Disease eradication and the challenges of global resource mobilization

An experimental approach to understand the perception of the benefits of polio eradication

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Abstract

The global effort to eradicate polio began in 1988. The target of the effort was to eradicate the disease by the year 2000, a target which was not attained. The annual number of polio cases has been reduced from 350,000 in 1988, to 650 in 2011. Research shows that financial setbacks are the main reason why polio has not yet been eradicated. When donor countries contribute less than the needed amount to eradicate, they signal that this effort is not in their interest. Cost-benefit analysis demonstrates that the high short term costs involved in the eradication effort are outweighed by the long term benefits of not needing to vaccinate the population. So why has polio not been eradicated? Studies show that even though a country would benefit from increasing its contribution, it will not do so unless other countries do the same.

Using an experimental approach we have investigated how the level of contributions differs under two conditions: if contributions are made on behalf of one donor country or on behalf of the whole group of donor countries. We have also tested to see if information emphasizing the benefits of eradication will increase contributions. The results show a weak difference between contributions made when playing the role as the policy maker for a country compared to contributions made when playing the same role for the whole group. Information did not have an effect on the performance. The experimental group was made up of students playing the role of policy makers. The make-up of the experimental group may have affected the results of the experiment. Students may have a better understanding of long term benefits and base their decisions on different incentives than policy makers, resulting in the weak difference of treatments. However, there may also be misperceptions of long term benefits which need different corrections than written information can give.

Keywords: Polio, eradication, game theory, system dynamics, free-riding, short term, costs, long term, benefits.

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1. Introduction

The feasibility of eradicating infectious diseases has made WHO start several global eradication programs. Smallpox was eradicated in 1979 after setting the eradication goal in the 1950's (Fenner et. al., 1988). In 1988, the World Health Assembly (1988) declared that polio would be the next disease in line to be eradicated with a goal by the year 2000. Polio is a vaccine preventable eradicable infectious disease which in 1 in 200 infecteds leads to irreversible paralysis (WHO, April 2013). To coordinate the effort from external donors, the Global Polio Eradication Initiative (GPEI) was launched in 1988 as a "public-private partnership led by national governments and spearheaded by the World Health Organization (WHO), Rotary International, the US Centers for Disease Control and Prevention (CDC), and the United Nations Children's Fund (UNICEF)" (GPEI, 2014a). Since 1988, the number of annually paralytic polio cases has been reduced from 350,000 to 650 cases in 2011 (CDC 2012; GPEI 2009). Polio has been eliminated from all but 3 countries; Afghanistan, Nigeria and Pakistan (CDC, 2012). Eradication requires elimination in every country at the same time (Thompson & Tebbens, 2007). Once eradicated, polio will never reemerge and vaccination can there cease. In a long-term perspective, the investment of eradication will give a tremendous return in forms of avoided vaccination costs (Barrett, 2004).

The polio eradication goal was not met in 2000. As a consequence, a new goal of zero wild polio transmission by 2005 was set, but never met. The present goal of no wild poliovirus by the end of 2014 is also likely to unattainable (GPEI, 2013b; 2014b; WHO, 2003). Political instability and poor vaccination efficacy explains this delay in some extent, but financial shortfalls is seen to be the "primary risk" to eradication failure (Barrett, 2013). Even though there are only a few endemic countries, low vaccination rates due to funding shortage makes non-endemic countries vulnerable for outbreak because of the risk of poliovirus importation. For example, the outbreak of polio in previously polio-free African and Asian countries in 2004-2006, caused by financial shortfalls, resulted in spending $400 million to once again eliminate polio in these countries (Thompson & Tebbens, 2007). The original eradication costs set in 1988 was 1 billion dollar, but from 1988-2013, 9 billion dollars has been used on eradication efforts (GPEI, 2012; Pirio & Kaufmann, 2010).

Eradication is a high risk and costly goal, making some researchers questioning the cost-effectiveness of such policies (Arita et. al., 2006). With the doubt of eradication as a starting point, Thompson and Tebbens (2007) compared control and eradication strategies concerning polio. They found that in spite of the high cost, the long term benefits of not needing any more vaccination makes eradication worth it (Thompson & Tebbens, 2007). Findings made by Barrett (2004) states that when eradication of any infectious diseases is feasible, controlling the epidemic on a certain level is not optimal compared to eradication. The global benefit of eradication was in 2010 estimated to 40-50 billion dollars (GPEI, 2011).

Polio eradication requires international financing since development countries have insufficient budget to eliminate polio domestically (Barrett, 2013). Khan and Ehreth (2003, p. 705) argues that "From the developed countries' point of view, providing support for the polio program is not simply helping the poor and the disadvantaged, it actually represents a good economic investment". But in spite of the benefits, there have been difficulties of getting donor countries to contribute, causing financial gaps and setbacks (Thompson & Tebbens, 2007). The same behavior was found during smallpox eradication where USA was the country that benefited the most from eradication and thus should have fully financed the program in endemic countries. However, USA's contributions was modest compared to the needed costs, and the eradication effort depended on contributions from other countries as well. (Barrett 2007). Barrett (2013, p. 8) states that "Financing is a zero sum game - if one country pays less, others must pay more". But even though it may be beneficial to pay for free-riding donor countries, they are reluctant to contribute (Barrett 2013). In order to avoid free-riding, donor countries and humanitarian organization puts political pressure on governments for making them contribute their "fair share" of costs needed (Barrett, 2004). Another way to avoid free-riding is to coordinate contributions. Pirio & Kaufmann, (2010) highlights how contribution from G8 countries increased when contributions was coordinated by GPEI.

Conveying policy-makers about the importance of using money on vaccination is difficult. As Scott C. Ratzan says at a hearing before the Subcommittee on International Organizations, Human Rights, and Oversight:

> *[…] what I can say is that some of the fundamental areas that would help make a difference would be better communication--and, most particularly, this is political-level communication--to get the leadership and community-based leaders able to understand the value of the polio vaccination. And that has been a very large challenge, not only with the anti-vaccine lobby, frankly, here in the United States, but really globally, the whole idea of vaccines making a difference in the challenge are continuing to be not only for polio but for other vaccine-preventible illnesses.*
> *(United States, 2010)*

For donor countries, the incentives for contributing to vaccination programs in developing countries may be low due to a focus on the short term costs rather than the long term benefits (Tebbens & Thompson, 2009). Information for policy makers about polio eradication is either presented as a way to strengthen health care regarding other countries and thus focusing on the short term costs (Obama, 2010; Pirio & Kaufmann, 2010; USAID, 2010). Or, it is presented as a good investment regarding its own country's self-interest of not needing to use money on domestic vaccination after eradication and thus focusing on the long-term benefits (Global eradication of polio and measles, 1999; GPEI, 2011; United States, 2010).

Disease eradication is a public good game where contributing money up to a certain threshold will cause rewards for every subjects. Thresholds used in classic public good games are typically fixed (Cadsby & Maynes, 1999). Using polio eradication in a public good game creates a threshold of zero cases which is affected by the amount of contribution made. Delaying eradication by making small contributions leads to outbreaks and the threshold will be more expensive to reach than if efforts were made from the start. Using a dynamic threshold rather than a fixed allows us to investigate how people understand and manage complex systems. Laboratory studies of controlling complex systems shows that people are lacking the sense of time, focusing on the short term rather than the long term and do not understand exponential growth. The complexity of the tasks lead in many cases to either a vagabond or encystment behavior: either drifting their strategy or sticking to a few variables and ignoring others (Davies & Logie, 1993).

For this experiment, we have built a public good game with a two level factorial design where subjects either play the role as the policy maker for USA or as the policy maker for the group

of USA, United Kingdom, Germany, Japan and Canada (these two treatments are hereafter called "country A" and "group A"). Subjects are given one out of two information treatments with either a focus on eradication in the interest of health benefit for endemic countries or on self-interest benefits of eradication (these two treatments are hereafter called "other-regarding" and "self-regarding"). The task is to contribute money to vaccination in the last polio endemic countries for a 20 year period with the goal of maximizing country A's or group A's benefit for a 70 year period. In reality, these 5 countries are not the only contributors to vaccination in endemic countries, but they constitute one third of GPEI's budget, which is about the same amount of contributions given to endemic countries (GPEI, 2012; 2013a).

The purpose of the experiment is to answer three research questions: Firstly, is contributions made by subjects affected by contribution given by other countries? We hypothesize that making decisions as country A leads to lower contribution and longer time to eradicate than making decision as group A. Here, we test if and in what extent country A will choose to free-ride on others countries contribution (Barrett, 2013). Secondly, does information have an effect on performance? Jolly (2004, p. 82) states that "Better is to frame global goals in ways that maximize their benefits and minimize their costs". Policy makers take decisions based on their own self-interest rather than regarding other countries (Jolly, 2004). We hypothesize that participants given information about the benefit of eradication for their own countries (self-regarding), will have higher contribution and faster eradication than participants given information where the benefit of eradication is related to endemic countries (other-regarding). Thirdly, is the effect of information different from group A than country A? We hypothesize that country A will mainly focus on comparing their contributions to the other countries' and are therefore less affected by information than group A.

The next chapter explains the underlying model used for the experiment. Chapter 3 describes differences between the four treatments and how the experiment was conducted. Chapter 4 and 5 reveals and discuss the results. We found a weak difference between group A and country A comparing how much they were willing to increase their contribution compared to the expert recommended increase. Country A is willing to increase their contribution below 90% of group A's increase, which is quite high considering that there were 4 other countries to share the increase. Information did not have any effect on the performance. Little

differences between the treatments might be explained by that the benefits of eradication are difficult to understand even with information emphasizing it. Using students to represent policy makers' opinion may also be problematic. Lastly, the paper makes some concluding remarks and suggestions for further research.

