic,alphaC,alphaA,betaC,betaA,lambda

                    SA_capT(:,i,1)=uCs;
                    SA_capT(:,i,2)=ts;
                    SA_capT(:,i,3)=uWs;
        end
        for CASE=2

                T=capT(i);

              [solution, ts, Ics, Ias, Ws, Ns, uCs, uWs, mda, EnvTre,
 NPV,damages_Children, damages_Adults, transportation, Results] = ...

 Cost_Effectiveness_ModelOptimization(T,Nset,x0ic,alphaC,alphaA,betaC,betaA,lambda
```

```
                    SA_capT(:,i,4)=uCs;
                    SA_capT(:,i,5)=ts;
        end

    end

       switchPoint1=zeros(1,length(capT));
       switchTime=zeros(1,length(capT));
       switchPoint2=zeros(1,length(capT));
       switchTimeNoEnvTre=zeros(1,length(capT));
    for i=1:length(capT)
      switchPoint1(i)=max(find(round(SA_capT(:,i,1),1)==0.9));
      switchTime(i)=SA_capT(switchPoint1(i),i,2)

        if isempty(max(find(round(SA_capT(:,i,4),1)==0.9)))==1
            switchPoint2(i)=0;
            switchTimeNoEnvTre(i)=0;
        elseif isempty(max(find(round(SA_capT(:,i,4),1)==0.9)))==0
          switchPoint2(i)=max(find(round(SA_capT(:,i,4),1)==0.9));
       switchTimeNoEnvTre(i)=SA_capT(switchPoint2(i),i,5)
        end
    end


    %%%%%%% Code for Figure  %%%%%%%%%%%
if true

    capTSwitch=capT;

    figure
    box(gca,'on');
    p1=plot(capTSwitch,switchTime./
capTSwitch,'k:','color',SW,'LineWidth',3); hold on
    p2=plot(capTSwitch,switchTimeNoEnvTre./
capTSwitch,'k-','color',S,'LineWidth',3); hold on
    title('Effect of Time Horizon on Reduction of SBDT Switch
 Time','Interpreter','tex','FontSize',16)
    ylabel({'Switch Time'; '(as proportion of
 T)'},'Interpreter','tex')
    xlabel('Length of Planning Horizon ($T$)','Interpreter','latex')
    axis([10 50 0.1 1])
    legend([p1 p2],{'SBDT','SBDT \&
 WASH'},'Interpreter','latex','location','southeast','Orientation','horizontal');
    drawbrace( [10 SwitchSBDT],[10
 SwitchSBDT_withEnvTre],10,'Color','k')% 0.9493
    text(12,0.89, 'For Base Case (T=10) \approx 1
 year','FontSize',12,'FontWeight','bold')
    drawbrace( [50 0.1978],[50 0.9849],15,'Color','k')% 0.9493
    text(36,0.595, 'For T=50 \approx 40
 years','FontSize',12,'FontWeight','bold')
    ax = gca;
    ax.FontSize = 12;
    box(gca,'on');
    set(gca,'TickLabelInterpreter','latex')
```

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```
        set(gca,'DefaultLegendAutoUpdate','off')
    end

    end
```

Table 2: Results for when the time horizon is T=50 years

```
if false

   %Changing the time horizon to T=50 years
   T=50;

       [Table2,
 Dynamics]=Cost_Effectiveness_ResultProcessing(Initial_Conditions,T,Nset,alphaC,al

       % Table 2 in the paper is given by Table2.Table.Table

end


%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%
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%%%%%%
%%%%%%%%%%%%%%%%%%%%%%   Supplementary Information   %%%%%%%%%%%%%%%%
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%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%


%Note that Figure S1 is a flow diagram of disease transmission that
%required no Matlab
```

Figure S2: Effect of the Rnaught on Switch Time

```
if false

[betaC,betaA,lambdaC,lambdaA,gammaC,gammaA,delta,f,K,cC,cA,cPC,cPW,r,qC,qW,params,
 = Cost_Effectiveness_Parameters();
```

```
% We vary the base case Rnaught from a factor of 1/3.5 to 2 (i.e., we
 vary the Rnaught from 1 to 7) in:
    %%%6 steps: Quick peek of results (takes about 1:25 minute to
 solve)
        Rnaught=linspace(1/3.5,2,6);
    %%%101 steps: Figure 4 in paper
     %  Rnaught=linspace(1/3.5,2,101);


    %%%%%%%% For Beta %%%%%%%%%%%
if true

    clear SA_RnaughtBeta SSsa Rnot
    SA_RnaughtBeta=zeros(Nset+1,length(Rnaught),5);

    for i=1:length(Rnaught)

[betaC,betaA,lambdaC,lambdaA,gammaC,gammaA,delta,f,K,cC,cA,cPC,cPW,r,qC,qW,params,
 = Cost_Effectiveness_Parameters()

    params.betaC=betaC*Rnaught(i);
    params.betaA=betaA*Rnaught(i);
    betaC=params.betaC;
    betaA=params.betaA;


    efF= [0 0 betaC 0 ; 0 0 betaA 0; 0 0 0 0; 0 0 0 0];
    V= [-gammaC 0 0 0; 0 -gammaA 0 0; alphaC*lambdaC alphaA*lambdaA -
delta 0; 0 0 0 f];
    FV=-efF*inv(V);
    Rnot(i)=eigs(FV,1,'lr');
    SS=zeros(101,4);
    j=0:0.01:1;

        for k=1:length(j)
            [SS(k,:)]=Cost_Effectiveness_SteadyState(j(k), j(k),j(k),
 0.9, alphaC, alphaA, betaC, betaA, lambdaC, lambdaA, gammaC, gammaA,
 delta, f);
        end

    %Initial conditions
    Initial_Conditions= [SS(45,1),SS(45,2),SS(45,3),SS(45,4)];

    SSsa(:,i)=Initial_Conditions';
    x0ic=Initial_Conditions';


            for CASE=4
            [solution, ts, Ics, Ias, Ws, Ns, uCs, uWs, mda, EnvTre,
 NPV,damages_Children, damages_Adults, transportation, Results] = ...

 Cost_Effectiveness_ModelOptimization(T,Nset,x0ic,alphaC,alphaA,betaC,betaA,lambda

                    SA_RnaughtBeta(:,i,1)=uCs;
```

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```
                   SA_RnaughtBeta(:,i,2)=ts;
                   SA_RnaughtBeta(:,i,3)=uWs;


           end

           for CASE=2
            [solution, ts, Ics, Ias, Ws, Ns, uCs, uWs, mda, EnvTre,
 NPV,damages_Children, damages_Adults, transportation, Results] = ...

 Cost_Effectiveness_ModelOptimization(T,Nset,x0ic,alphaC,alphaA,betaC,betaA,lambda
                   SA_RnaughtBeta(:,i,4)=uCs;
                   SA_RnaughtBeta(:,i,5)=ts;


           end

   end

       switchPointRnaughtBeta=zeros(1,length(Rnaught));
       switchTimeRnaughtBeta=zeros(1,length(Rnaught));
       switchPointRnaughtBeta2=zeros(1,length(Rnaught));
       switchTimeRnaughtBeta2=zeros(1,length(Rnaught));
       switchPointRnaughtBetaNoEnvTre=zeros(1,length(Rnaught));
       switchTimeRnaughtBetaNoEnvTre=zeros(1,length(Rnaught));

   for i=1:length(Rnaught)

 switchPointRnaughtBeta(i)=max(find(round(SA_RnaughtBeta(:,i,1),1)==0.9));

 switchTimeRnaughtBeta(i)=SA_RnaughtBeta(switchPointRnaughtBeta(i),i,2)


 switchPointRnaughtBetaNoEnvTre(i)=max(find(round(SA_RnaughtBeta(:,i,4),1)==0.9));

 switchTimeRnaughtBetaNoEnvTre(i)=SA_RnaughtBeta(switchPointRnaughtBetaNoEnvTre(i)

       if isempty(max(find(round(SA_RnaughtBeta(:,i,3),1)==1)))==1
           switchPointRnaughtBeta2(i)=0;
           switchTimeRnaughtBeta2(i)=0;
       elseif
 isempty(max(find(round(SA_RnaughtBeta(:,i,3),1)==1)))==0

 switchPointRnaughtBeta2(i)=max(find(round(SA_RnaughtBeta(:,i,3),1)==1));

 switchTimeRnaughtBeta2(i)=SA_RnaughtBeta(switchPointRnaughtBeta2(i),i,2)
       end

   end

end

   %%%%%%%% For Lambda %%%%%%%%%%%
if true
```

```
   clear SA_RnaughtLambda SSsa Rnot
   SA_RnaughtLambda=zeros(Nset+1,length(Rnaught),5);

    for i=1:length(Rnaught)

[betaC,betaA,lambdaC,lambdaA,gammaC,gammaA,delta,f,K,cC,cA,cPC,cPW,r,qC,qW,params,
 = Cost_Effectiveness_Parameters();

    params.lambdaC=lambdaC*Rnaught(i);
    params.lambdaA=lambdaA.*Rnaught(i);
    lambdaC=params.lambdaC;
    lambdaA=params.lambdaA;

    efF= [0 0 betaC 0 ; 0 0 betaA 0; 0 0 0 0; 0 0 0 0];
    V= [-gammaC 0 0 0; 0 -gammaA 0 0; alphaC*lambdaC alphaA *lambdaA -
delta 0; 0 0 0 f];
    FV=-efF*inv(V);
    Rnot(i)=eigs(FV,1,'lr');
    SS=zeros(101,4);
    j=0:0.01:1;

        for k=1:length(j)
            [SS(k,:)]=Cost_Effectiveness_SteadyState(j(k), j(k),j(k),
 0.9, alphaC, alphaA, betaC, betaA, lambdaC, lambdaA, gammaC, gammaA,
 delta, f);
        end

    %Initial conditions
    Initial_Conditions= [SS(45,1),SS(45,2),SS(45,3),SS(45,4)];

    SSsa(:,i)=Initial_Conditions';
    x0ic=Initial_Conditions';

     for CASE=4
          [solution, ts, Ics, Ias, Ws, Ns, uCs, uWs, mda, EnvTre,
 NPV,damages_Children, damages_Adults, transportation, Results] = ...

 Cost_Effectiveness_ModelOptimization(T,Nset,x0ic,alphaC,alphaA,betaC,betaA,lambda

                   SA_RnaughtLambda(:,i,1)=uCs;
                   SA_RnaughtLambda(:,i,2)=ts;
                   SA_RnaughtLambda(:,i,3)=uWs;

     end

     for CASE=2
             [solution, ts, Ics, Ias, Ws, Ns, uCs, uWs, mda, EnvTre,
 NPV,damages_Children, damages_Adults, transportation, Results] = ...

 Cost_Effectiveness_ModelOptimization(T,Nset,x0ic,alphaC,alphaA,betaC,betaA,lambda
                   SA_RnaughtLambda(:,i,4)=uCs;
                   SA_RnaughtLambda(:,i,5)=ts;
```

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```
      end

   end
         switchPointRnaughtLambda=zeros(1,length(Rnaught));
         switchTimeRnaughtLambda=zeros(1,length(Rnaught));
         switchPointRnaughtLambda2=zeros(1,length(Rnaught));
         switchTimeRnaughtLambda2=zeros(1,length(Rnaught));
         switchPointRnaughtLambdaNoEnvTre=zeros(1,length(Rnaught));
         switchTimeRnaughtLambdaNoEnvTre=zeros(1,length(Rnaught));

     for i=1:length(Rnaught)

 switchPointRnaughtLambda(i)=max(find(round(SA_RnaughtLambda(:,i,1),1)==0.9));

 switchTimeRnaughtLambda(i)=SA_RnaughtLambda(switchPointRnaughtLambda(i),i,2)


 switchPointRnaughtLambdaNoEnvTre(i)=max(find(round(SA_RnaughtLambda(:,i,4),1)==0.

 switchTimeRnaughtLambdaNoEnvTre(i)=SA_RnaughtLambda(switchPointRnaughtLambdaNoEnv

         if isempty(max(find(round(SA_RnaughtLambda(:,i,3),1)==1)))==1
             switchPointRnaughtLambda2(i)=0;
             switchTimeRnaughtLambda2(i)=0;
         elseif
 isempty(max(find(round(SA_RnaughtLambda(:,i,3),1)==1)))==0

 switchPointRnaughtLambda2(i)=max(find(round(SA_RnaughtLambda(:,i,3),1)==1));

 switchTimeRnaughtLambda2(i)=SA_RnaughtLambda(switchPointRnaughtLambda2(i),i,2)
         end

     end
end

    %%%%%%% Code for Figure  %%%%%%%%%%%
if true

   %Common Naming the x-axis for the Figure
    RnaughtSwitch=Rnaught.*3.5;

    figure
    ax = gca;
    ax.FontSize = 12;
    box(gca,'on');
    set(gca,'TickLabelInterpreter','latex')

    subplot(311)
    p3=plot(RnaughtSwitch,switchTimeRnaughtBeta./
T,'k:','LineWidth',3','color',SW); hold on
    p2=plot(RnaughtSwitch,switchTimeRnaughtBetaNoEnvTre./
T,'k-','LineWidth',3','color',S); hold on
    title('Effect of Contact Rate on
 MDA','Interpreter','tex','FontSize',16)
```