2. Methodology

The complexity of infectious diseases makes it difficult to predict how an epidemic will behave (Nokes & Anderson, 1988). Misunderstandings like expecting the number of infections to have a 50% reduction if 50% of the population is vaccinated, reveals the need for a framework for analyzing infectious diseases (Nokes & Anderson, 1988). Mathematical models of infectious diseases have a long history of aiding decision makers from the first Kermack-McKendrick model in the 1920's which serves as the building block for modeling epidemics (Kermack & McKendrick, 1927). System Dynamics is used as a method of modelling the SIR (Susceptible-Infected-Recovered) model with vaccination. System Dynamics use stocks and flows to calculate accumulations and has been used in SIR modelling (Sterman, 2000, Thompson & Tebbens, 2008).

The dynamics of infectious disease modeling comes from the idea that the rate of infections is affected by the fraction of infected and susceptibles of the population (figure 2.1): The higher the fraction of infecteds, the higher the likelihood is for a susceptible to meet an infected and thus get infected. This reinforcing loop (contagion) depletes the stock of susceptibles. The exponential growth of infectious diseases will be decreased when there are only a little amount of susceptibles left causing an S-shaped behavior. The stock of infecteds decreases by recovery. Recovered is the accumulation of recovered infecteds and in this experiment also people who are successfully vaccinated. The following section describes the SIR model with vaccination. All costs used in the model are inflated to 2013 level using inflation calculator (Bureau of Labor Statistics, 2013).

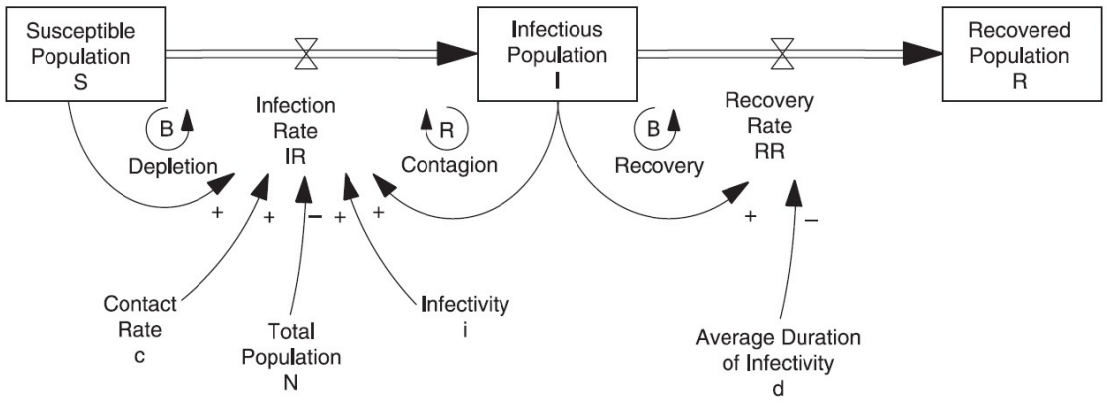

Figure 2.1 Suceptible-Infected-Recovered (SIR) model (Sterman, 2000, figure 9-5, reprinted with permission)

Modeling description

In the following part we will describe how the model is build and assumptions done to make a simple model with a realistic behavior. The model and experimental game was built using the simulation software iThink 10.0.5. We will first describe the SIR model which is much the same as in figure 2.1, we will then continue with explaining vaccination and contribution structure. All model equations are listed in appendix A.

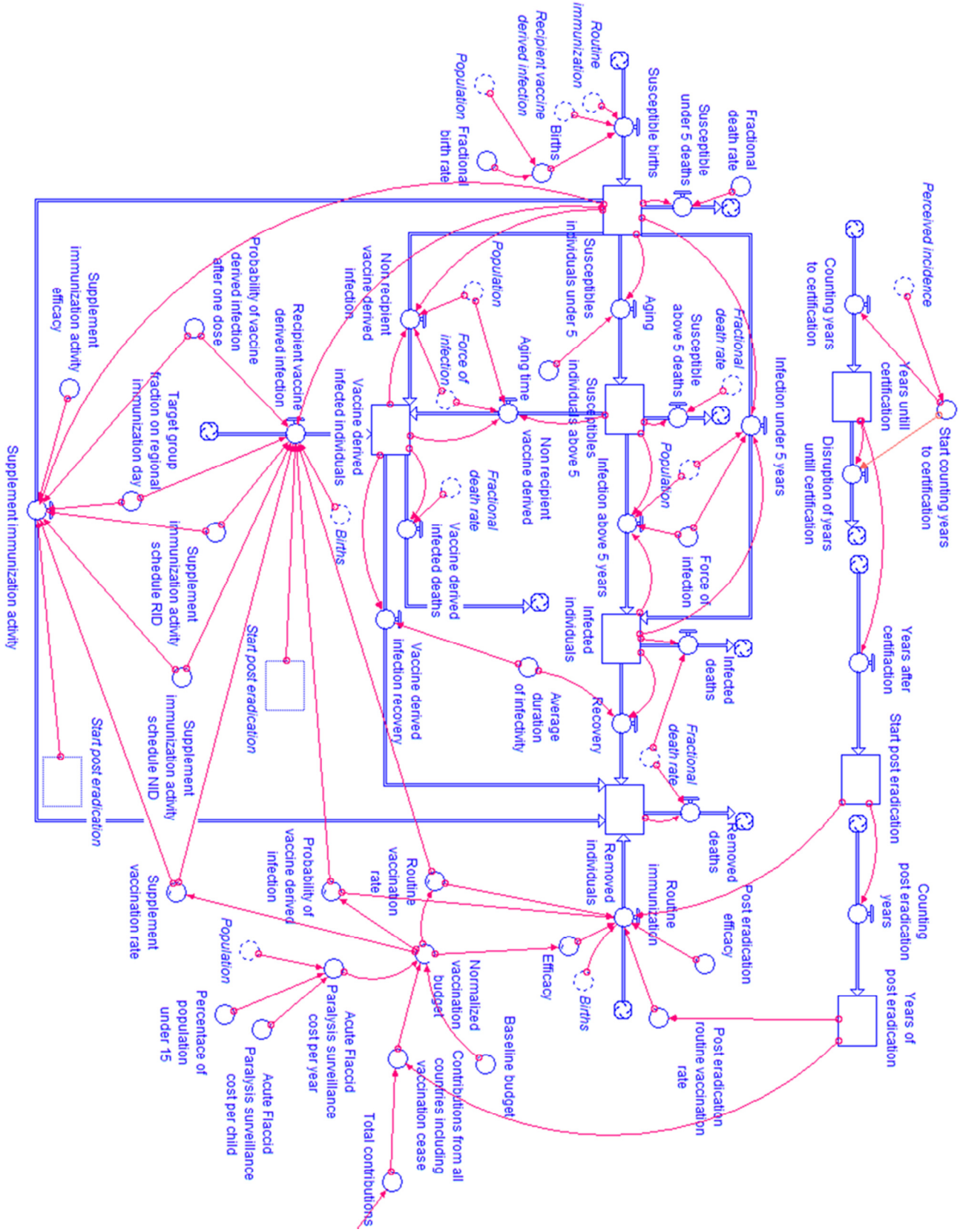

Figure 2.2 SIR model with vaccination

SIR model

The SIR model describes how susceptible people get infected and eventually recovers. Vaccination structures are explained in the next section. All population stocks decrease by multiplying the stock with the same fractional death rate of 0.02, assuming a constant population. *Susceptibles individuals under 5* are accumulated by *Susceptibles births*:

Susceptible births

=Births - Routine immunization - Recipient vaccine derived infection

Where *Births* is, assuming a constant population, *Fractional birth rate* of 0.02 multiplied with *Population*.

Aging =

Susceptibles individuals under 5 / Aging time

After an aging time of 5 years *Susceptible individuals under 5* enters *Susceptible individuals above 5*. The infection flow is the same for both susceptible stocks:

Infection under 5=

*IF Susceptible individuals under 5 * Force of infection*
** (Infected individuals / Population)*
< 1 THEN 0 ELSE
*Susceptible individuals under 5 * Force of infection*
** (Infected individuals / Population)*

The *Force of infection* is derived from the basic reproduction number (R°), *fractional death rate* and *Average duration of infectivity*. R° is a measure of how many infectious contacts an infected person has in a totally susceptible population within one year. The force of infection is an estimation of the number of infectious contacts an infected can have, in a totally susceptible population, during his infectious period. (Keeling & Rohani, 2008). Polio has an R° of 6. (Anderson & May, 1982)

Force of infection =

*R° * (fractional death rate + (1 / Average duration on infectivity)*

How many people one person can infect is decided by the number of infecteds in the population (*Infected individuals / Population*). Multiplying by the stock of susceptible assess the likelihood than an infectious contact is done with a susceptible. The equation leads to exponential decay, and thus the number of infections will never reach zero and unrealistically never eradicate since we do not have any stochastic factors in the model. In order to make eradication possible, the number of infections will go to zero if less than 1 person gets infected.

Recovery =

Infected individuals / Average duration of infectivity

Average duration of infectivity is 35 days (Tebbens et. al., 2005). *Vaccine derived infection recovery* use the same duration of infectivity.

Vaccination

There are two types of polio vaccine; the oral poliovirus vaccine (OPV) given by oral drops and the inactivated poliovirus vaccine (IPV) given by injection. The OPV consists of live attenuated poliovirus which may cause vaccine-derived poliovirus (VDPV). 1 in 200 infected with vaccine-derived poliovirus develops vaccine-associated paralytic polio (VAPP) (Wringe et. al., 2008). Because of the risk of VAPP, it is impossible to eradicate polio using OPV vaccination but since the OPV vaccine is considerably cheaper and easier to administer than IPV, it is widely used in developing countries.