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```
    ylabel({'Switch Time'; '(as proportion of
 T)'},'Interpreter','tex')

  %xlabel('R_O(\beta_i)','FontSize',12,'interpreter','tex','color','black');
    %text(1.7,0.86, '\leftarrow SBDT
 Only','FontSize',12,'FontWeight','bold')
    %text(1.7,0.7, '\leftarrow SBDT &
 WASH','FontSize',12,'FontWeight','bold')
    legend([p2 p3],{'MDA','MDA \&
 EnvTre'},'Interpreter','latex','location','southeast','Orientation','horizontal')



    xticks([1 2 3 3.5 4 5 6 7]);
    xticklabels({'1','2','3','Base Case','4','5','6','7'});
    p4=plot([3.5 3.5],[SwitchSBDT_withEnvTre
 SwitchSBDT_withEnvTre],'k.','LineWidth',1,'MarkerSize',25);
    p4=plot([3.5 3.5],[SwitchSBDT
 SwitchSBDT],'k.','LineWidth',1,'MarkerSize',25);
    axis([1 7 0.4 1])
    set(0,'DefaultLegendAutoUpdate','off')


    subplot(312)
    ax = gca;
    ax.FontSize = 20;
    box(gca,'on');
    set(gca,'TickLabelInterpreter','latex')
    p3=plot(Rnot,switchTimeRnaughtLambda./
T,'k:','LineWidth',3','color',SW); hold on
    p2=plot(Rnot,switchTimeRnaughtLambdaNoEnvTre./
T,'k-','LineWidth',3','color',S); hold on
    title('Effect of Shedding Rate on
 MDA','Interpreter','tex','FontSize',16)
    axis([1 7 0.4 1])
        ylabel({'Switch Time'; '(as proportion of
 T)'},'Interpreter','tex')
    p4=plot([3.5 3.5],[SwitchSBDT_withEnvTre
 SwitchSBDT_withEnvTre],'k.','LineWidth',1,'MarkerSize',25);
    p4=plot([3.5 3.5],[SwitchSBDT
 SwitchSBDT],'k.','LineWidth',1,'MarkerSize',25);
    xticks([1 2 3 3.5 4 5 6 7]);
    xticklabels({'1','2','3','Base Case','4','5','6','7'});
    %text(1.7,0.88, '\leftarrow SBDT
 Only','FontSize',12,'FontWeight','bold')
    %text(1.7,0.74, '\leftarrow SBDT &
 WASH','FontSize',12,'FontWeight','bold')
       legend([p2 p3],{'MDA','MDA \&
 EnvTre'},'Interpreter','latex','location','southeast','Orientation','horizontal')


    subplot(313)
    p5=plot(Rnot,switchTimeRnaughtBeta2./
T,'k:','LineWidth',3','color',SW); hold on
```

```
    p6=plot(Rnot,switchTimeRnaughtLambda2./
T,'k-','LineWidth',3','color',SW); hold on
    title('Effect of Contact and Shedding Rate on
 EnvTre','Interpreter','tex','FontSize',16)
     xticks([1 2 3 3.5 4 5 6 7]);
         axis([1 7 0 0.4])
             ylabel({'Switch Time'; '(as proportion of
 T)'},'Interpreter','tex')
    xticklabels({'1','2','3','Base Case','4','5','6','7'});
    p4=plot([3.5 3.5],[SwitchSBDT
 SwitchSBDT],'k.','LineWidth',1,'MarkerSize',25);
    xlabel('$R_O
$','FontSize',12,'interpreter','latex','color','black');
    %%text(1.43,0.35, 'Shedding
 \rightarrow','FontSize',12,'FontWeight','bold')
    %%text(1.57,0.22, '\leftarrow
 Contact','FontSize',12,'FontWeight','bold')
    %legend([p2 p3 p5 p6],{'SBDT','SBDT \& WASH','Varying
 Contact','Varying Shedding',},'Interpreter','latex','location',
[0.207798298888798 0.00578923146046607 0.582812493131496
 0.0485714272090367],'Orientation','horizontal');

    legend([p5 p6],{'MDA \& EnvTre: Varying Contact','MDA \& EnvTre:
 Varying
 Shedding',},'Interpreter','latex','location','southeast','Orientation','vertical'

end


 end
```

Figure S3: Varying composition of Rnaught, keeping Rnaught constant

```
if false


[betaC,betaA,lambdaC,lambdaA,gammaC,gammaA,delta,f,K,cC,cA,cPC,cPW,r,qC,qW,params,
 = Cost_Effectiveness_Parameters()

% We vary the composition of the Rnaught in:
    %6 steps: Quick peek of results (takes about 1:40 minute to solve)
       Rnaught=linspace(0.5,2,11);
    %31 steps: Figure S2 in SI
       %Rnaught=linspace(0.5,2,31); % Need to uncomment

    clear SA_Rnaught SSsa
    SA_Rnaught=zeros(Nset+1,length(Rnaught),5);


    for CASE=4
```

```
        for i=1:length(Rnaught)

 [betaC,betaA,lambdaC,lambdaA,gammaC,gammaA,delta,f,K,cC,cA,cPC,cPW,r,qC,qW,params
 = Cost_Effectiveness_Parameters()
    params.betaC=betaC*Rnaught(i);
    params.betaA=betaA*Rnaught(i);
    betaC=params.betaC;
    betaA=params.betaA;

    params.lambdaC=lambdaC*(1/Rnaught(i));
    params.lambdaA=lambdaA*(1/Rnaught(i));
    lambdaC=params.lambdaC;
    lambdaA=params.lambdaA;

    efF= [0 0 betaC 0 ; 0 0 betaA 0; 0 0 0 0; 0 0 0 0];
    V= [-gammaC 0 0 0; 0 -gammaA 0 0; alphaC*lambdaC alphaA*lambdaA -
delta 0; 0 0 0 f];
    FV=-efF*inv(V);
    Rnot(i)=eigs(FV,1,'lr');
    SS=zeros(101,4);
    j=0:0.01:1;

        for k=1:length(j)
        [SS(k,:)]=Cost_Effectiveness_SteadyState(j(k), j(k), j(k),
 0.9, alphaC, alphaA, betaC, betaA, lambdaC, lambdaA, gammaC, gammaA,
 delta, f)

        end

    %Initial conditions
    Initial_Conditions= [SS(32,1),SS(32,2),SS(32,3),SS(32,4)];

    SSsa(:,i)=Initial_Conditions';
    x0ic=Initial_Conditions';

            [solution, ts, Ics, Ias, Ws, Ns, uCs, uWs, mda, EnvTre,
 NPV,damages_Children, damages_Adults, transportation, Results] = ...

 Cost_Effectiveness_ModelOptimization(T,Nset,x0ic,alphaC,alphaA,betaC,betaA,lambda

                SA_Rnaught(:,i,1)=uCs;
                SA_Rnaught(:,i,2)=ts;
                SA_Rnaught(:,i,3)=uWs;

        end

        switchPointRnaught=zeros(1,length(Rnaught));
        switchTimeRnaught=zeros(1,length(Rnaught));
        switchPointRnaught2=zeros(1,length(Rnaught));
        switchTimeRnaught2=zeros(1,length(Rnaught));

     for i=1:length(Rnaught)
```

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```
switchPointRnaught(i)=max(find(round(SA_Rnaught(:,i,1),1)==0.9));
      switchTimeRnaught(i)=SA_Rnaught(switchPointRnaught(i),i,2);


        if isempty(max(find(round(SA_Rnaught(:,i,3),1)==1)))==1
           switchPointRnaught2(i)=0;
           switchTimeRnaught2(i)=0;
       elseif isempty(max(find(round(SA_Rnaught(:,i,3),1)==1)))==0

switchPointRnaught2(i)=max(find(round(SA_Rnaught(:,i,3),1)==1));
         switchTimeRnaught2(i)=SA_Rnaught(switchPointRnaught2(i),i,2)
        end
    end

    end
   for CASE=2

      for i=1:length(Rnaught)

[betaC,betaA,lambdaC,lambdaA,gammaC,gammaA,delta,f,K,cC,cA,cPC,cPW,r,qC,qW,params
= Cost_Effectiveness_Parameters()
   params.betaC=betaC*Rnaught(i);
   params.betaA=betaA*Rnaught(i);
   betaC=params.betaC;
   betaA=params.betaA;

   params.lambdaC=lambdaC*(1/Rnaught(i));
   params.lambdaA=lambdaA*(1/Rnaught(i));
   lambdaC=params.lambdaC;
   lambdaA=params.lambdaA;

   efF= [0 0 betaC 0 ; 0 0 betaA 0; 0 0 0 0; 0 0 0 0];
   V= [-gammaC 0 0 0; 0 -gammaA 0 0; alphaC*lambdaC alphaA*lambdaA -
delta 0; 0 0 0 f];
   FV=-efF*inv(V);
   Rnot(i)=eigs(FV,1,'lr');
   SS=zeros(101,4);
   j=0:0.01:1;

       for k=1:length(j)
       [SS(k,:)]=Cost_Effectiveness_SteadyState(j(k), j(k), j(k),
0.9, alphaC, alphaA, betaC, betaA, lambdaC, lambdaA, gammaC, gammaA,
delta, f)

       end

   %Initial conditions
   Initial_Conditions= [SS(32,1),SS(32,2),SS(32,3),SS(32,4)];

   SSsa(:,i)=Initial_Conditions';
   x0ic=Initial_Conditions';
```

```
   [solution, ts, Ics, Ias, Ws, Ns, uCs, uWs, mda, EnvTre,
NPV,damages_Children, damages_Adults, transportation, Results] = ...

Cost_Effectiveness_ModelOptimization(T,Nset,x0ic,alphaC,alphaA,betaC,betaA,lambda

                   SA_Rnaught(:,i,4)=uCs;
                   SA_Rnaught(:,i,5)=ts;
        end

       switchPointRnaught_noEnvTre=zeros(1,length(Rnaught));
       switchTimeRnaught_noEnvTre=zeros(1,length(Rnaught));
   for i=1:length(Rnaught)


switchPointRnaught_noEnvTre(i)=max(find(round(SA_Rnaught(:,i,4),1)==0.9));

switchTimeRnaught_noEnvTre(i)=SA_Rnaught(switchPointRnaught_noEnvTre(i),i,5);


   end

   end




   %%%%%%% Code for Figure  %%%%%%%%%%%
  if true

      RnaughtSwitch=Rnaught;

   figure
   %set(0,'DefaultLegendAutoUpdate','off')
   ax = gca;
   ax.FontSize = 20;
   box(gca,'on');
   set(gca,'TickLabelInterpreter','latex')
   subplot(211)
   p3=plot(RnaughtSwitch,switchTimeRnaught./
T,'k:','color',SW,'LineWidth',3); hold on
  p2=plot(RnaughtSwitch,switchTimeRnaught_noEnvTre./
T,'k-','color',S,'LineWidth',3); hold on
   title('MDA','Interpreter','tex','FontSize',16)
   ylabel({'Switch Time'; '(as proportion of
T)'},'Interpreter','tex')
   legend([p2 p3],{'MDA','MDA \&
EnvTre'},'Interpreter','latex','location','southeast','Orientation','horizontal')
   xticks([0.5 1 1.5 2]);
   xticklabels({'0.5','Base Case','1.5','2'});
   p4=plot([1 1],[SwitchSBDT_withEnvTre
SwitchSBDT_withEnvTre],'k.','LineWidth',1,'MarkerSize',25);
```

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```
    p4=plot([1 1],[SwitchSBDT
 SwitchSBDT_withEnvTre],'k.','LineWidth',1,'MarkerSize',25);
    axis([0.5 2 0.75 1])


    subplot(212)
    ax = gca;
    ax.FontSize = 20;
    box(gca,'on');
    set(gca,'TickLabelInterpreter','latex')
    p3=plot(RnaughtSwitch,switchTimeRnaught2./
T,'k:','color',SW,'LineWidth',3); hold on
    title('Environmental Treatment','Interpreter','tex','FontSize',16)
    ylabel({'Switch Time'; '(as proportion of
 T)'},'Interpreter','tex')
    p4=plot([1 1],[SwitchEnvTre_withSBDT
 SwitchEnvTre_withSBDT],'k.','LineWidth',1,'MarkerSize',25);
    xticks([0.5 1 1.5 2]);
    xticklabels({'0.5','Base Case','1.5','2'});
    axis([0.5 2 0.3 0.38])
    xlabel('Contact Rate (\beta_i) versus
 Shedding Rate (\lambda_i) Keeping R_0
 Constant','FontSize',12,'interpreter','tex','color','black');
    legend([p3],{'MDA \&
 EnvTre'},'Interpreter','latex','location','southeast','Orientation','horizontal')

    % saveas(gcf,'SARnaught.png'); hold off


   end

end
```

Figure S4: Proportion of population

```
if false

%We vary the proportion of the children in the population from 0.2 to
 0.6 in:
    %6 steps: Quick peek of results (takes about 1:10 minute to solve)
     PROP=linspace(0.2,0.6,11);

%In Figure S3, we take 21 steps:
    %PROP=linspace(0.2,0.6,21);


x0ic=Initial_Conditions';

SA_PROP=zeros(Nset+1,length(PROP),5);


for CASE=4
    for i=1:length(PROP)
```

```
                params.alphaC=PROP(i);
                alphaC=params.alphaC;
                params.alphaA=1-PROP(i);
                alphaA=params.alphaA;


                params.cC=520670.*alphaC;
                cC=params.cC;
                params.cA=520670.*alphaA;
                cA=params.cA;

                params.cPC=HumanPopulationSize.*alphaC.*.105;
                cPC=params.cPC;


                   [solution, ts, Ics, Ias, Ws, Ns, uCs, uWs, mda,
 EnvTre, NPV,damages_Children, damages_Adults, transportation,
 Results] = ...

 Cost_Effectiveness_ModelOptimization(T,Nset,x0ic,alphaC,alphaA,betaC,betaA,lambda


                    SA_PROP(:,i,1)=uCs;
                    SA_PROP(:,i,2)=ts;
                    SA_PROP(:,i,3)=uWs;
    end

        switchPoint1PROP=zeros(1,length(PROP));
        switchTime1PROP=zeros(1,length(PROP));
        switchPoint2PROP=zeros(1,length(PROP));
        switchTime2PROP=zeros(1,length(PROP));

    for i=1:length(PROP)
        switchPoint1PROP(i)=max(find(round(SA_PROP(:,i,1),2)==0.9));
        switchTime1PROP(i)=SA_PROP(switchPoint1PROP(i),i,2)

        if isempty(max(find(round(SA_PROP(:,i,3),2)==1)))==1
           switchPoint2PROP(i)=0;
           switchTime2PROP(i)=0;
        elseif isempty(max(find(round(SA_PROP(:,i,3),2)==1)))==0
           switchPoint2PROP(i)=max(find(round(SA_PROP(:,i,3),1)==1));
           switchTime2PROP(i)=SA_PROP(switchPoint2PROP(i),i,2)
        end
    end



end

for CASE=2


        for i=1:length(PROP)
```

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```
                params.alphaC=PROP(i);
                alphaC=params.alphaC;
                params.alphaA=1-PROP(i);
                alphaA=params.alphaA;

                params.cC=520670*alphaC;
                cC=params.cC;
                params.cA=520670*alphaA;
                cA=params.cA;

                params.cPC=HumanPopulationSize.*alphaC.*.105;
                cPC=params.cPC;

                   [solution, ts, Ics, Ias, Ws, Ns, uCs, uWs, mda,
 EnvTre, NPV,damages_Children, damages_Adults, transportation,
 Results] = ...

 Cost_Effectiveness_ModelOptimization(T,Nset,x0ic,alphaC,alphaA,betaC,betaA,lambda

                   SA_PROP(:,i,4)=uCs;
                   SA_PROP(:,i,5)=ts;


        end

        switchPointPROP_noEnvTre=zeros(1,length(PROP));
        switchTimePROP_noEnvTre=zeros(1,length(PROP));

    for i=1:length(PROP)


 switchPointPROP_noEnvTre(i)=max(find(round(SA_PROP(:,i,4),2)==0.9));

 switchTimePROP_noEnvTre(i)=SA_PROP(switchPointPROP_noEnvTre(i),i,5)
    end



end

    PROPSwitch=PROP;


%Code for Figure
    if true
    figure
    ax = gca;
    ax.FontSize = 20;
    box(gca,'on');
    set(gca,'TickLabelInterpreter','latex')
    subplot(211)
    p3=plot(PROPSwitch,switchTime1PROP./
T,'k:','color',SW,'LineWidth',3); hold on
```

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```
    p2=plot(PROPSwitch,switchTimePROP_noEnvTre./
T,'k-','color',S,'LineWidth',3); hold on
    title('MDA','Interpreter','tex','FontSize',16)
    ylabel({'Switch Time'; '(as proportion of
 T)'},'Interpreter','tex')
    legend([p2 p3],{'MDA','MDA \&
 EnvTre'},'Interpreter','latex','location','southeast','Orientation','horizontal')
    xticks([0.2 0.3 0.4 0.5 0.6]);
    xticklabels({'0.2','0.3','Base Case','0.5','0.6'});
    p4=plot([0.4 0.4],[SwitchSBDT_withEnvTre
 SwitchSBDT_withEnvTre],'k.','LineWidth',1,'MarkerSize',25);
    p4=plot([0.4 0.4],[SwitchSBDT
 SwitchSBDT],'k.','LineWidth',1,'MarkerSize',25);
    axis([0.2 0.6 0.72 1])


    subplot(212)
    ax = gca;
    ax.FontSize = 20;
    box(gca,'on');
    set(gca,'TickLabelInterpreter','latex')
    p3=plot(PROPSwitch,switchTime2PROP./
T,'k:','color',SW,'LineWidth',3); hold on
    title('Environmental Treatment','Interpreter','tex','FontSize',16)
    ylabel({'Switch Time'; '(as proportion of
 T)'},'Interpreter','tex')
    p4=plot([0.4 0.4],[SwitchSBDT_withEnvTre
 SwitchSBDT_withEnvTre],'k.','LineWidth',1,'MarkerSize',25);
    xticks([0.2 0.3 0.4 0.5 0.6]);
    xticklabels({'0.2','0.3','Base Case','0.5','0.6'});
    axis([0.2 0.6 0.3 0.36])
    xlabel('Proportion of Children in Total
 Population','FontSize',12,'interpreter','tex','color','black');
    legend([p3],{'MDA \&
 EnvTre'},'Interpreter','latex','location','southeast','Orientation','horizontal')

    saveas(gcf,'SAProp.png'); hold off

    end

end
```

Figure S5: Initial conditions

```
if false



% We vary the initial conditions from 0.1 to 1 of steady states in:
    %%%- 6 steps: Quick peek of results (takes about 40 seconds to
 solve)
    %Quick example to solve:
    IC=linspace(0.1,1,6);
```

```
%In Figure S4, we take 31 steps:
    %IC=linspace(0.1,1,31);




SA_IC=zeros(Nset+1,length(IC),5);


for CASE=4
    for i=1:length(IC)

        x0ic=[SS(1)*IC(i) SS(2)*IC(i) SS(3)*IC(i) SS(4)]';

                  [solution, ts, Ics, Ias, Ws, Ns, uCs, uWs, mda,
 EnvTre, NPV,damages_Children, damages_Adults, transportation,
 Results] = ...

 Cost_Effectiveness_ModelOptimization(T,Nset,x0ic,alphaC,alphaA,betaC,betaA,lambda

                    SA_IC(:,i,1)=uCs;
                    SA_IC(:,i,2)=ts;
                    SA_IC(:,i,3)=uWs;

    end
       switchPoint1IC=zeros(1,length(IC));
       switchTime1IC=zeros(1,length(IC));
       switchPoint2IC=zeros(1,length(IC));
       switchTime2IC=zeros(1,length(IC));
    for i=1:length(IC)
      switchPoint1IC(i)=max(find(round(SA_IC(:,i,1),1)==0.9));
      switchTime1IC(i)=SA_IC(switchPoint1IC(i),i,2)

        if isempty(max(find(round(SA_IC(:,i,3),1)==1)))==1
            switchPoint2IC(i)=0;
            switchTime2IC(i)=0;
        elseif isempty(max(find(round(SA_IC(:,i,3),1)==1)))==0
            switchPoint2IC(i)=max(find(round(SA_IC(:,i,3),1)==1));
            switchTime2IC(i)=SA_IC(switchPoint2IC(i),i,2)
        end
    end
end

for CASE=2
    for i=1:length(IC)

        x0ic=[SS(1)*IC(i) SS(2)*IC(i) SS(3)*IC(i) SS(4)]';

                  [solution, ts, Ics, Ias, Ws, Ns, uCs, uWs, mda,
 EnvTre, NPV,damages_Children, damages_Adults, transportation,
 Results] = ...
```

```
 Cost_Effectiveness_ModelOptimization(T,Nset,x0ic,alphaC,alphaA,betaC,betaA,lambda

                   SA_IC(:,i,4)=uCs;
                   SA_IC(:,i,5)=ts;

    end
       switchPointIC_noEnvTre=zeros(1,length(IC));
       switchTimeIC_noEnvTre=zeros(1,length(IC));
    for i=1:length(IC)
      switchPointIC_noEnvTre(i)=max(find(round(SA_IC(:,i,4),1)==0.9));
      switchTimeIC_noEnvTre(i)=SA_IC(switchPointIC_noEnvTre(i),i,5)
    end
end

    ICSwitch=IC;


    %Code for Figure
    if true

    figure
    %set(0,'DefaultLegendAutoUpdate','off')
    ax = gca;
    ax.FontSize = 20;
    box(gca,'on');
    set(gca,'TickLabelInterpreter','latex')
    subplot(211)
    p3=plot(ICSwitch,switchTime1IC./T,'k:','color',SW,'LineWidth',3);
 hold on
    p2=plot(ICSwitch,switchTimeIC_noEnvTre./
T,'k-','color',S,'LineWidth',3); hold on
    title('MDA','Interpreter','tex','FontSize',16)
    ylabel({'Switch Time'; '(as proportion of
 T)'},'Interpreter','tex')
    legend([p2 p3],{'MDA','MDA \&
 EnvTre'},'Interpreter','latex','location','southeast','Orientation','horizontal')
    xticks([0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1]);

 xticklabels({'0.1','0.2','0.3','0.4','0.5','0.6','0.7','0.8','0.9','Base
 Case'});
    p4=plot([1 1],[SwitchSBDT_withEnvTre
 SwitchSBDT_withEnvTre],'k.','LineWidth',1,'MarkerSize',25);
    p4=plot([1 1],[SwitchSBDT
 SwitchSBDT],'k.','LineWidth',1,'MarkerSize',25);

    subplot(212)
    ax = gca;
    ax.FontSize = 20;
    box(gca,'on');
    set(gca,'TickLabelInterpreter','latex')
    p3=plot(ICSwitch,switchTime2IC./T,'k:','color',SW,'LineWidth',3);
 hold on
    title('Environmental Treatment','Interpreter','tex','FontSize',16)
```

```
    ylabel({'Switch Time'; '(as proportion of
 T)'},'Interpreter','tex')
    p4=plot([1 1],[SwitchEnvTre_withSBDT
 SwitchEnvTre_withSBDT],'k.','LineWidth',1,'MarkerSize',25);
    xticks([0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1]);

 xticklabels({'0.1','0.2','0.3','0.4','0.5','0.6','0.7','0.8','0.9','Base
 Case'});
    axis([0.1 1 0.15 0.37])
    xlabel('Proportion of Steady-State
 Levels','FontSize',12,'interpreter','tex','color','black');
    legend([p3],{'MDA \&
 EnvTre'},'Interpreter','latex','location','southeast','Orientation','horizontal')


    % saveas(gcf,'SAIC.png'); hold off

    end

end
```

Figure S6: Discount rate

```
if false

    %We vary the discount rate from 0 (0%) to 0.2 (20%) in:
    %6 steps: Quick peek of results (takes about 40 seconds to solve)
        Rdiscount=linspace(0,0.2,6);

    %In Figure S5, we take 31 steps:
    %Rdiscount=linspace(0,0.2,31);



x0ic=Initial_Conditions';


SA_discount=zeros(Nset+1,length(Rdiscount),5);


for CASE=4
    for i=1:length(Rdiscount)


                params.r=Rdiscount(i);
                r=params.r;


                     [solution, ts, Ics, Ias, Ws, Ns, uCs, uWs,
 mda, EnvTre, NPV,damages_Children, damages_Adults, transportation,
 Results] = ...