There are three different polioviruses; 1, 2 and 3. IPV protects against all 3 types, but the three OPV vaccines aims at different combination of polioviruses: Trivalent (tOPV) gives immunity against all 3 polioviruses; monovalent (mOPV) gives immunity against either poliovirus 1, 2 or 3 and bOPV gives immunity against poliovirus 1 and 3 (Sutter et. al., 2010). Costs and efficacy estimations reflects using a combination of these types.

Vaccination is given by either *routine immunization* at birth or as a *supplement immunization activity* for children younger than 5 years (Tebbens et. al., 2006). *Supplement immunization activities* consists of 4 national immunization days (NID) and 4 regional immunization days (RID) (aimed at 50% of children under 5 years) per year where children get one dose of OPV. This is equivalent to recent programs for endemic countries (GPEI, 2012). In the model, only *Susceptible individuals under 5 years* participate in *Supplement immunization activity* whereas in reality, children are immunized regardless of previous infections or vaccination. The costs of *Supplement immunization activity* use therefor the total number for children under 5 years in the population as the target group.

In *routine immunization*, a child receives 3 doses at birth which is a simplification of the real vaccination program where 3 doses are given in separate doses during the child's first year. 3 doses of OPV are used as the routine vaccination policy for vaccination rate up to 80%. Above 80%, one dose of IPV and two doses of bOPV are used. Inclusion of one dose of IPV in *routine immunization* is a part of eradicating type 2 poliovirus, but the shift in vaccination policy is in reality set to a date rather than a certain vaccination rate (UNICEF Supply Division, 2013). Since bOPV protects only against poliovirus 1 and 3, hence it will not cause VAPP derived from poliovirus 2. At baseline, the *routine vaccination rate* is 68% and the *supplement immunization activity* is 80% (Tebbens et. al., 2006; World Health Organization, 2013, July). The relationship between them is fixed so that *supplement immunization rate* is 17% higher than *routine vaccination rate.*

We estimate an OPV costs of 0.13 US$2013 (Rodríguez-Álvarez et. al., 2013). The IPV cost is difficult to estimate since it is used mainly by high income countries. A global switch from OPV to IPV will most likely cause the price to decline drastically. In this model, an IPV cost of 1.3 US$2013 is used (Tebbens et. al., 2006). To give a realistic perspective of actual costs, there are several unvaccination costs to consider like equipment, personnel, training, monitoring and surveillance, transportation, cold chain, building and social mobilization. Tebbens and colleagues (2006) estimations of unvaccination costs is used with a 60% increase to reflect the real vaccination costs in Afghanistan, Pakistan and Nigeria (GPEI, 2011; GPEI, 2012), corresponding to the baseline vaccination rates. Unvaccination costs per OPV dose in routine immunization is 1.376 US$2013, for one dose OPV in supplement immunization activity it is 0.96 US$2013 and unvaccination costs per dose IPV is 2.608

US$2013. In addition we have included a wastage factor of 20% for OPV and 10% for IPV (Tebbens et. al., 2006). This generates a total supplement immunization cost per dose of 1.1095 US$2013, 3 doses OPV costs 4.596 US$2013, a combination of one dose IPV and two doses OPV costs 7.102 US$2013 and 2 doses IPV costs 8.076 US$2013.

Unvaccination costs are derived from studies of low-income countries with average vaccination coverage of three doses of OPV of 68 % (Tebbens et. al., 2006). As the vaccination coverage increases, using a fixed cost per dose may be unrealistic. Several studies have investigated the cost of scaling up vaccination rate (Barett & Hoel, 2007; Bishai et. al., 2010; Chee et al., 2007; England et. al., 2001; Johns & Baltussen, 2004; Johns & Torres, 2005; Levin et. al., 2011; Measham et. al., 2006; Walker et al., 2004). Findings from these studies conclude that the cost per dose increase concurrently with an increasing vaccination rate because of challenges of vaccinating hard-to-reach people. Levin and colleagues (2011) estimations of variations in cost per dose are used in the model: Using 60% vaccination rate as a baseline, we add an additional cost of 0.06 US$2013 per additional percent vaccination rate increase. Coverage above 80% adds 0.13 US$2013 per additional percentage increase. Assuming a baseline supplement immunization rate at 80%, 0.06 US$2013 is added per additional percentage increase above 80% and up to 100%.

Efficacy of OPV vaccination variates according to vaccine type, number of doses and environmental factors. In temperate climates the efficacy after three doses is 95% whereas in some parts of India, ten doses are required to obtain the same immunity (Grassly, 2007). One dose tOPV in low income country has an efficacy of 45% (Tebbens et. al., 2005) However in endemic countries, efficacy is much lower (Grassly et. al., 2006; Mangal et. al., 2014; O'Reilly et al., 2012). Estimated efficacy is based on literature above reflecting different OPV vaccine types against different poliovirus with the following rates: per dose OPV efficacy at 30% and OPV efficacy after three doses at 60%. It is unknown what the effect of combining bOPV and IPV is in developing countries with low OPV efficacy, although it will for sure increase the efficacy (Jehan et. al., 2013). The combination of one dose IPV and 2 doses bOPV is in the model estimated to be 80%. Two doses of IPV has an efficacy of 90% (Bonnet & Dutta, 2008)

The risk of getting VAPP is 1 in 4.1 million doses OPV (Kohler et. al., 2002). Similar to the wild poliovirus, the vaccine associated poliovirus will only cause VAPP in 1 in 200 infecteds (Wringe et. al., 2008). Estívariz and colleagues (2007) states that the force of infection of vaccine derived infecteds is the same as for wild poliovvirus, investigating an outbreak in Indonesia. However, Kim and colleagues (2007) shows that there are 7 VAPP cases per million birth cohorts in India, a country more comparable to polio endemic countires conserdering environmental factors. Using the same ratio of paralytic polio cases per people with poliovirus (1/200) and same force of infection for persons with VDPV as wild poliovirus in the model, gave much more than 7 VAPP cases per million birth cohort with baseline vacciantion rates. The force of infection for vaccine derived poliovirus is therefor reduced to 88% of the wild poliovirus force of infections, which gives approximatley the same rate of VAPP incidence as in Kim and collegues research (2007).

In addition to vaccination costs, there is acute flaccid paralysis (AFP) surveillance for detecting poliovirus. Surveillance is crucial for identifying the real number of paralytic polio cases and is necessary to use in order to reach certification. The AFP surveillance is an annually cost per child under 15 years of 0.09 US$2013 (Tebbens & Thompson, 2006).

In order to eradicate polio, there must be a shift from the use of OPV to IPV, which is proposed to happen once polio has reached global certification. Certification means that the incidence of wild poliovirus has been zero for three consecutive years (Khan, 2008). To model this transition we accumulate the years where *perceived incidence* is less than 1 in the stock *Years until certification*. *Counting years to certification* is the same as *Start counting years to certification*.

Start counting years to certification =
IF Perceived incidence < 1
THEN 1
ELSE 0

If *perceived incidence* is higher than 1 after the first year until certification is counted, certification is disrupted and begins again when *perceived incidence* is less than 1:

Disruption of years until certification =

IF Start counting years to certification = 0

THEN Years until certification

ELSE 0

Post eradication is the period from certification to vaccination cessation. The vaccination costs will be significantly lower during post eradication since supplement immunization activities is stopped and the only vaccination is two dose of IPV in routine immunization (GPEI, 2009; Tebbens et. al., 2006). Estimating when vaccination can cease is complicated (Wood et. al., 2000). In this model we estimate that an IPV vaccination rate at 100% will be necessary for 7 years after certification before polio vaccination can be stopped. In the model, post eradication starts when *Years until certification* is more than 3:

Start post eradication =

IF Years until certification > 3

THEN 1

ELSE 0

The number of post eradication years is then counted. Contributions and vaccination rates are stopped when *Years of post eradication* is more than 7 years:

Counting post eradication years =

IF Start post eradication = 0

THEN 0

ELSE 1

People who are successfully immunized at birth enter the stock of *Removed individuals* by *Routine immunization*. During post eradication, the *Post eradication routine vaccination rate* is constant 100% and using only IPV vaccination results in no *probability of vaccine derived infection*:

Routine immunization =

IF Start post eradication = 0

*THEN (Routine vaccination rate * Births * Efficacy) - Births * Probability of vaccine derived infection*
*ELSE Births * Post eradication routine vaccination rate * Post eradication efficacy*

People who are successfully immunized on a national immunization day (NID) or regional immunization day (RID) enters the stock of *Removed individuals*. A PULSE function is used to resemble the short time immunization days lasts:

Supplement immunization activity =
(IF Start post eradication = 0
*THEN PULSE((Susceptibles individuals_under 5 **
*Supplement vaccination rate * Supplement immunization activity efficacy)*
-
*(Susceptibles individuals under 5 * Supplement vaccination rate * Probability of vaccine derived infection after one dose) , 0 , Supplement immunization activity schedule NID)*
+
*PULSE(((Susceptibles individuals under 5 * Target group fraction on regional immunization day) * Supplement vaccination rate * Supplement immunization activity efficacy)*
-
*(Susceptibles individuals under 5 * Target group fraction on regional immunization_day * Supplement vaccination rate * Probability of vaccine derived infection after one dose) , 0.25 , Supplement immunization activity schedule RID)*
ELSE 0)

OPV vaccination gives a *Probability of vaccine derived infection*. The risk is higher for routine vaccinated since they receive multiple doses. *Recipient vaccine derived infection* means those who get vaccine associated infection directly from vaccine. Both people getting infected by the vaccine or is infected by vaccine-derived infecteds, enters the stock *Vaccine derived infected individuals* which depletes by the same recovery time as *Infected individuals*, but because certification use wild poliovirus as a measurement, it is important to distinguish

these two. *Births* subtracts both newborns who either are successfully vaccinated and newborns who get vaccine derived infection due to OPV.