 Cost_Effectiveness_ModelOptimization(T,Nset,x0ic,alphaC,alphaA,betaC,betaA,lambda
```

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```
                  SA_discount(:,i,1)=uCs;
                  SA_discount(:,i,2)=ts;
                  SA_discount(:,i,3)=uWs;

    end
       switchPoint1Discount=zeros(1,length(Rdiscount));
       switchTime1Discount=zeros(1,length(Rdiscount));
       switchPoint2Discount=zeros(1,length(Rdiscount));
       switchTime2Discount=zeros(1,length(Rdiscount));
    for i=1:length(Rdiscount)

 switchPoint1Discount(i)=max(find(round(SA_discount(:,i,1),1)==0.9));
      switchTime1Discount(i)=SA_discount(switchPoint1Discount(i),i,2)

        if isempty(max(find(round(SA_discount(:,i,3),1)==1)))==1
          switchPoint2Discount(i)=0;
          switchTime2Discount(i)=0;
        elseif isempty(max(find(round(SA_discount(:,i,3),1)==1)))==0

 switchPoint2Discount(i)=max(find(round(SA_discount(:,i,3),1)==1));

 switchTime2Discount(i)=SA_discount(switchPoint2Discount(i),i,2)
        end
    end
end

for CASE=2
    for i=1:length(Rdiscount)


               params.r=Rdiscount(i);
               r=params.r;


                    [solution, ts, Ics, Ias, Ws, Ns, uCs, uWs,
 mda, EnvTre, NPV,damages_Children, damages_Adults, transportation,
 Results] = ...

 Cost_Effectiveness_ModelOptimization(T,Nset,x0ic,alphaC,alphaA,betaC,betaA,lambda

                  SA_discount(:,i,4)=uCs;
                  SA_discount(:,i,5)=ts;

    end
       switchPointDiscount_noEnvTre=zeros(1,length(Rdiscount));
       switchTimeDiscount_noEnvTre=zeros(1,length(Rdiscount));

    for i=1:length(Rdiscount)

 switchPointDiscount_noEnvTre(i)=max(find(round(SA_discount(:,i,4),1)==0.9));

 switchTimeDiscount_noEnvTre(i)=SA_discount(switchPointDiscount_noEnvTre(i),i,5)
```

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```
    end
end

    DiscountSwitch=Rdiscount;



    %%%Code for Figure
    if true
     figure
    ax = gca;
    ax.FontSize = 20;
    box(gca,'on');
    set(gca,'TickLabelInterpreter','latex')
    subplot(211)
    p3=plot(DiscountSwitch,switchTime1Discount./
T,'k:','color',SW,'LineWidth',3); hold on
    p2=plot(DiscountSwitch,switchTimeDiscount_noEnvTre./
T,'k-','color',S,'LineWidth',3); hold on
    title('MDA','Interpreter','tex','FontSize',16)
    ylabel({'Switch Time'; '(as proportion of
 T)'},'Interpreter','tex')
    legend([p2 p3],{'MDA','MDA \&
 EnvTre'},'Interpreter','latex','location','southeast','Orientation','horizontal')
    xticks([0 0.02 0.04 0.06 0.08 0.10 0.12 0.14 0.16 0.18 0.2]);
    xticklabels({'0','0.02','Base
 Case','0.06','0.08','0.10','0.12','0.14','0.16','0.18','0.20'});
    p4=plot([0.04 0.04],[SwitchSBDT_withEnvTre
 SwitchSBDT_withEnvTre],'k.','LineWidth',1,'MarkerSize',25);
    p4=plot([0.04 0.04],[SwitchSBDT
 SwitchSBDT],'k.','LineWidth',1,'MarkerSize',25);
    axis([0 0.2 0.75 1])


    subplot(212)
    ax = gca;
    ax.FontSize = 20;
    box(gca,'on');
    set(gca,'TickLabelInterpreter','latex')
    p3=plot(DiscountSwitch,switchTime2Discount./
T,'k:','color',SW,'LineWidth',3); hold on
    title('Environmental Treatment','Interpreter','tex','FontSize',16)
    ylabel({'Switch Time'; '(as proportion of
 T)'},'Interpreter','tex')
    p4=plot([0.04 0.04],[SwitchEnvTre_withSBDT
 SwitchEnvTre_withSBDT],'k.','LineWidth',1,'MarkerSize',25);
    xticks([0 0.02 0.04 0.06 0.08 0.10 0.12 0.14 0.16 0.18 0.2]);
    xticklabels({'0','0.02','Base
 Case','0.06','0.08','0.10','0.12','0.14','0.16','0.18','0.20'});
    axis([0 0.2 0.27 0.36])
    xlabel('Discount Rate
 (r)','FontSize',12,'interpreter','tex','color','black');
    legend([p3],{'MDA \&
 EnvTre'},'Interpreter','latex','location','southeast','Orientation','horizontal')
```

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```
    %saveas(gcf,'SADiscount.png'); hold off

    end

end
```

Figure S7: Value of DALY

```
if false


 %We vary the discount rate from 1/3 to 10/3 of their value in:
    %11 steps: Quick peek of results (takes about 1:03 minute to
 solve)
    DALY=linspace((1/3),(10/3),11);

    %In Figure S6, we take 31 steps:
    %DALY=linspace((1/3),(10/3),31);



x0ic=Initial_Conditions';

SA_DALY=zeros(Nset+1,length(DALY),3);



for CASE=4

    for i=1:length(DALY)


                params.cC=520670*alphaC*DALY(i);
                cC=params.cC;
                params.cA=520670*alphaA*DALY(i);
                cA=params.cA;

[solution, ts, Ics, Ias, Ws, Ns, uCs, uWs, mda, EnvTre,
 NPV,damages_Children, damages_Adults, transportation, Results] = ...

 Cost_Effectiveness_ModelOptimization(T,Nset,x0ic,alphaC,alphaA,betaC,betaA,lambda


                    SA_DALY(:,i,1)=uCs;
                    SA_DALY(:,i,2)=ts;
                    SA_DALY(:,i,3)=uWs;


    end

        switchPoint1DALY=zeros(1,length(DALY));
```

```
        switchTime1DALY=zeros(1,length(DALY));
        switchPoint2DALY=zeros(1,length(DALY));
        switchTime2DALY=zeros(1,length(DALY));
    for i=1:length(DALY)
      switchPoint1DALY(i)=max(find(round(SA_DALY(:,i,1),1)==0.9));
      switchTime1DALY(i)=SA_DALY(switchPoint1DALY(i),i,2)

        if isempty(max(find(round(SA_DALY(:,i,3),1)==1)))==1
            switchPoint2DALY(i)=0;
            switchTime2DALY(i)=0;
        elseif isempty(max(find(round(SA_DALY(:,i,3),1)==1)))==0
          switchPoint2DALY(i)=max(find(round(SA_DALY(:,i,3),1)==1));
       switchTime2DALY(i)=SA_DALY(switchPoint2DALY(i),i,2)
        end
    end
end
for CASE=2

    for i=1:length(DALY)


                params.cC=520670*alphaC*DALY(i);
                cC=params.cC;
                params.cA=520670*alphaA*DALY(i);
                cA=params.cA;

[solution, ts, Ics, Ias, Ws, Ns, uCs, uWs, mda, EnvTre,
 NPV,damages_Children, damages_Adults, transportation, Results] = ...

 Cost_Effectiveness_ModelOptimization(T,Nset,x0ic,alphaC,alphaA,betaC,betaA,lambda


                    SA_DALY(:,i,4)=uCs;
                    SA_DALY(:,i,5)=ts;


    end

        switchPointDALY_noEnvTre=zeros(1,length(DALY));
        switchTimeDALY_noEnvTre=zeros(1,length(DALY));

    for i=1:length(DALY)

 switchPointDALY_noEnvTre(i)=max(find(round(SA_DALY(:,i,4),1)==0.9));

 switchTimeDALY_noEnvTre(i)=SA_DALY(switchPointDALY_noEnvTre(i),i,5)
    end
end

    DALYSwitch=DALY*3000;


    %Code for Figure
    if true
```

```
    figure
    ax = gca;
    ax.FontSize = 20;
    box(gca,'on');
    set(gca,'TickLabelInterpreter','latex')
    subplot(211)
    p3=plot(DALYSwitch,switchTime1DALY./
T,'k:','color',SW,'LineWidth',3); hold on
    p2=plot(DALYSwitch,switchTimeDALY_noEnvTre./
T,'k-','color',S,'LineWidth',3); hold on
    title('MDA','Interpreter','tex','FontSize',16)
    ylabel({'Switch Time'; '(as proportion of
 T)'},'Interpreter','tex')
    legend([p2 p3],{'MDA','MDA \&
 EnvTre'},'Interpreter','latex','location','southeast','Orientation','horizontal')
    xticks([1000 2000 3000 4000 5000 6000 7000 8000 9000 10000]);
    xticklabels({'1000','2000','Base
 Case','4000','5000','6000','7000','8000','9000','10000'});
    p4=plot([3000 3000],[SwitchSBDT_withEnvTre
 SwitchSBDT_withEnvTre],'k.','LineWidth',1,'MarkerSize',25);
    p4=plot([3000 3000],[SwitchSBDT
 SwitchSBDT],'k.','LineWidth',1,'MarkerSize',25);
    axis([1000 10000 0.7 1])


    subplot(212)
    ax = gca;
    ax.FontSize = 20;
    box(gca,'on');
    set(gca,'TickLabelInterpreter','latex')
    p3=plot(DALYSwitch,switchTime2DALY./
T,'k:','color',SW,'LineWidth',3); hold on
    title('Environmental Treatment','Interpreter','tex','FontSize',16)
    ylabel({'Switch Time'; '(as proportion of
 T)'},'Interpreter','tex')
    p4=plot([3000 3000],[SwitchEnvTre_withSBDT
 SwitchEnvTre_withSBDT],'k.','LineWidth',1,'MarkerSize',25);
    xticks([1000 2000 3000 4000 5000 6000 7000 8000 9000 10000]);
    xticklabels({'1000','2000','Base
 Case','4000','5000','6000','7000','8000','9000','10000'});
    axis([1000 10000 0.2 0.45])
    xlabel('VALUE of
 DALY','FontSize',12,'interpreter','tex','color','black');
    legend([p3],{'MDA \&
 EnvTre'},'Interpreter','latex','location','southeast','Orientation','horizontal')


    % saveas(gcf,'SADALY.png'); hold off

    end

end
```

Figure S8: Effectiveness of MDA controls

```
if false

 %We vary the effectiveness of MDA controls from 0.6 to 1 in:
    %6 steps: Quick peek of results (takes about 35 seconds to solve)
    EFF=linspace(0.6,1,6);

     %In Figure S7, we take 41 steps:
    %EFF=linspace(0.6,1,41);


x0ic=Initial_Conditions';

SA_EFF=zeros(Nset+1,length(EFF),5);



for CASE=4
    for i=1:length(EFF)

                params.qC=EFF(i);
                qC=params.qC;



[solution, ts, Ics, Ias, Ws, Ns, uCs, uWs, mda, EnvTre,
 NPV,damages_Children, damages_Adults, transportation, Results] = ...

 Cost_Effectiveness_ModelOptimization(T,Nset,x0ic,alphaC,alphaA,betaC,betaA,lambda


                    SA_EFF(:,i,1)=uCs;
                    SA_EFF(:,i,2)=ts;
                    SA_EFF(:,i,3)=uWs;


    end

        switchPoint1EFF=zeros(1,length(EFF));
        switchTime1EFF=zeros(1,length(EFF));
        switchPoint2EFF=zeros(1,length(EFF));
        switchTime2EFF=zeros(1,length(EFF));
    for i=1:length(EFF)
      switchPoint1EFF(i)=max(find(round(SA_EFF(:,i,1),1)==0.9));
      switchTime1EFF(i)=SA_EFF(switchPoint1EFF(i),i,2)

        if isempty(max(find(round(SA_EFF(:,i,3),1)==1)))==1
            switchPoint2EFF(i)=0;
            switchTime2EFF(i)=0;
        elseif isempty(max(find(round(SA_EFF(:,i,3),1)==1)))==0
          switchPoint2EFF(i)=max(find(round(SA_EFF(:,i,3),1)==1));
       switchTime2EFF(i)=SA_EFF(switchPoint2EFF(i),i,2)
```

```
        end
    end
end

for CASE=2
    for i=1:length(EFF)

                params.qC=EFF(i);
                qC=params.qC;



[solution, ts, Ics, Ias, Ws, Ns, uCs, uWs, mda, EnvTre,
 NPV,damages_Children, damages_Adults, transportation, Results] = ...

 Cost_Effectiveness_ModelOptimization(T,Nset,x0ic,alphaC,alphaA,betaC,betaA,lambda


                    SA_EFF(:,i,4)=uCs;
                    SA_EFF(:,i,5)=ts;


    end

        switchPointEFF_noEnvTre=zeros(1,length(EFF));
        switchTimeEFF_noEnvTre=zeros(1,length(EFF));

    for i=1:length(EFF)

 switchPointEFF_noEnvTre(i)=max(find(round(SA_EFF(:,i,4),1)==0.9));
      switchTimeEFF_noEnvTre(i)=SA_EFF(switchPointEFF_noEnvTre(i),i,5)

    end
end


    EFFSwitch=EFF;

    %Code for Figure
if true
    figure
    ax = gca;
    ax.FontSize = 20;
    box(gca,'on');
    set(gca,'TickLabelInterpreter','latex')
    subplot(211)
    p3=plot(EFFSwitch,switchTime1EFF./
T,'k:','color',SW,'LineWidth',3); hold on
    p2=plot(EFFSwitch,switchTimeEFF_noEnvTre./
T,'k-','color',S,'LineWidth',3); hold on
    title('MDA','Interpreter','tex','FontSize',16)
    ylabel({'Switch Time'; '(as proportion of
 T)'},'Interpreter','tex')
```

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```
    legend([p2 p3],{'MDA','MDA \&
 EnvTre'},'Interpreter','latex','location','southeast','Orientation','horizontal')
    xticks([0.6 0.65 0.7 0.75 0.8 0.85 0.9 0.95 1]);
    xticklabels({'0.60','0.65','0.7','0.75','Base
 Case','0.85','0.90','0.95','1'});
    p4=plot([0.8 0.8],[SwitchSBDT_withEnvTre
 SwitchSBDT_withEnvTre],'k.','LineWidth',1,'MarkerSize',25);
    p4=plot([0.8 0.8],[SwitchSBDT
 SwitchSBDT],'k.','LineWidth',1,'MarkerSize',25);
    axis([0.6 1 0.67 1])


    subplot(212)
    ax = gca;
    ax.FontSize = 20;
    box(gca,'on');
    set(gca,'TickLabelInterpreter','latex')
    p3=plot(EFFSwitch,switchTime2EFF./
T,'k:','color',SW,'LineWidth',3); hold on
    title('Environmental Treatment','Interpreter','tex','FontSize',16)
    ylabel({'Switch Time'; '(as proportion of
 T)'},'Interpreter','tex')
    p4=plot([0.8 0.8],[SwitchEnvTre_withSBDT
 SwitchEnvTre_withSBDT],'k.','LineWidth',1,'MarkerSize',25);
    xticks([0.6 0.65 0.7 0.75 0.8 0.85 0.9 0.95 1]);
    xticklabels({'0.60','0.65','0.7','0.75','Base
 Case','0.85','0.90','0.95','1'});
    axis([0.6 1 0.3 0.36])
    xlabel('Effectiveness of MDA
 Treatment','FontSize',12,'interpreter','tex','color','black');
    legend([p3],{'MDA \&
 EnvTre'},'Interpreter','latex','location','southeast','Orientation','horizontal')

    %saveas(gcf,'SAEFFmda.png'); hold off
end


end
```

Figure S9: Effectiveness of EnvTre controls

```
if false

     %We vary the effectiveness of EnvTre controls from 0.6 to 1 in:
    %6 steps: Quick peek of results (takes about 40 seconds to solve)

    EFF2=linspace(0.6,1,6);

    %In Figure S7, we take 31 steps:
    %EFF2=linspace(0.6,1,31);


x0ic=Initial_Conditions';
```

```
SA_EFF2=zeros(Nset+1,length(EFF2),5);


for CASE=4


    for i=1:length(EFF2)

                params.qW=EFF2(i);
                qW=params.qW;



[solution, ts, Ics, Ias, Ws, Ns, uCs, uWs, mda, EnvTre,
 NPV,damages_Children, damages_Adults, transportation, Results] = ...