Recipient vaccine derived infection =

IF Start_post_eradication = 0
*THEN PULSE (Susceptibles individuals under 5 * Supplement vaccination rate * Probability of vaccine derived infection after one dose , 0 , Supplement immunization activity schedule_NID)*
+
*PULSE (Susceptibles individuals under 5 * Target group fraction on regional immunization day * Supplement vaccination rate * Probability of vaccine derived infection after one dose , 0.25 , Supplement immunization activity schedule RID)*
+
*(Births * Probability of vaccine derived infection * Routine vaccination rate)*
ELSE 0

Perceived incidence is the sum of *infection under 5 years* and *infection above 5 years* with a one year delay to represent both the time to get information about incidences and the time to initialize new vaccination policies (Tebbens & Thompson, 2009).

Baseline budget is 318 million US$2013. *Acute Flaccid Paralysis surveillance cost per year* is the first cost to be subtracted from contributions. Inclusion of full financed AFP is important in order to detect all incidences. *Normalized vaccination budget* affects *probability of vaccine derived infection*, *Efficacy*, *Supplement vaccination rate*, and *Routine vaccination rate* in graph functions explained in appendix B.

Normalized vaccination budget =

(Contributions from all countries including vaccination cease - Acute Flaccid Paralysis surveillance cost per year) / Baseline budget

Contributions

In the experiment, contributions are either given as individual donor countries with USA (country A), Canada (country B), Germany (country C), Japan (country D) and United Kingdom (country E) in country A treatment. Or as all donor countries as one group, in group A treatment. The countries chosen are the countries with the highest contributions to polio eradication (GPEI 2013a). In the following section I will first describe the country A structure and secondly the group A structure.

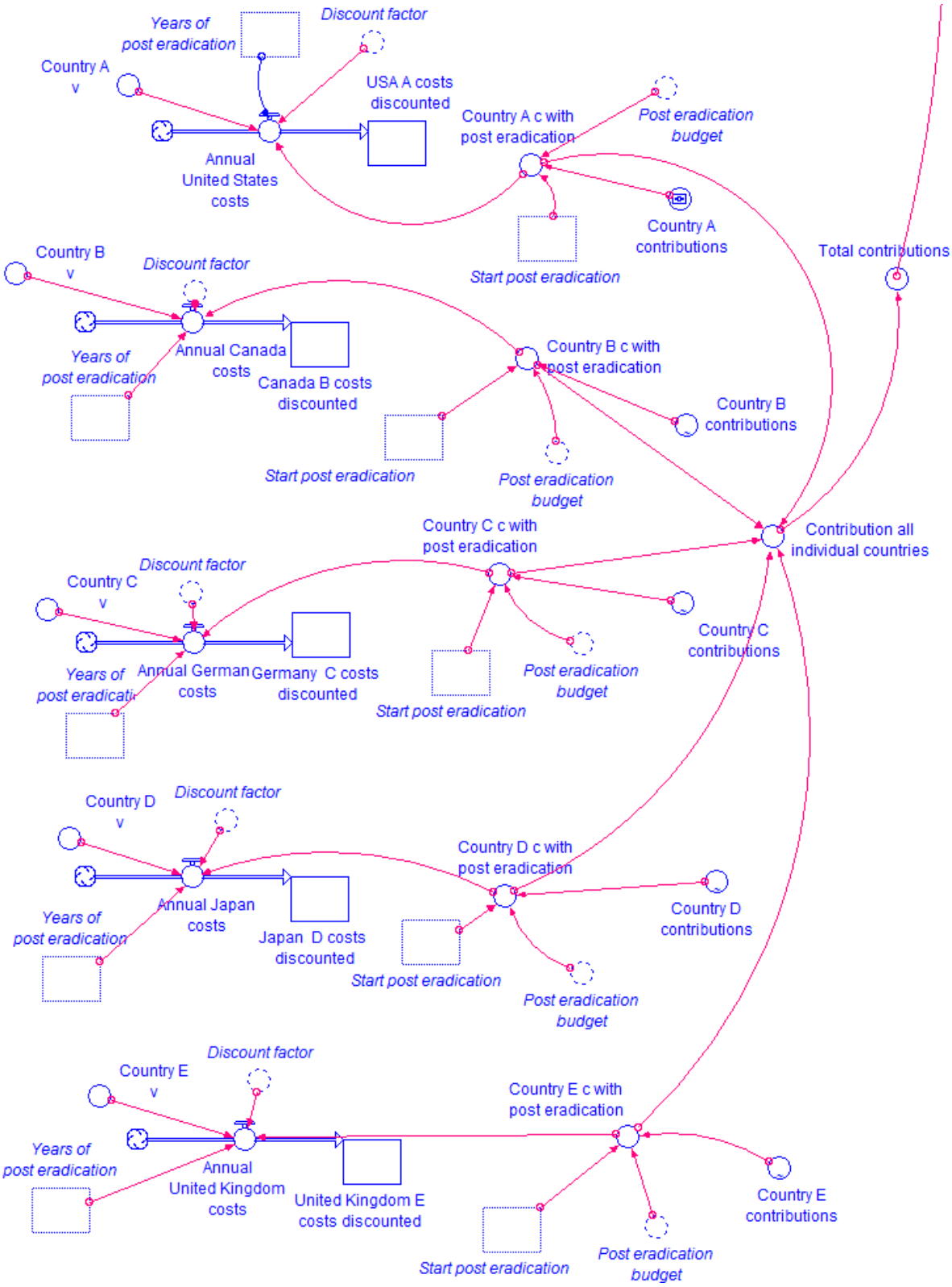

Figure 2.3 All individual countries (country A, B, C, D and E) expenditures

Figure 2.3 shows the stock and flow model of the country A structure. Domestic vaccination costs, "v" in model, are fixed and are described in appendix C. Contributions from country B,

C, D and E are derived from using the fraction of contributions given from 1985-2012 of the total amount of contributions from all 5 countries in the same years. The amount is divided in two where one part is fixed and the other part has a variation where the amount is multiplied with a random number between 0 and 2. This reflects the randomness of historical contributions (GPEI, 2013a). Graph functions used for the country B, C, D and E contribution are described in appendix D.

With the exception of that country A contribution is decided by the subjects, all other equations is the same for all countries:

Annual United States costs =

IF Years of post eradication > 7

THEN 0

*ELSE (Country A v + Country A c with post eradication) * Discount factor*

After 7 years of post eradication, all vaccination is ceased. The donor countries' costs are the sum of domestic vaccination costs and contributions to polio vaccination in endemic countries. All costs are discounted at 3% (Weinstein et. al., 1996). Post eradication contributions are not decided by subjects. For every country, the post eradication budget is divided between the countries with the same fraction used for country B, C, D and E contributions with the inclusion of USA (country A) calculated in the same manner as the other countires (GPEI, 2013a). Post eradication costs is estimated to be significatly lower than the pre-post period (GPEI, 2009). In the model, the costs of post eradication is 88 million US$2013. Since the cost is so low, we expect that all countries are willing to contributes in this last effort, and therefore leave this out of subjects decisions. In reality, if donor countries do not make any contributions during the post eradication period, it is very likely that private organizations, which contribution level is the same as the sum of donor countries, would cover donor coutries "share" because of the low costs.

Contribution all indivudual countries is the same as *Total contributions* and is the the sum of all the 5 countries's or group A's contributions.

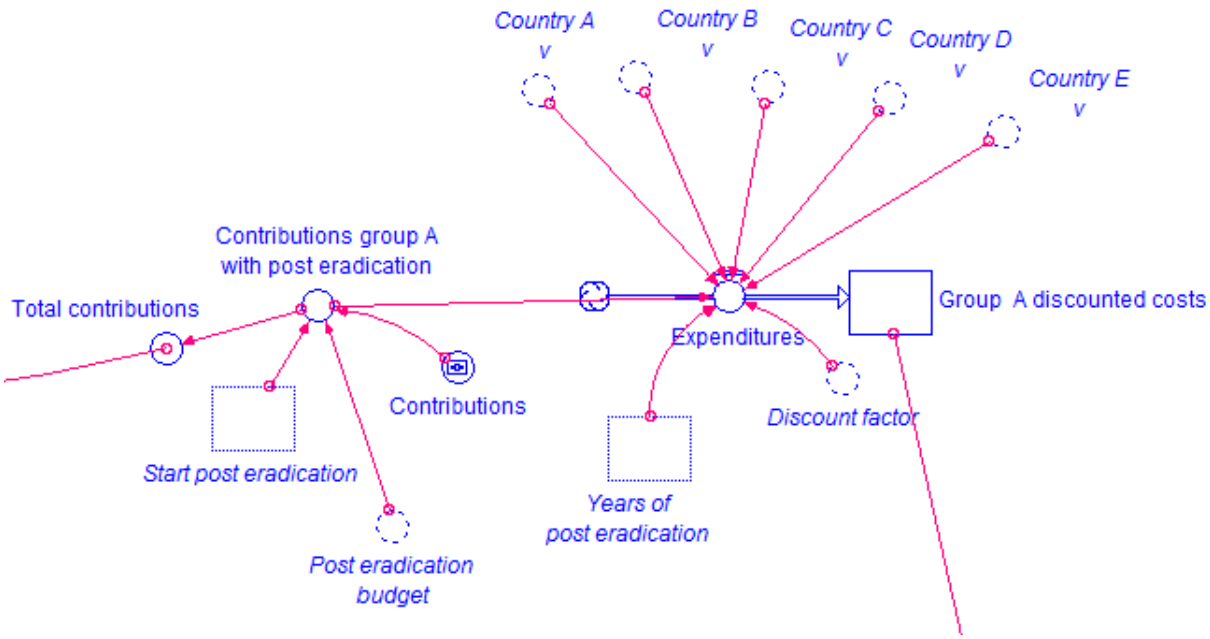

Figure 2.4 All countries as one (group a) treatment expenditures.

In the group A treatment, all domestic vaccination costs and contributions for group A is summed up using the same equations as when using individual countries (figure 2.4).

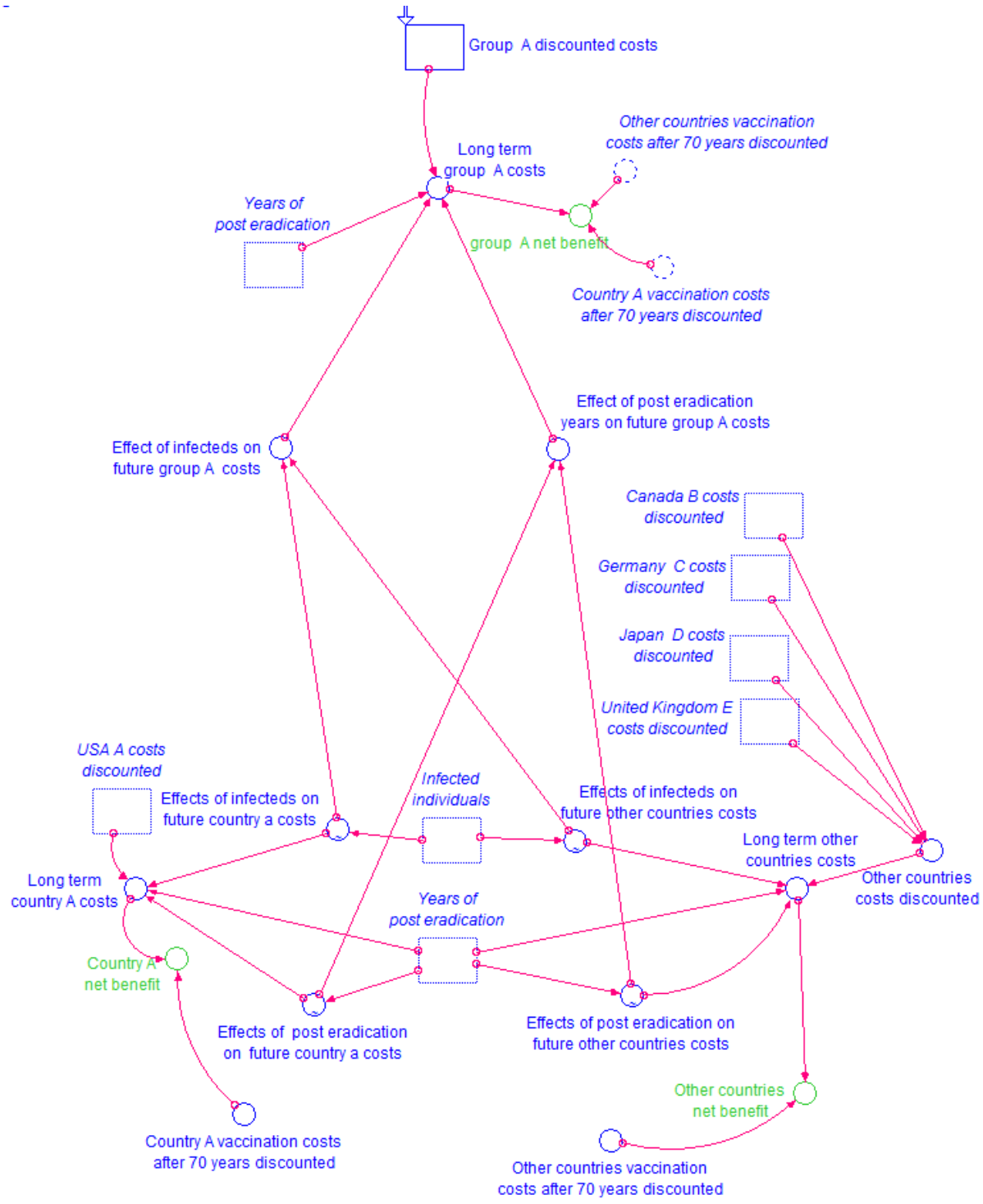

Figure 2.5 Long term costs and net benefits.

The simulation runs for 20 years, but in the experiment the subjects' policies are tested in a 70 year perspective in order to estimate long term costs and benefits. If subjects do not reach vaccination cessation before the end of the simulation, additional vaccination costs are added. We assume a future policy where polio is eradicated. Estimations of future costs are made by

using a fixed baseline country A contribution of 133 million US$2013 or baseline group A contribution of 318 million US$2013 from year 19 until post eradication policy implementation. Using different country A contributions from year 0-19 gives a graphical function where *Infected individuals* in year 19 affects the vaccination costs for all countries from year 19-69 (Table 2.1).

Table 2.1 Effect of infecteds on future costs

Infected individuals **(People at year 19)**	***Effects of infecteds on future country A costs*** **(million US$2013)**	***Effects of infecteds on future other countries costs*** **(million US$2013)**
158 839.85	2 602.54	2 205.03
844.83	2 235.40	1 844.27
31.91	1 707.87	1 354.29
5.62	1 040.80	789.76

There is a possibility of having 0 *Infected individuals* in year 19, although the *Years of post eradication* is less than 7 years. In order to continue the post eradication policy for 7 years also for future vaccination, we estimate the effect of post eradication in year 19 on future costs for all countries (Table 2.2).

Long term country A costs =

IF Years of post eradication > 0

THEN Effects of post eradication on future country a costs + USA A costs discounted

ELSE Effects of infected on future country a costs + USA A costs discounted

Long term costs use either future costs linked to *Years of post eradication* or *Infected individuals* in year 19. Effects for group A costs is the sum of country A and other countries effects.

Table 2.2 Effect of post eradication on future costs

Post eradication years **(years at year 19)**	***Effects of post eradication on future country a costs*** **(million US$2013)**	***Effects of post eradication on future other countries costs*** **(million US$2013)**
0.8	846.03	632.13
3.7	466.4	348.50
5.7	196.41	146.75
6.9	22.22	16.60
7	0	0

Net benefit is the countries' or group's domestic vaccination costs for 70 years minus the sum of domestic vaccination costs until vaccination cease and contributions made to endemic countries.

The model is simulated with small dt of 0.05 which is necessary considering the short delay of *Average duration of infectivity* (35 days).

Validation

Models are not a perfect representation of reality and running different tests is important to find out if the model can replicate historical trends and also searching for behavioral errors and parameter sensitivity (Sterman, 2000).

Initialization

Population used in the model is the 2011 population in endemic countries (Afghanistan, Pakistan and Nigeria (World Bank, 2014). Vaccination costs are estimated on the basis of the real birth cohort for endemic countries by multiplying the crude birth rate for low income countries by population. Fraction of population under 15 years is used to estimate the AFP surveillance cost (World Bank, 2014).

Stocks are simply initialized to an equilibrium level with a perceived incidence of 795 cases, meaning a total annually contribution of 161 million dollar. A base of 795 cases is chosen to reflect the global 2011 level adjusted for underestimation (CDC, 2012; Tebbens et. al., 2010) The number of cases (2011) in the endemic countries is used in the model counts for only half

the global amount due to outbreaks in previously endemic countries (CDC, 2012). Since the model reflects the only remaining countries with polio, we use the global level of cases in 2011 as a base to reproduce the global prevalence of polio. Figure 2.6 compares different initial values of perceived incidence to the same base contribution policy (318 million US$2013). The initial value of perceived incidence do not affect the time it takes to eradicate. Using a higher initial value of perceived incidence does not give an unrealistically long time to eradicate compared to the real 2011 incidences in endemic countries.