 Cost_Effectiveness_ModelOptimization(T,Nset,x0ic,alphaC,alphaA,betaC,betaA,lambda


                    SA_EFF2(:,i,1)=uCs;
                    SA_EFF2(:,i,2)=ts;
                    SA_EFF2(:,i,3)=uWs;


    end

        switchPoint1EFF2=zeros(1,length(EFF2));
        switchTime1EFF2=zeros(1,length(EFF2));
        switchPoint2EFF2=zeros(1,length(EFF2));
        switchTime2EFF2=zeros(1,length(EFF2));
    for i=1:length(EFF2)
      switchPoint1EFF2(i)=max(find(round(SA_EFF2(:,i,1),2)>=0.9));
      switchTime1EFF2(i)=SA_EFF2(switchPoint1EFF2(i),i,2)

        if isempty(max(find(round(SA_EFF2(:,i,3),2)>=0.99)))==1
            switchPoint2EFF2(i)=0;
            switchTime2EFF2(i)=0;
        elseif isempty(max(find(round(SA_EFF2(:,i,3),2)>=0.99)))==0

 switchPoint2EFF2(i)=max(find(round(SA_EFF2(:,i,3),2)>=0.99));
       switchTime2EFF2(i)=SA_EFF2(switchPoint2EFF2(i),i,2)
        end
    end
end

for CASE=2


    for i=1:length(EFF2)

                params.qW=EFF2(i);
                qW=params.qW;
```

```
[solution, ts, Ics, Ias, Ws, Ns, uCs, uWs, mda, EnvTre,
 NPV,damages_Children, damages_Adults, transportation, Results] = ...

 Cost_Effectiveness_ModelOptimization(T,Nset,x0ic,alphaC,alphaA,betaC,betaA,lambda


                   SA_EFF2(:,i,4)=uCs;
                   SA_EFF2(:,i,5)=ts;


    end

        switchPointEFF2_noEnvTre=zeros(1,length(EFF2));
        switchTimeEFF2_noEnvTre=zeros(1,length(EFF2));


    for i=1:length(EFF2)

 switchPointEFF2_noEnvTre(i)=max(find(round(SA_EFF2(:,i,4),1)==0.9));

 switchTimeEFF2_noEnvTre(i)=SA_EFF2(switchPointEFF2_noEnvTre(i),i,5)
    end
end




    %Code for Figure
   if true

   EFF2Switch=EFF2

   figure
    ax = gca;
    ax.FontSize = 20;
    box(gca,'on');
    set(gca,'TickLabelInterpreter','latex')
    subplot(211)
    p3=plot(EFF2Switch,switchTime1EFF2./
T,'k:','color',SW,'LineWidth',3); hold on
    p2=plot(EFF2Switch,switchTimeEFF2_noEnvTre./
T,'k-','color',S,'LineWidth',3); hold on
    title('MDA','Interpreter','tex','FontSize',16)
    ylabel({'Switch Time'; '(as proportion of
 T)'},'Interpreter','tex')
    legend([p2 p3],{'MDA','MDA \&
 EnvTre'},'Interpreter','latex','location','southeast','Orientation','horizontal')
    xticks([0.6 0.65 0.7 0.75 0.8 0.88 0.95 1]);
    xticklabels({'0.60','0.65','0.70','0.75','0.80','Base
 Case','0.95','1'});
    p4=plot([0.88 0.88],[SwitchSBDT_withEnvTre
 SwitchSBDT_withEnvTre],'k.','LineWidth',1,'MarkerSize',25);
```

```
    p4=plot([0.88 0.88],[SwitchSBDT
 SwitchSBDT],'k.','LineWidth',1,'MarkerSize',25);
    axis([0.6 1 0.7 1])


    subplot(212)
    ax = gca;
    ax.FontSize = 20;
    box(gca,'on');
    set(gca,'TickLabelInterpreter','latex')
    p3=plot(EFF2Switch,switchTime2EFF2./
T,'k:','color',SW,'LineWidth',3); hold on
    title('Environmental Treatment','Interpreter','tex','FontSize',16)
    ylabel({'Switch Time'; '(as proportion of
 T)'},'Interpreter','tex')
    p4=plot([0.88 0.88],[SwitchEnvTre_withSBDT
 SwitchEnvTre_withSBDT],'k.','LineWidth',1,'MarkerSize',25);
    xticks([0.6 0.65 0.7 0.75 0.8 0.88 0.95 1]);
    xticklabels({'0.60','0.65','0.70','0.75','0.80','Base
 Case','0.95','1'});
    axis([0.6 1 0.28 0.42])
    xlabel('Effectiveness of EnvTre
 Treatment','FontSize',12,'interpreter','tex','color','black');
    legend([p3],{'MDA \&
 EnvTre'},'Interpreter','latex','location','southeast','Orientation','horizontal')

    % saveas(gcf,'SAEFFenvtre.png'); hold off

   end

end
```

Figure S10: Growth rate of snails

```
if false

[betaC,betaA,lambdaC,lambdaA,gammaC,gammaA,delta,f,K,cC,cA,cPC,cPW,r,qC,qW,params,
 = Cost_Effectiveness_Parameters()

 %We vary the growth rate from +- 50% of its baseline value in:
    %6 steps: Quick peek of results (takes about 50 seconds to solve)
        B=linspace(0.5*f,1.5*f,6);

    %In Figure S9, we take 31 steps:
       % B=linspace(0.5*f,1.5*f,31);


SA_B=zeros(Nset+1,length(B),5);

for CASE=4
    for i=1:length(B)
```

```
%
[beta1,beta2,lambda1,lambda2,gamma1,gamma2,deltaW,deltaS,b,K,c1,c2,c31,c32,c322,c
= Parameters2()


               params.f=B(i);
               f=params.f;
               SS=zeros(101,4);
               j=0:0.01:1;
               for k=1:length(j)
               [SS(k,:)]=Cost_Effectiveness_SteadyState(j(k), j(k),
j(k), 0.9, alphaC, alphaA, betaC, betaA, lambdaC, lambdaA, gammaC,
gammaA, delta, f);
               end

           %Initial conditions may change because of different growth
rate

Initial_Conditions=[mode(round(SS(:,1),2)),mode(round(SS(:,2),2)),mode(round(SS(:
           x0ic=Initial_Conditions';


       [solution, ts, Ics, Ias, Ws, Ns, uCs, uWs, mda, EnvTre,
NPV,damages_Children, damages_Adults, transportation, Results] = ...

Cost_Effectiveness_ModelOptimization(T,Nset,x0ic,alphaC,alphaA,betaC,betaA,lambda


                   SA_B(:,i,1)=uCs;
                   SA_B(:,i,2)=ts;
                   SA_B(:,i,3)=uWs;
                   Bnot(i)=f;


   end

       switchPoint1B1=zeros(1,length(B));
       switchTime1B1=zeros(1,length(B));
       switchPoint2B12=zeros(1,length(B));
       switchTime2B1=zeros(1,length(B));
   for i=1:length(B)
     switchPoint1B1(i)=max(find(round(SA_B(:,i,1),1)==0.9));
     switchTime1B1(i)=SA_B(switchPoint1B1(i),i,2)

       if isempty(max(find(round(SA_B(:,i,3),2)==1)))==1
           switchPoint2B12(i)=0;
           switchTime2B1(i)=0;
       elseif isempty(max(find(round(SA_B(:,i,3),2)==1)))==0
         switchPoint2B12(i)=max(find(round(SA_B(:,i,3),2)==1));
      switchTime2B1(i)=SA_B(switchPoint2B12(i),i,2)
       end
   end

end
```

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```
for CASE=2
    for i=1:length(B)

 %
 [beta1,beta2,lambda1,lambda2,gamma1,gamma2,deltaW,deltaS,b,K,c1,c2,c31,c32,c322,c
 = Parameters2()


                params.f=B(i);
                f=params.f;
                SS=zeros(101,4);
                j=0:0.01:1;
                for k=1:length(j)
                [SS(k,:)]=Cost_Effectiveness_SteadyState(j(k), j(k),
 j(k), 0.9, alphaC, alphaA, betaC, betaA, lambdaC, lambdaA, gammaC,
 gammaA, delta, f);
                end

            %Initial conditions

 Initial_Conditions=[mode(round(SS(:,1),2)),mode(round(SS(:,2),2)),mode(round(SS(:

             SSsa(:,i)=Initial_Conditions';
             x0ic=Initial_Conditions';


        [solution, ts, Ics, Ias, Ws, Ns, uCs, uWs, mda, EnvTre,
 NPV,damages_Children, damages_Adults, transportation, Results] = ...

 Cost_Effectiveness_ModelOptimization(T,Nset,x0ic,alphaC,alphaA,betaC,betaA,lambda


                    SA_B(:,i,4)=uCs;
                    SA_B(:,i,5)=ts;
                    Bnot(i)=f;


    end

        switchPointB_noEnvTre=zeros(1,length(B));
        switchTimeB_noEnvTre=zeros(1,length(B));
    for i=1:length(B)
      switchPointB_noEnvTre(i)=max(find(round(SA_B(:,i,4),1)==0.9));
      switchTimeB_noEnvTre(i)=SA_B(switchPointB_noEnvTre(i),i,5)
    end

end

    B1Switch=B/1.1680;

    %Code for Figure
    if true

    figure
```

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```
    set(0,'DefaultLegendAutoUpdate','off')
    ax = gca;
    ax.FontSize = 20;
    box(gca,'on');
    set(gca,'TickLabelInterpreter','latex')
    subplot(211)
    p3=plot(B1Switch,switchTime1B1./T,'k:','color',SW,'LineWidth',3);
 hold on
    p2=plot(B1Switch,switchTimeB_noEnvTre./
T,'k-','color',S,'LineWidth',3); hold on
    title('MDA','Interpreter','tex','FontSize',16)
    ylabel({'Switch Time'; '(as proportion of
 T)'},'Interpreter','tex')
    legend([p2 p3],{'MDA','MDA \&
 EnvTre'},'Interpreter','latex','location','southeast','Orientation','horizontal')
    xticks([0.5 0.75 1 1.25 1.5]);
    xticklabels({'-50%','-25%','Base Case','25%','50%'});
    p4=plot([1 1],[SwitchSBDT_withEnvTre
 SwitchSBDT_withEnvTre],'k.','LineWidth',1,'MarkerSize',25);
    p4=plot([1 1],[SwitchSBDT
 SwitchSBDT],'k.','LineWidth',1,'MarkerSize',25);
    axis([0.5 1.5 0.7 1])


    subplot(212)
    ax = gca;
    ax.FontSize = 20;
    box(gca,'on');
    set(gca,'TickLabelInterpreter','latex')
    p3=plot(B1Switch,switchTime2B1./T,'k:','color',SW,'LineWidth',3);
 hold on
    title('Environmental Treatment','Interpreter','tex','FontSize',16)
    ylabel({'Switch Time'; '(as proportion of
 T)'},'Interpreter','tex')
    p4=plot([1 1],[SwitchEnvTre_withSBDT
 SwitchEnvTre_withSBDT ],'k.','LineWidth',1,'MarkerSize',25);
    xticklabels({'-50%','-25%','Base Case','25%','50%'});
    xticks([0.5 0.75 1 1.25 1.5]);
    xlabel('Percentage off of Base Case of Growth Rate of
 Snails','FontSize',12,'interpreter','tex','color','black');
    legend([p3],{'MDA \&
 EnvTre'},'Interpreter','latex','location','southeast','Orientation','horizontal')

   %saveas(gcf,'SAgrowth.png'); hold off

    end


end
```

Figure S11: Time Horizon with T=15

```
if false
```

```
    T=15; %Takes about 12 seconds to solve

    [TableT15,
 Dynamics]=Cost_Effectiveness_ResultProcessing(Initial_Conditions,T,Nset,alphaC,al

    % j = number of sets of initial conditions; here we try only one,
 i.e., the steady state
    j=1;
    figure
    subplot(221)

 plot(Dynamics.Dynamics(j).Results(2).time,Dynamics.Dynamics(j).Results(2).Ic./
SS(1),'k-','color',S,'LineWidth',3); hold on

 plot(Dynamics.Dynamics(j).Results(3).time,Dynamics.Dynamics(j).Results(3).Ic./
SS(1),'k--','color',W,'LineWidth',3); hold on

 plot(Dynamics.Dynamics(j).Results(4).time,Dynamics.Dynamics(j).Results(4).Ic./
SS(1),'k:.','color',SW,'LineWidth',3); hold on
    title('A','Interpreter','tex','FontSize',16)
    ylabel({'Infection Level'},'Interpreter','tex')
    axis([0 T 0 1])
    ax = gca;
    ax.FontSize = 12;
    box(gca,'on');
    set(gca,'TickLabelInterpreter','latex')

    subplot(222)

 p1=plot(Dynamics.Dynamics(j).Results(2).time,Dynamics.Dynamics(j).Results(2).W./
SS(3),'k-','color',S,'LineWidth',3); hold on

 p2=plot(Dynamics.Dynamics(j).Results(3).time,Dynamics.Dynamics(j).Results(3).W./
SS(3),'k--','color',W,'LineWidth',3); hold on

 p3=plot(Dynamics.Dynamics(j).Results(4).time,Dynamics.Dynamics(j).Results(4).W./
SS(3),'k:','color',SW,'LineWidth',3); hold on
    title('B','Interpreter','tex','FontSize',16)
    axis([0 T 0 1])
    ax = gca;
    ax.FontSize = 12;
    box(gca,'on');
    h_leg=legend([p1 p2 p3],{'MDA','EnvTre',['MDA \&'
 newline 'EnvTre']},'Interpreter','latex','Orientation','vertical');
    HeightScaleFactor = 1.5;
    NewHeight = h_leg.Position(4) * HeightScaleFactor;
    h_leg.Position(2) = h_leg.Position(2) - (NewHeight -
 h_leg.Position(4));
    h_leg.Position(4) = NewHeight;
    set(gca,'TickLabelInterpreter','latex')

    subplot(223)
```

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```
    plot(Dynamics.Dynamics(j).Results(2).time,Dynamics.Dynamics(j).Results(2).uC,'k-'
    hold on

    plot(Dynamics.Dynamics(j).Results(3).time,Dynamics.Dynamics(j).Results(3).uC,'k--
    hold on

    plot(Dynamics.Dynamics(j).Results(4).time,Dynamics.Dynamics(j).Results(4).uC,'k:'
    hold on
       title('C','Interpreter','tex','FontSize',16)
       xlabel('Time (years)','Interpreter','tex')
       ylabel({'Treatment Level'},'Interpreter','tex')
       axis([0 T 0 1])
       ax = gca;
       ax.FontSize = 12;
       box(gca,'on');
       set(gca,'TickLabelInterpreter','latex')

       subplot(224)

    p2=plot(Dynamics.Dynamics(j).Results(2).time,Dynamics.Dynamics(j).Results(2).uW,'
    hold on %

    p4=plot(Dynamics.Dynamics(j).Results(3).time,Dynamics.Dynamics(j).Results(3).uW,'
    hold on %

    p5=plot(Dynamics.Dynamics(j).Results(4).time,Dynamics.Dynamics(j).Results(4).uW,'
    hold on %
       title('D','Interpreter','tex','FontSize',16)
       xlabel('Time (years)','Interpreter','tex')
       axis([0 T 0 1])
       ax = gca;
       ax.FontSize = 12;
       box(gca,'on');
       set(gca,'TickLabelInterpreter','latex')
end

%Need to change collocation point sampling method from "gauss" to
%"fem1s" in line 15 of "Cost_Effectiveness_ModelOptimization.m" to
%obtain the same figure as in the paper for Figure S11 and S12.
 Splines
% (fem1s) do a better job at approximating the solutions to long-term
 problems.
```

Figure S12: Time Horizon with T=30

```
if false

     %%%Need to change collocation point sampling method from "gauss"
 to
    %%%"fem1s" in line 15 of "Cost_Effectiveness_ModelOptimization.m"
 to
```

```
    %%%obtain the same figure as in the paper. Splines (fem1s) do a
 better
    %%%job at approximating the solutions to long-term problems.

%New Time horizon is 30 years
    T=30; %Takes about 1:45 minute to solve
%Solving a first time to get result
    GUESS=[];
    [TableT30,
 Dynamics]=Cost_Effectiveness_ResultProcessing(Initial_Conditions,T,Nset,alphaC,al
%Solving a second time with result of previous round as initial guess;
%This helps convergence to the solution for T=30
   GUESS=Dynamics.Dynamics.Results;
   [TableT30,
 Dynamics]=Cost_Effectiveness_ResultProcessing(Initial_Conditions,T,Nset,alphaC,al


    % j = number of sets of initial conditions; here we try only one,
 i.e., the steady state
    j=1;
    figure
    subplot(221)

 plot(Dynamics.Dynamics(j).Results(2).time,Dynamics.Dynamics(j).Results(2).Ic./
SS(1),'k-','color',S,'LineWidth',3); hold on

 plot(Dynamics.Dynamics(j).Results(3).time,Dynamics.Dynamics(j).Results(3).Ic./
SS(1),'k--','color',W,'LineWidth',3); hold on

 plot(Dynamics.Dynamics(j).Results(4).time,Dynamics.Dynamics(j).Results(4).Ic./
SS(1),'k:.','color',SW,'LineWidth',3); hold on
    title('A','Interpreter','tex','FontSize',16)
    ylabel({'Infection Level'},'Interpreter','tex')
    axis([0 T 0 1])
    ax = gca;
    ax.FontSize = 12;
    box(gca,'on');
    set(gca,'TickLabelInterpreter','latex')


    subplot(222)

 p1=plot(Dynamics.Dynamics(j).Results(2).time,Dynamics.Dynamics(j).Results(2).W./
SS(3),'k-','color',S,'LineWidth',3); hold on

 p2=plot(Dynamics.Dynamics(j).Results(3).time,Dynamics.Dynamics(j).Results(3).W./
SS(3),'k--','color',W,'LineWidth',3); hold on

 p3=plot(Dynamics.Dynamics(j).Results(4).time,Dynamics.Dynamics(j).Results(4).W./
SS(3),'k:','color',SW,'LineWidth',3); hold on
    title('B','Interpreter','tex','FontSize',16)
    axis([0 T 0 1])
    ax = gca;
    ax.FontSize = 12;
```

```
    box(gca,'on');
    h_leg=legend([p1 p2 p3],{'MDA','EnvTre',['MDA \&'
 newline 'EnvTre']},'Interpreter','latex','Orientation','vertical');
    HeightScaleFactor = 1.5;
    NewHeight = h_leg.Position(4) * HeightScaleFactor;
    h_leg.Position(2) = h_leg.Position(2) - (NewHeight -
 h_leg.Position(4));
    h_leg.Position(4) = NewHeight;
    set(gca,'TickLabelInterpreter','latex')

    subplot(223)

 plot(Dynamics.Dynamics(j).Results(2).time,Dynamics.Dynamics(j).Results(2).uC,'k-'
 hold on

 plot(Dynamics.Dynamics(j).Results(3).time,Dynamics.Dynamics(j).Results(3).uC,'k--
 hold on

 plot(Dynamics.Dynamics(j).Results(4).time,Dynamics.Dynamics(j).Results(4).uC,'k:'
 hold on
    title('C','Interpreter','tex','FontSize',16)
    xlabel('Time (years)','Interpreter','tex')
    ylabel({'Treatment Level'},'Interpreter','tex')
    axis([0 T 0 1])
    ax = gca;
    ax.FontSize = 12;
    box(gca,'on');
    set(gca,'TickLabelInterpreter','latex')

    subplot(224)

 p2=plot(Dynamics.Dynamics(j).Results(2).time,Dynamics.Dynamics(j).Results(2).uW,'
 hold on %

 p4=plot(Dynamics.Dynamics(j).Results(3).time,Dynamics.Dynamics(j).Results(3).uW,'
 hold on %

 p5=plot(Dynamics.Dynamics(j).Results(4).time,Dynamics.Dynamics(j).Results(4).uW,'
 hold on %
    title('D','Interpreter','tex','FontSize',16)
    xlabel('Time (years)','Interpreter','tex')
    axis([0 T 0 1])
    ax = gca;
    ax.FontSize = 12;
    box(gca,'on');
    set(gca,'TickLabelInterpreter','latex')
end
```

Figure S13: Time Horizon with T=50

```
if false
```

```
    %%%Need to change collocation point sampling method from "gauss"
 to
    %%%"fem1s" in line 15 of "Cost_Effectiveness_ModelOptimization.m"
 to
    %%%obtain the same figure as in the paper. Splines (fem1s) do a
 better
    %%%job at approximating the solutions to long-term problems.


%New Time horizon is 50 years
    T=50; %Takes about 50 seconds to solve

%Solving one first time to get result
   GUESS=[];
   % GUESS=Dynamics.Dynamics.Results;
    [TableT50,
 Dynamics]=Cost_Effectiveness_ResultProcessing(Initial_Conditions,T,Nset,alphaC,al

  % j = number of sets of initial conditions; here we try only one,
 i.e., the steady state
    j=1;
    figure
    subplot(221)

 plot(Dynamics.Dynamics(j).Results(2).time,Dynamics.Dynamics(j).Results(2).Ic./
SS(1),'k-','color',S,'LineWidth',3); hold on

 plot(Dynamics.Dynamics(j).Results(3).time,Dynamics.Dynamics(j).Results(3).Ic./
SS(1),'k--','color',W,'LineWidth',3); hold on

 plot(Dynamics.Dynamics(j).Results(4).time,Dynamics.Dynamics(j).Results(4).Ic./
SS(1),'k:.','color',SW,'LineWidth',3); hold on
    title('A','Interpreter','tex','FontSize',16)
    ylabel({'Infection Level'},'Interpreter','tex')
    axis([0 T 0 1])
    ax = gca;
    ax.FontSize = 12;
    box(gca,'on');
    set(gca,'TickLabelInterpreter','latex')


    subplot(222)

 p1=plot(Dynamics.Dynamics(j).Results(2).time,Dynamics.Dynamics(j).Results(2).W./
SS(3),'k-','color',S,'LineWidth',3); hold on

 p2=plot(Dynamics.Dynamics(j).Results(3).time,Dynamics.Dynamics(j).Results(3).W./
SS(3),'k--','color',W,'LineWidth',3); hold on

 p3=plot(Dynamics.Dynamics(j).Results(4).time,Dynamics.Dynamics(j).Results(4).W./
SS(3),'k:','color',SW,'LineWidth',3); hold on
    title('B','Interpreter','tex','FontSize',16)
    axis([0 T 0 1])
    ax = gca;
```

```
    ax.FontSize = 12;
    box(gca,'on');
    h_leg=legend([p1 p2 p3],{'MDA','EnvTre',['MDA \&'
 newline 'EnvTre']},'Interpreter','latex','Orientation','vertical');
    HeightScaleFactor = 1.5;
    NewHeight = h_leg.Position(4) * HeightScaleFactor;
    h_leg.Position(2) = h_leg.Position(2) - (NewHeight -
 h_leg.Position(4));
    h_leg.Position(4) = NewHeight;
    set(gca,'TickLabelInterpreter','latex')

    subplot(223)

 plot(Dynamics.Dynamics(j).Results(2).time,Dynamics.Dynamics(j).Results(2).uC,'k-'
 hold on

 plot(Dynamics.Dynamics(j).Results(3).time,Dynamics.Dynamics(j).Results(3).uC,'k--
 hold on

 plot(Dynamics.Dynamics(j).Results(4).time,Dynamics.Dynamics(j).Results(4).uC,'k:'
 hold on
    title('C','Interpreter','tex','FontSize',16)
    xlabel('Time (years)','Interpreter','tex')
    ylabel({'Treatment Level'},'Interpreter','tex')
    axis([0 T 0 1])
    ax = gca;
    ax.FontSize = 12;
    box(gca,'on');
    set(gca,'TickLabelInterpreter','latex')

    subplot(224)

 p2=plot(Dynamics.Dynamics(j).Results(2).time,Dynamics.Dynamics(j).Results(2).uW,'
 hold on %

 p4=plot(Dynamics.Dynamics(j).Results(3).time,Dynamics.Dynamics(j).Results(3).uW,'
 hold on %

 p5=plot(Dynamics.Dynamics(j).Results(4).time,Dynamics.Dynamics(j).Results(4).uW,'
 hold on %
    title('D','Interpreter','tex','FontSize',16)
    xlabel('Time (years)','Interpreter','tex')
    axis([0 T 0 1])
    ax = gca;
    ax.FontSize = 12;
    box(gca,'on');
    set(gca,'TickLabelInterpreter','latex')
end
```

Undefined function 'fsolve' for input arguments of type 'function_handle'.