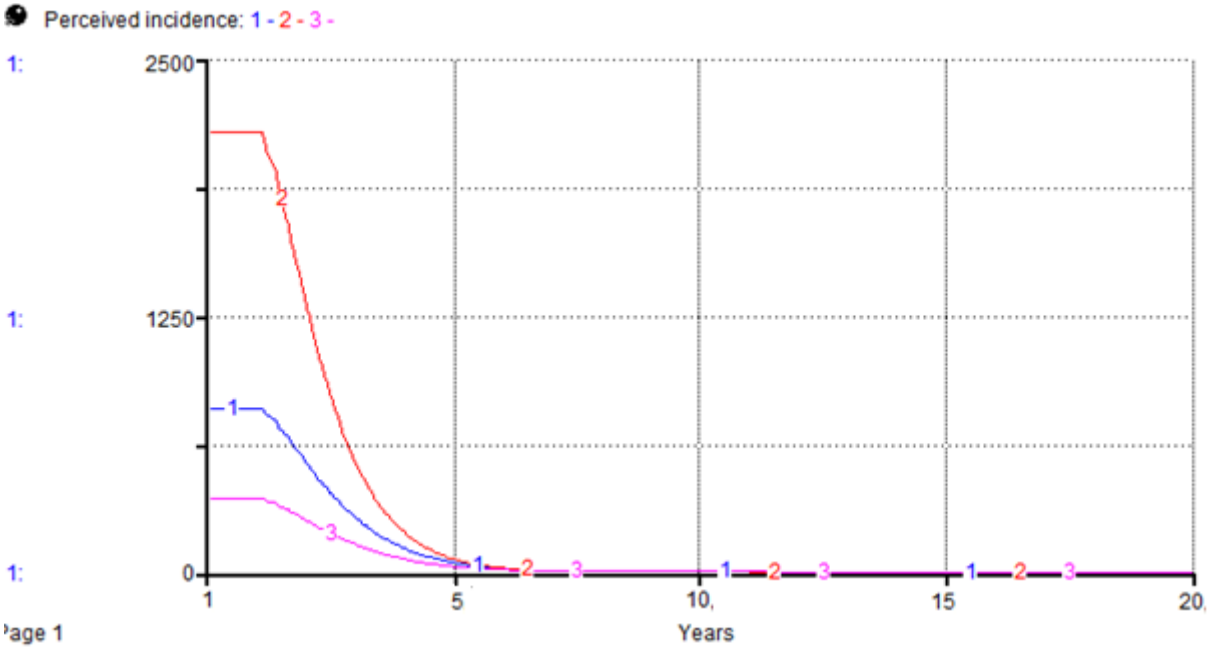

Figure 2.6 Comparing different perceived incidence initialization

Extreme condition tests

Figure 2.7 shows what happens after 100 years of zero vaccination. Perceived cases of polio will oscillate towards the pre-vaccine equilibrium. This equilibrium is consistent with the case rate for polio in USA before polio vaccination started in 1955 at about 9 cases per 100 000 (figure 2.8).

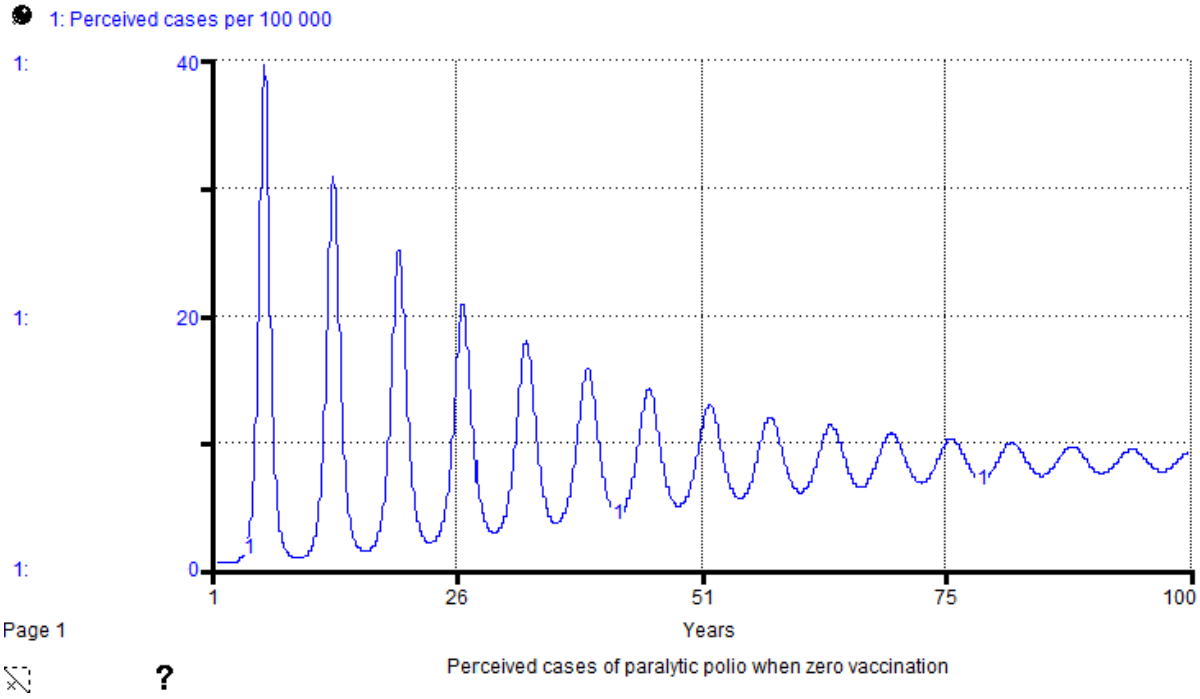

Figure2.7 Extreme condition test: No vaccination

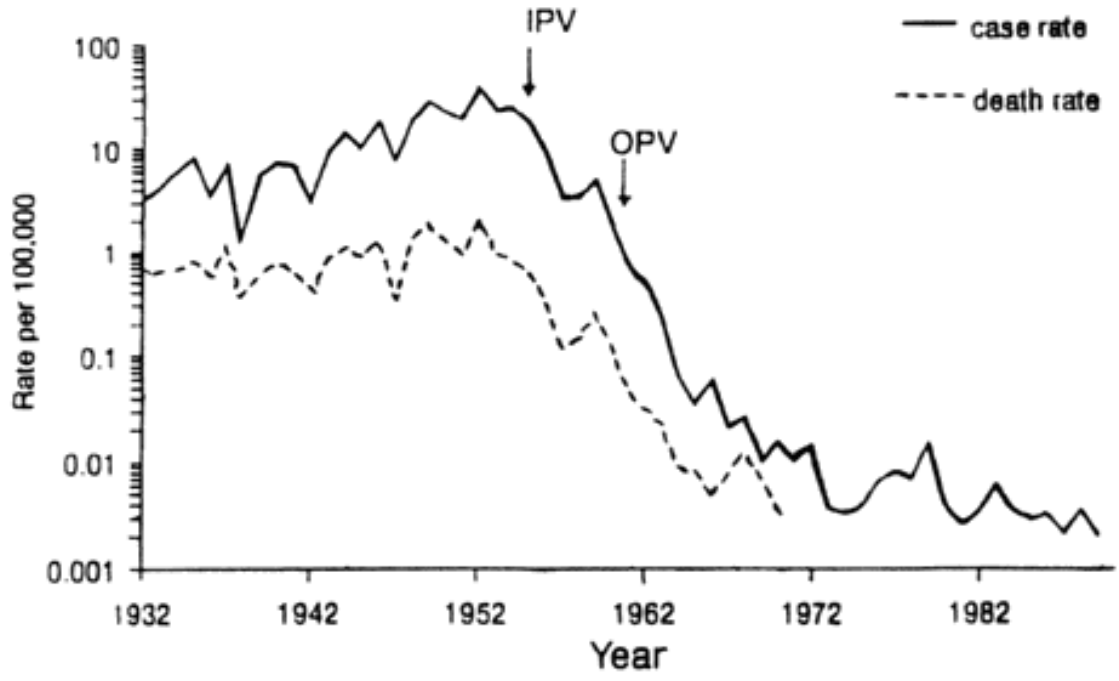

Figure 2.8 Polio cases in USA from 1932 (Strebel. et. al.,1992, figure 1, reprinted with permission)

Using OPV after eradication shows the behavior of the vaccine derived poliovirus. In figure 2.9, there is a 100% OPV vaccination rate after reaching vaccination cessation with IPV in year 18 (meaning no new wild polio infections). There are small outbreaks of vaccine derived poliovirus with damped oscillations.

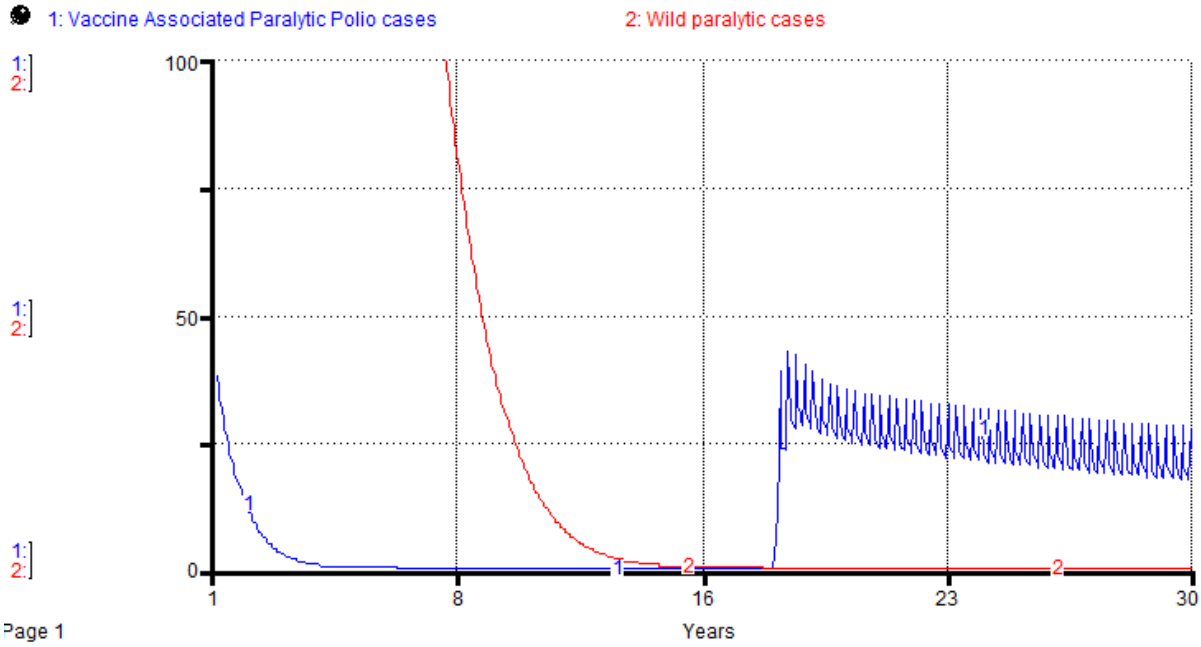

Figure 2.9 Using OPV after eradication

Behavior sensitivity tests

OPV vaccination efficacy has a large variation and it is difficult to estimate a realistic value. Figure 2.10 compares different vaccination efficacies for supplement immunization activity using baseline contribution for group A, where 1 is base efficacy of 30%, 2 is 20% and 3 is 40%. Using a lower efficacy has a greater effect on the time it takes to eradicate than using a higher efficacy. With the low efficacy, post eradication starts in year 14. Using base efficacy it starts in year 12 and with the higher efficacy, it starts in year 11.