Error in Cost_Effectiveness_SteadyState (line 4)

```
[SS]=fsolve(@sseqs,[IcSS_guess IaSS_guess Wss_guess Nss_guess],
[],alphaC, alphaA, betaC, betaA, lambdaC, lambdaA, gammaC, gammaA,
 delta, f);

Error in Cost_Effectiveness_Main (line 47)
[SS(k,:)]=Cost_Effectiveness_SteadyState(i(k), i(k), i(k), 0.9,
 alphaC, alphaA, betaC, betaA, lambdaC, lambdaA, gammaC, gammaA,
 delta, f);
```

DRAWBRACE FUNCTION

```
%To draw curly brackets on figures
function h = drawbrace(start, stop, width, varargin)
% DRAWBRACE   Draw curly brace on current figure
%    DRAWBRACE([X1, Y1], [X2, Y2]) draws a curly brace from the point
 [X1,
%    Y1] to the point [X2, Y2]
%
%    DRAWBRACE([X1,Y1], [X2,Y2], W) draws a brace using the brace
 width W.
%
%    DRAWBRACE(..., 'Param1', 'Value1', 'Param2', 'Value2') draws a
 brace
%    using the LineSeries property values specified by
 'Param1'/'Value1',
%    'Param2'/'Value2', ... .
%
%    H = DRAWBRACE(...) returns the LineSeries handle to the brace.
%
%    Example:
%       H = drawbrace([0 0], [1 1], 20, 'Color', 'k')

    % Get axis size
    pos = get(gca, 'Position');
    opos = get(gcf, 'Position');
    ylims = ylim;
    xlims = xlim;

    % Take logarithmic scale into account
    isxlog = strcmp(get(gca, 'XScale'), 'log');
    isylog = strcmp(get(gca, 'YScale'), 'log');
    if isxlog
        start(1) = log(start(1));
        stop(1) = log(stop(1));
        xlims = log(xlims);
    end
    if isylog
        start(2) = log(start(2));
        stop(2) = log(stop(2));
        ylims = log(ylims);
    end

    % Transform from axis to screen coordinates
```

```
    xscale = pos(3) * opos(3) / diff(xlims);
    yscale = pos(4) * opos(4) / diff(ylims);
    start = (start - [xlims(1) ylims(1)]) .* [xscale yscale];
    stop = (stop - [xlims(1) ylims(1)]) .* [xscale yscale];
    % Find standard width
    if nargin == 2
        width = norm(stop - start)/10;
    end

    % Find brace points
    th = atan2(stop(2)-start(2), stop(1)-start(1));
    c1 = start + width*[cos(th) sin(th)];
    c2 = 0.5*(start+stop) + 2*width*[-sin(th) cos(th)] -
 width*[cos(th) sin(th)];
    c3 = 0.5*(start+stop) + 2*width*[-sin(th) cos(th)] +
 width*[cos(th) sin(th)];
    c4 = stop - width*[cos(th) sin(th)];

    % Assemble brace coordinates
    q = linspace(0+th, pi/2+th, 50)';
    t = flipud(q);
    part1x = width*cos(t+pi/2) + c1(1);
    part1y = width*sin(t+pi/2) + c1(2);
    part2x = width*cos(q-pi/2) + c2(1);
    part2y = width*sin(q-pi/2) + c2(2);
    part3x = width*cos(q+pi) + c3(1);
    part3y = width*sin(q+pi) + c3(2);
    part4x = width*cos(t) + c4(1);
    part4y = width*sin(t) + c4(2);
    x = [part1x; part2x; part3x; part4x];
    y = [part1y; part2y; part3y; part4y];

    % Transform back to axis coordinates
    x = x / xscale + xlims(1);
    y = y / yscale + ylims(1);
    if isxlog
        x = exp(x); end
    if isylog
        y = exp(y); end

    % Plot brace
    h = line(x, y);
    for i = 1:2:numel(varargin)
        set(h, varargin{i}, varargin{i+1}); end
end
```

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Cost_Effectiveness_ModelOptimization.m

```
function [solution, ts, Ics, Ias, Ws, Ns, uCs, uWs, mda, EnvTre,
 NPV,damages_Children, damages_Adults, transportation, Results] = ...

 Cost_Effectiveness_ModelOptimization(T,Nset,x0ic,alphaC,alphaA,betaC,betaA,lambda
% State and Control Variables

    if CASE== 1
toms t;
p=tomPhase('p', t, 0, T, Nset,[],'gauss'); %'gauss' 'cheb' or 'fem1s'
 or 'fem1'
setPhase(p);
tomStates Ic Ia W N
tomControls uC uW

    else
        % for T=30 and T=50, need to replace "gauss" with "fem1s"
toms t;
p=tomPhase('p', t, 0, T, Nset,[],'gauss'); %main results with gauss
 %'gauss' 'cheb' or 'fem1s' or 'fem1'
setPhase(p);
tomStates Ic Ia W N
tomControls uC uW
    end



%Things that don't change with cases
state = [Ic; Ia; W; N];
control = [uC ; uW];
combined = [Ic ; Ia; W; N; uC ; uW];

%Terminal Conditions
cterm=final({});

% Box constraints
lower = zeros(6,1); %Nonnegativity constraints


%ODEs
ode = collocate({
    dot(Ic) == betaC.*W.*(1-Ic) - gammaC.*Ic - qC.*uC.*Ic; %I1 dot
    dot(Ia) == betaA.*W.*(1-Ia) - gammaA.*Ia ; %I2 dot
    dot(W) == (alphaC.*lambdaC.*Ic + alphaA.*lambdaA.*Ia).*(N-W) -
 delta.*W - qW.*uW.*W;% qS.*uS.*W;   %W dot
    dot(N) == f.*(1-N).*(N-W) - qW.*uW.*N });   %qS.*uS.*S });

%Constraints on Controls for different cases
if CASE==1 %%% No Controls
```

1

```
   % Box constraints
    upper = [1 ; 1; N ; 1; 0 ; 0 ];
    cbb={mcollocate(lower <= combined <= upper)
    initial(state == x0ic)};

elseif CASE==2 %%% SBDT

   % Box constraints
    upper = [1 ; 1; N; 1; .9 ; 0 ];
    cbb={mcollocate(lower <= combined <= upper)
    initial(state == x0ic)};

elseif CASE==3 %%% EnvTre

    % Box constraints
    upper = [1 ; 1; N; 1; 0 ; 1];
    cbb={mcollocate(lower <= combined <= upper)
    initial(state == x0ic)};
    %cterm=final({{}});

elseif CASE==4 %%% SBDT and EnvTre

    % Box constraints
    upper = [1 ; 1; N; 1; .9 ; 1];
    cbb={mcollocate(lower <= combined <= upper)
    initial(state == x0ic)};

end


if CASE==1
    objective = integrate(exp(-r.*t).*(cC.*Ic + cA.*Ia));
else
    objective = integrate(exp(-r.*t).*(cC.*Ic + cA.*Ia + cPC.*uC +
 cPW.*uW + F));
end


options=struct;
    if CASE==1
        options.name='No Controls';
    elseif CASE==2
        options.name='SBDT';
    elseif CASE==3
        options.name='EnvTre';
    elseif CASE==4
        options.name='SBDT & EnvTre';
    end

    options.solver = 'knitro'; % choose solver ('knitro' is other good
 one)
    options.norm = 'L2'; %Type of norm assumed for "control" vector
 (L2 is default)
```

```
    if isempty(GUESS)==1
        %Creating initial guess
    x0_guess = { icollocate({Ic == x0ic(1);
    Ia == x0ic(2);
    W==x0ic(3)
    N==x0ic(4)}) ;
    collocate(uC==0)%upper(5))%*(t<6))+0*(t>=6))
    collocate(uW==0)};%upper(7))};%*(t<3))+0*(t>=3))};

    elseif isempty(GUESS)~=1


    x0_guess = { icollocate({Ic == GUESS(CASE).Ic;
        Ia == GUESS(CASE).Ia;
        W==GUESS(CASE).W
        N==GUESS(CASE).N}) ;
        collocate(uC==GUESS(CASE).uC)
        collocate(uW==GUESS(CASE).uW)};

    end

        [solution,result]= ezsolve(objective,
 {ode,cbb,cterm},x0_guess, options);


% Changing solver if exitflag~=0
counter=0;
    while result.ExitFlag~=0 && counter<2  % limits the lopp size

        options.solver = 'npsol';
        [solution, result]= ezsolve(objective,
 {ode,cbb,cterm},x0_guess, options);

        if result.ExitFlag~=0


        options.solver = 'snopt';
        [solution, result]= ezsolve(objective,
 {ode,cbb,cterm},x0_guess, options);
        end

        if result.ExitFlag~=0

        options.solver = 'knitro';
        [solution, result]= ezsolve(objective,
 {ode,cbb,cterm},x0_guess, options);
        end

        counter=counter+1;
    end

    if result.ExitFlag==0
```

```
        Results=result;
        ts=subs(icollocate(t), solution);
        Ics=subs(icollocate(Ic), solution);
        Ias=subs(icollocate(Ia), solution);
        Ws=subs(icollocate(W), solution);
        Ns=subs(icollocate(N), solution);
        uCs=subs(icollocate(uC), solution);
        uWs=subs(icollocate(uW), solution);

    else
     Result=-999999; % did not work

    end



        damages_Children=(cC.*Ics);
        damages_Adults=(cA.*Ias);
        mda= (cPC.*uCs);
        EnvTre=(cPW.*uWs);

        if CASE==1
            transportation=0;
        else
            transportation=F;
        end


        NPV = (cC.*Ics + cA.*Ias + cPC.*uCs + cPW.*uWs  +
 transportation);




end
```

Not enough input arguments.

Error in Cost_Effectiveness_ModelOptimization (line 6)
*   if CASE== 1*

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Cost_Effectiveness_Parameters.m

```
function
 [betaC,betaA,lambdaC,lambdaA,gammaC,gammaA,delta,f,K,cC,cA,cPC,cPW,r,qC,qW,params
 = Cost_Effectiveness_Parameters()


%For interpretations and units see SI.


% 550 DALYs over 10 years w\o intervention (for high prelavance);
 3000 of GDP per capita; 550*3000=total damages in Case 0 with 38%
 infection in t=0
%To find c1 and c2
if false

    % % % % Is ok with Lo et al's estimate?
CASE=1;
x0ic=Initial_Conditions';
[beta1,beta2,lambda1,lambda2,gamma1,gamma2,deltaW,deltaS,b,K,c1,c2,c31,c32,c322,c3
 = Parameters2()

 [solution, ts, I1s, I2s, Ws, Ss, u1s, u2s, uSs, mda_Children,
 mda_Adults, mda, wash, NPV,damages_Children, damages_Adults,
 damages_Env, transportation, Results] = ...

 SchistoTomlabFixedCosts2Phase(T,T2,Nset(CASE),Nset2,x0ic,a1,a2,beta1,beta2,lambda

         xx=linspace(0,T,1000);

             f = fittype('pchipinterp');
    gChildren=fit(ts,exp(-r.*ts).*damages_Children,f);
    gAdults=fit(ts,exp(-r.*ts).*damages_Adults,f);
    gTrans=fit(ts,exp(-r.*ts).*transportation,f);

    gChildren2=fit(ts,exp(-r.*ts).*((c1+750/SS(1)).*I1s),f);
    gAdults2=fit(ts,exp(-r.*ts).*((c2+750/SS(2)).*I2s),f);

A=trapz(xx,CHSpline(T,ts,exp(-r.*ts).*damages_Children))
 + trapz(xx,CHSpline(T,ts,exp(-r.*ts).*damages_Adults)) +
 trapz(xx,CHSpline(T,ts,exp(-r.*ts).*transportation)) ;
A2= integrate(gChildren,T,0) + integrate(gAdults,T,0) +
 integrate(gTrans,T,0);
A3= integrate(gChildren2,T,0) + integrate(gAdults2,T,0) ;
B=550*3000;
C= A-B
C2= A2-B
C3= A3-B



end
```

1

```
%%%%%%%%%%%%%%%%%%%%%     Population parameters     %%%%%%%%%%%%%%%%%%
params.HumanPopulationSize=5000; %Size of the simulated population
 (from Lo et al. 2016)
params.alphaC=.4 ; %Proportion of children in the population (The
 World Factbook 2018, CIA)
params.alphaA=.6 ; %Proportion of adults in the population (The World
 Factbook 2018, CIA)

%Naming the parameters
HumanPopulationSize=params.HumanPopulationSize; alphaC=params.alphaC;
 alphaA=params.alphaA;



%%%%%%%%%%%%%%%%%%%%     Economic parameters      %%%%%%%%%%%%%%%%%%
params.r=.04; % Discount rate

% Costs: Damage Parameters
params.cC= 520670*alphaC; %Cost of infection to children (calibrated
 using Lo et al. 2016)
params.cA= 520670*alphaA; %Cost of infection to adults (calibrated
 using Lo et al. 2016)

% Costs: Treatment & Transportation Parameters
params.cPC=HumanPopulationSize.*alphaC.*.105; % Cost of child MDA
params.cPW=370;   % Cost of the environmental treatment
params.F=1500;% ; % Fixed cost of transportation

%Efficiency of controls
params.qC=.8; params.qW=0.88;

%Naming the parameters
r=params.r; cC=params.cC; cA=params.cA; cPC=params.cPC;
 cPW=params.cPW; F=params.F;
qC=params.qC; qW=params.qW;


%%%%%%%%%%%%%%%%%%%%     Biological parameters      %%%%%%%%%%%%%%%%%%
params.lambdaC=1/(1000/3)*0.4*1.5; params.lambdaA=1/
(1000/3)*0.4*1.5; %shedding rate ; per capita snail infection
 probability ; Sokolow et al. *375 (gives an R0 of 3.5)
params.betaC = 1/500*2.5; params.betaA = 1/500*2.5;  %contact rate ;
 daily infection probability from snail to man ; Sokolow et al.(2015)
params.gammaC=0.3/70 ; params.gammaA=0.3/70; %.3/70; %death rate
 of the disease in human; i.e. adult worm lifespan in human host ;
 Sokolow et al.(2015) (see worm lifespan and mean adult worm per human
 host)
params.delta=6/(10000); %death rate of the disease in the environment
 *** See Kariuki, H. Curtis, et al. "Divergent effects of Schistosoma
 haematobium exposure on intermediate-host snail species Bulinus
 nasutus and Bulinus globosus from coastal Kenya." The American
```

2

```
 journal of tropical medicine and hygiene 96.4 (2017): 850-855. for
 snail life span; see Sokolow et al. (2015) for prawn density per site
 (i.e. 250
params.K=1; % Snail Normalized Carrying Capicity
params.f=(0.16*365*200)/10000; %Snail Growth Rate; (0.16 per day*365
 days*200 m^2)/10000 (carrying capacity) (Sokolow et al. reduced
 transmission)

%Naming the parameters
lambdaC=params.lambdaC; lambdaA=params.lambdaA; betaC=params.betaC;
 betaA=params.betaA;
gammaC=params.gammaC; gammaA=params.gammaA; delta=params.delta;
 K=params.K; f=params.f;

%Color/RGB triplets to change colors in Figures
   S=[0.0000 0.1262 0.3015]; %SBDT
   W=[0.5008 0.4945 0.4727]; %EnvTre
   SW=[0.9037 0.8182 0.3507]; % SBDT & EnvTre



% Life Span given death rates
info.LifeSpan_AdultWorm1 = (1./gammaC)/70;% In years; I assume a human
 host has 70 worms (Sokolow et al.(2015))
info.LifeSpan_AdultWorm2 = (1./gammaA)/70;% In years
info.LifeSpan_Infected_Snail = (1./delta)/10000;  % In years

%Number of contacts needed for one infection
info.nbContacts1=(1/betaC);
info.nbContacts2=(1/betaA);
%Number of environmental contamination per shedding
info.nbShedding1=(1/lambdaC);
info.nbShedding2=(1/lambdaA);

% R naught
%F= [0 0 beta1 ; 0 0 beta2 ; lambda1 lambda2 0];
%V= [gamma1 0 0 ; 0 gamma2 0; 0 0 delta];
efF= [0 0 betaC 0 ; 0 0 betaA 0; 0 0 0 0; 0 0 0 0];
V= [-gammaC 0 0 0; 0 -gammaA 0 0; alphaC*lambdaC alphaA*lambdaA -delta
 0; 0 0 0 f];
FV=-efF*inv(V);
R0=eigs(FV,1,'lr');
%R0_all=eig(FV)
%clear F V FV


%%%% To Find c1 and c2:
%%%%%%%%Initial conditions on state variables
% % x0ic = [0.38; 0.38; SS(3)]; % This is what I used to find c1 and
 c2 with 550 DALYs
% % %x0ic = [0.12; 0.12; SS(3)]; % This is what I used to find c1 and
 c2 with 172 DALYs
% % % % Is ok with Lo et al's estimate?
% % CASE=1;
```

3

```
% % [solution, ts, ts_All, I1s, I1s_All, I2s, I2s_All, Ws,
 Ws_All, u1s, u2s, uWs, mda_Children, mda_Adults, mda, wash,
 NPV,NPV_All,damages_Children,damages_Children_All, damages_Adults,
 damages_Adults_All, damages_Env, damages_Env_All, Results] = ...
% %
 SchistoTomlab(T,Tinf,Nset,Nset2,x0ic,SS,a1,a2,beta1,beta2,lambda1,lambda2,gamma1,
% %
% % A=trapz(xx,CHSpline(T,ts,exp(-r.*ts).*damages_Children)) +
 trapz(xx,CHSpline(T,ts,exp(-r.*ts).*damages_Adults));
% % B=550*3000;
% % C= A-B;

end
```

```
ans =

    0.0050
```

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Cost_Effectivenes_ResultProcessing.m

```
function[Table,
 Dynamics]=Cost_Effectiveness_ResultProcessing(Initial_Conditions,T,Nset,alphaC,al


% % %Dynamic Results and Summary Table
for j=1:size(Initial_Conditions,1)

    x0ic=Initial_Conditions(j,:)';

    Table.Table(j).I1_0=x0ic(1);
    Table.Table(j).I2_0=x0ic(2);
    Table.Table(j).W_0=x0ic(3);

    Dynamics.Dynamics(j).I1_0=x0ic(1);
    Dynamics.Dynamics(j).I2_0=x0ic(2);
    Dynamics.Dynamics(j).W_0=x0ic(3);

for CASE=[1 2 3 4]


[solution, ts, Ics, Ias, Ws, Ns, uCs, uWs, mda, EnvTre,
 NPV,damages_Children, damages_Adults, transportation, Results] = ...

 Cost_Effectiveness_ModelOptimization(T,Nset,x0ic,alphaC,alphaA,betaC,betaA,lambda
    if CASE==1
        Dynamics.Dynamics(j).Results(CASE).Scenario='No Controls';
        Table.Table(j).Table(CASE).Scenario='No Controls';
        Table.Table(j).Baseline(CASE).Scenario= 'No Controls';
    end

    if CASE==2
        Dynamics.Dynamics(j).Results(CASE).Scenario='SBDT ';
        Table.Table(j).Table(CASE).Scenario='SBDT';
        Table.Table(j).Baseline(CASE).Scenario= 'SBDT';
    end

    if CASE==3
        Dynamics.Dynamics(j).Results(CASE).Scenario='EnvTre';
        Table.Table(j).Table(CASE).Scenario='EnvTre';
        Table.Table(j).Baseline(CASE).Scenario= 'EnvTre';
    end

    if CASE==4
        Dynamics.Dynamics(j).Results(CASE).Scenario='SBDT & EnvTre';
        Table.Table(j).Table(CASE).Scenario='SBDT & EnvTre';
        Table.Table(j).Baseline(CASE).Scenario= 'SBDT & EnvTre';
    end

    % % % Common between cases
```

```
    Table.Table(j).Results(CASE).Output= Results;

    %Interpolation of data
    fitApprox = fittype('pchipinterp');
    gNPV=fit(ts,exp(-r.*ts).*NPV,fitApprox);
    gChildren=fit(ts,exp(-r.*ts).*damages_Children,fitApprox);
    gAdults=fit(ts,exp(-r.*ts).*damages_Adults,fitApprox);
    gMDA=fit(ts,exp(-r.*ts).*mda,fitApprox);
    gEnvTre=fit(ts,exp(-r.*ts).*EnvTre,fitApprox);
    gTransportation=fit(ts,exp(-r.*ts).*transportation,fitApprox);

    %Baseline values
    Table.Table(j).Baseline(CASE).NPV= integrate(gNPV,T,0);
    Table.Table(j).Baseline(CASE).damages_Children=
 integrate(gChildren,T,0);
    Table.Table(j).Baseline(CASE).damages_Adults=
 integrate(gAdults,T,0);
    Table.Table(j).Baseline(CASE).damages= integrate(gChildren,T,0) +
 integrate(gAdults,T,0);
    Table.Table(j).Baseline(CASE).mda= integrate(gMDA,T,0);
    Table.Table(j).Baseline(CASE).EnvTre= integrate(gEnvTre,T,0);
    Table.Table(j).Baseline(CASE).Expenditures= integrate(gMDA,T,0)+
 integrate(gEnvTre,T,0) + integrate(gTransportation,T,0);
    Table.Table(j).Baseline(CASE).DALYs= (integrate(gChildren,T,0) +
 integrate(gAdults,T,0))/3000;

    % Normalized Values
    Table.Table(j).Table(CASE).NPV= integrate(gNPV,T,0)/
Table.Table(j).Baseline(1).NPV;
    Table.Table(j).Table(CASE).damages_Children=
 integrate(gChildren,T,0)/Table.Table(j).Baseline(1).damages_Children;
    Table.Table(j).Table(CASE).damages_Adults= integrate(gAdults,T,0)/
Table.Table(j).Baseline(1).damages_Adults;
    Table.Table(j).Table(CASE).damages= (integrate(gChildren,T,0) +
 integrate(gAdults,T,0))/Table.Table(j).Baseline(1).damages;
    Table.Table(j).Table(CASE).AvertedDALYs=
 Table.Table(j).Baseline(1).DALYs -
 Table.Table(j).Baseline(CASE).DALYs;

    if CASE==2 || CASE==4
    Table.Table(j).Table(CASE).mda_Children= integrate(gMDA,T,0)/
Table.Table(j).Baseline(2).mda;
    end

    if CASE==3 || CASE==4
    Table.Table(j).Table(CASE).EnvTre= integrate(gEnvTre,T,0)/
Table.Table(j).Baseline(3).EnvTre;
    end

    if CASE== 2 || CASE==3 || CASE==4
    Table.Table(j).Table(CASE).Expenditures=
 (integrate(gMDA,T,0)+integrate(gEnvTre,T,0)+
 integrate(gTransportation,T,0))/
Table.Table(j).Baseline(2).Expenditures;
```

```
    end

    % Dynamic Results
    Dynamics.Dynamics(j).Results(CASE).NPV=NPV;

 Dynamics.Dynamics(j).Results(CASE).Damages_Children=damages_Children;
    Dynamics.Dynamics(j).Results(CASE).Damages_Adults=damages_Adults;
    Dynamics.Dynamics(j).Results(CASE).mda=mda;
    Dynamics.Dynamics(j).Results(CASE).EnvTre=EnvTre;
    Dynamics.Dynamics(j).Results(CASE).time=ts;
    Dynamics.Dynamics(j).Results(CASE).Ic=Ics;
    Dynamics.Dynamics(j).Results(CASE).Ia=Ias;
    Dynamics.Dynamics(j).Results(CASE).W=Ws;
    Dynamics.Dynamics(j).Results(CASE).N=Ns;
    Dynamics.Dynamics(j).Results(CASE).uC=uCs;
    Dynamics.Dynamics(j).Results(CASE).uW=uWs;
    Dynamics.Dynamics(j).Results(CASE).Transportation=transportation;

end

end

end
```

```
Not enough input arguments.

Error in Cost_Effectiveness_ResultProcessing (line 7)
for j=1:size(Initial_Conditions,1)
```

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Cost_Effectiveness_SteadyState.m

```
function[SS]=Cost_Effectiveness_SteadyState(IcSS_guess, IaSS_guess,
 Wss_guess, Nss_guess, alphaC, alphaA, betaC, betaA, lambdaC, lambdaA,
 gammaC, gammaA, delta, f)

[SS]=fsolve(@sseqs,[IcSS_guess IaSS_guess Wss_guess Nss_guess],
[],alphaC, alphaA, betaC, betaA, lambdaC, lambdaA, gammaC, gammaA,
 delta, f);


    function dx=sseqs(x ,alphaC, alphaA, betaC, betaA, lambdaC,
 lambdaA, gammaC, gammaA, delta, f)
    dx = zeros(3,1);
    dx(1) = betaC.*x(3).*(1-x(1)) - gammaC.*x(1); %I1 dot
    dx(2) = betaA.*x(3).*(1-x(2)) - gammaA.*x(2); %I2 dot
    dx(3) =(alphaC.*lambdaC.*x(1) + alphaA.*lambdaA.*x(2)).*(x(4)-
x(3)) - delta.*x(3); %W dot
    dx(4) = f.*(1-x(4)).*(x(4)-x(3)) - delta.*x(4) ; % Ndot = Xdot +
 Wdot
    end

end
```

```
Not enough input arguments.

Error in Cost_Effectiveness_SteadyState (line 4)
[SS]=fsolve(@sseqs,[IcSS_guess IaSS_guess Wss_guess Nss_guess],
[],alphaC, alphaA, betaC, betaA, lambdaC, lambdaA, gammaC, gammaA,
 delta, f);
```

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