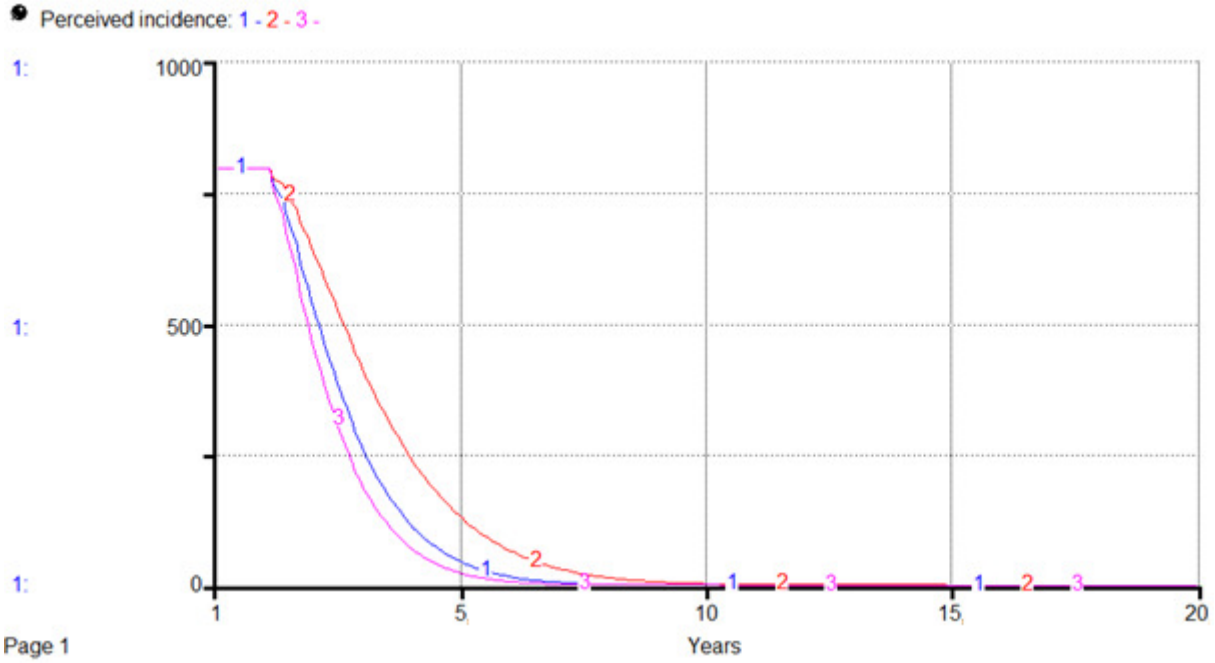

Figure 2.10 Comparing different vaccination efficacies

Table 2.3 shows the sensitivity when using different discounting rates to measure net benefit for group A. We have used baseline contribution (318 million US$2013). Higher discounting rates means that the cost of vaccinating group A countries for 70 years is so little that the benefit of eradication gets less.

Table 2.3 Group A net benefit with different discount rates

Group A net benefit **(million US$2013)**	***Group A net benefit*** **(million US$2013)**	***Group A net benefit*** **(million US$2013)**
Discount rate 0%	Discount rate 3%	Discount rate 6%
15 731.13	2 446.71	- 784.78

Policy sensitivity

The lowest annual amount needed to start post eradication before year 19 is 36 million US$2013 for country A and 199 million US$2013 for group A. Polio eradication is very beneficial for the group of donor countries if post eradication occurs between year 10 and 13 (table 2.4 and 2.5). Using more money to eradicate sooner is not beneficial.

The best policy for group A treatment is a gradually reduction in contributions from around 400 million US$2013 to 0 (table 2.11). Gradually reduction gives a faster eradication than the baseline at a lower discounted cost. The best solution is therefore to follow the risk of

outbreaks; high number of perceived incidence requires more contribution to vaccination to avoid outbreaks than if there are few perceived incidence.

Table 2.4 Comparing policies for group A

Group A contribution **(million US$2013)**	***Group A net benefit*** **(million US$2013)**	**Post eradication starts (year)**
100	-857.81	After year 19
200	994.19	19
Baseline: 318	2 446.71	11
400	2 100.24	10
500	1 600.45	9
600	866.48	9
(Figure 2.11)	2 827.82	10

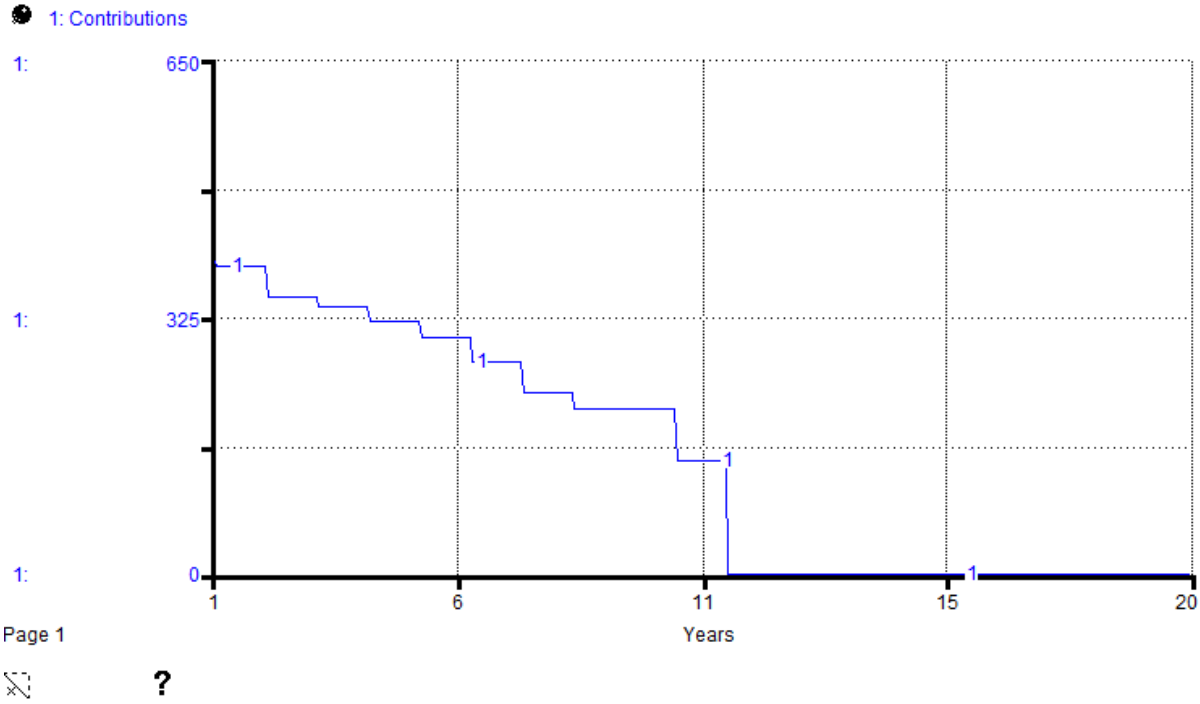

Figure 2.11 Group A policy with decreasing contribution

In country A treatment, a higher contribution while the contributions from other countries stay fixed lead to a low net benefit for country A, but a high net benefit for the sum of other countries (table 2.5). This is a situation where other countries are free-riding on country A's contributions. The opposite happens when country A contributes less than baseline and therefore in some extent free-rides on the other countries contributions, although this policy is not that beneficial for country A if post eradication occurs after year 19 (table 2.5). The best

policy for country A is to gradually decrease the contribution and stop them after year 6, letting the other countries take the rest of the cost before post eradication (figure 2.12). This yields also the highest net benefit although other countries gain more from policies with a higher country A contribution. Creating policies that implies free-riding is problematic since in reality one countries free-riding will cause other countries to contribute less (Barrett, 2007)

Table 2.5 Comparison of policies for country A and other countries

Country A contribution **(million US$2013)**	***Country A net benefit***	***Other countries net benefit*** **(million US$2013)**	**Post eradication starts (year)**	**Sum of Net Benefit (million US$2013)**
0	1 009.94	-2 165.26	After year 19	-1 155.32
50	1 866.98	-631.22	17	1 235.76
100	1 961.76	242.93	13	2 204.69
Baseline: 133	1 859.62	500.09	11	2 359.71
200	1 524.58	751.72	10	2 276.30
300	804.46	863.51	10	1 667.96
400	190.53	988.93	9	1 179.46
550	-885.53	1 051.06	9	165.53
(figure 2.12)	2 363.74	379.87	12	2 743.61

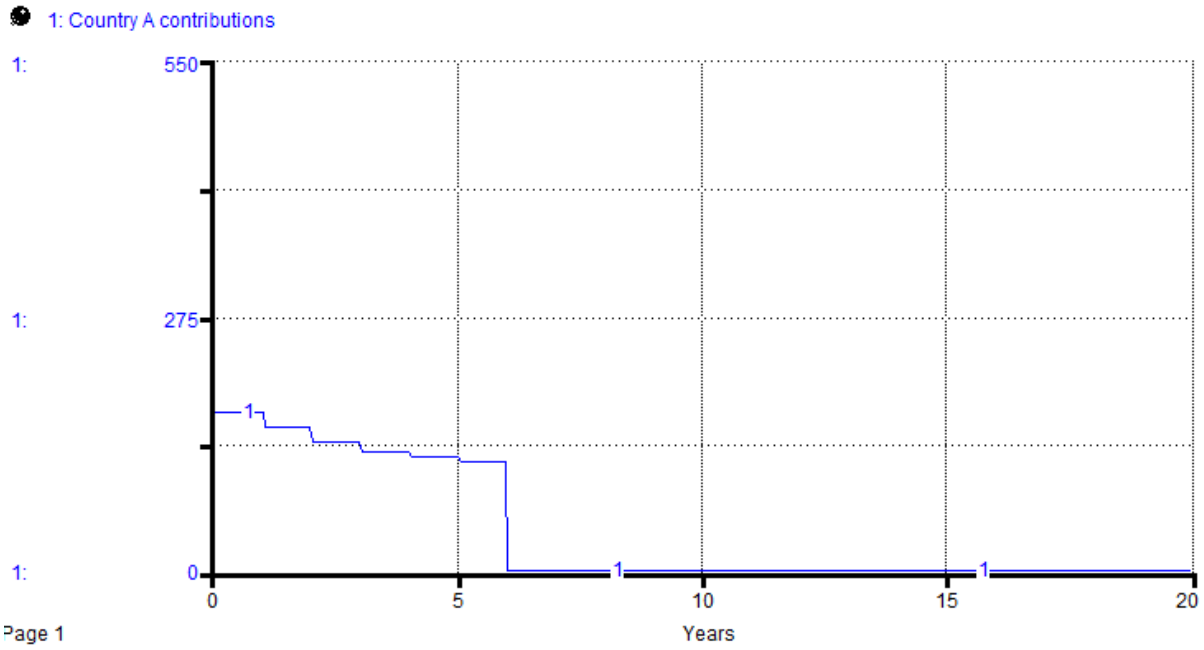

Figure 2.12 Group A policy with decreasing contribution

Polio eradication is estimated to be certified in 2014; however, the goal is highly unlikely to be achieved since there are still incidences both in endemic and non-endemic countries (GPEI, 2013b). Using baseline level, this goal is overshot by 8 years. With baseline levels, vaccination cease in year 18. We use a 20 year simulation time in order to give subjects the chance to reach at least certification. This is done for being able to see subjects' decisions for the whole period before post eradication.

Bondaries

The model used for the experiment is much simpler than other polio models (Tebbens et. al., 2005). Compared to other SIR models we have excluded:

- Differenzation of the three polioviruses
- Multiple age groups
- Seasonality of force of infection
- Age adjusted force of infection
- Case fatality rate
- Waning immunity
- Realistic birth and death rates
- Outbreaks response
- Extra costs of eradication like global immunization day, surveillance, stockpile, destruction of OPV, laboratory costs (Tebbens et. al., 2006)
- Latency time
- Delays beteween the three routine immunization doses
- Research costs

3. Experimental design

Virtual worlds let the learner try different strategies and to compare them according to the feedback received (Sterman, 2000). Using a computer simulated virtual world allows us to compare the effect different treatments have on the performance of the simulation. In this experiment we have used 4 treatments as a two level factorial design (table 3.1): Other-regarding and self-regarding are information treatments emphasizing either the responsibility of strengthen health services in endemic countries or the net benefit for the country or group the subject are playing. Group A means being the policy maker for a group of 5 donor countries. In country A, the subjects are the policy maker for country A and get information about contributions from the four other donor countries.

Table 3.1 Two level factorial design presentation of treatments

	Group A	**Country A**
Other-regarding	Group 1 (OTGR)	Group 3 (OTCO)
Self-regarding	Group 2 (SEGR)	Group 4 (SECO)

32 subjects participated in the experiment, 8 in each group. 15 subjects was in-class recruited meaning that the experiment was conducted as a part of a lecture. The rest of the subjects were self-recruited via information given during lecture, social media, e-mail and SMS. The results from one subject (SECO) was excluded because the participant thought the simulator had a test round first.

Task

In the experiment, the subjects were asked to make annually contributions to vaccination in endemic countries for 20 years. Their goal was to maximize its own country or group's net benefit in a 70 year perspective. Both disease and countries were anonymized to avoid subjects preexisting knowledge about polio or feelings about donor countries interfere with their decisions. In order to increase effort, the subjects with the 5 best results (using net benefit as a measure) were in a drawing where the prize was 500 NOK. Treatments were randomized.

Pre-experiment information

Before starting the experiment, subjects were told to carefully read a page of information (Appendix E). Decision making in a naturalistic context aids performance (Sterman & Sweeney, 2002). We have therefore used information derived from sources like GPEI, government hearings, CDC and USAID, which are all likely information sources for policy makers. One paragraph separated the two information treatments:

Other-regarding (group 1 and 3):

> *Funding vaccination in developing countries is a global challenge that requires international collaboration. Funding vaccination is an important part of reaching UN's millennium development goal of reducing child mortality, which the world society is committed to work towards. Vaccination is an effective way for protecting children against the deadly and crippling disease X.*

Self-regarding (group 2 and 4):

> *Global eradication is the most cost-effective and permanent way to protect country A against importing disease X. No single country can be safe from disease X until all countries are free of the disease and the disease is eradicated.*

Group 1 and 3 were given information where vaccination is seen as important for reaching UN's millennium development goal for reducing child mortality and thus focusing on health care regarding other countries (Obama, 2010; USAID, 2010). Information in group 2 and 4 put weight on the benefit of eradication for country A or group A (Global eradication of polio and measles, 1999; GPEI, 2011).

The subjects were presented for the amount of contributions given last year (2011) and an estimation of increase needed in order to eradicate within 5 years. The real 2011 contributions (baseline) are so high that an increase do neither eradicate much faster nor increase the net benefit. In order to make a starting point where more effort is needed, we have set last year's contributions lower than baseline in the pre-experiment information. Country A contribution was set to 80 instead of 150 million US$2013. The total contributions were set to 230 instead

of 318 million US$2013. The 2011 level in the graph from GPEI (figure 3.1) was also adjusted to make it coherent.

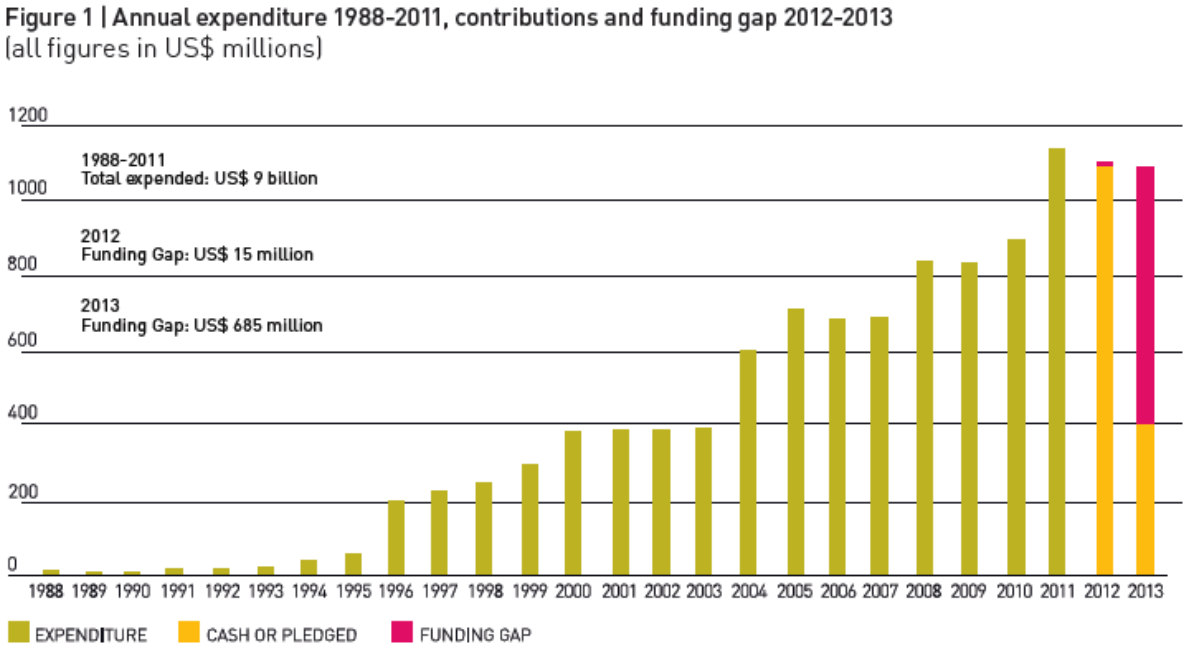

Figure 3.1 Annual expenditures of GPEI 1988-2011 (GPEI, 2012, reprinted with permission)

Missing polio eradication targets have questioned GPEI's creditability for making financial requirements (Pirio & Kaufmann, 2010). In addition to increased requirements following financial setbacks, political conflicts, poor vaccine efficacy and higher infectivity than expected may also give an impression of a lower financial requirement than actually needed. The uncertainty of calculating the real costs needed to eradicate was emphasized in the pre-experiment information:

> *Experts have estimated that if the total contribution is increased by 10 million dollars, perceived incidence of disease X will decrease to zero after 5 years. However, experts have previously miscalculated the cost of immunization due to higher infectivity than assumed, poor vaccination efficacy and political conflicts. These difficulties are expected to continue.*

Using the expert estimated increase, perceived incidence of polio will not reach zero until year 10. Subjects were misinformed on purpose to add a level of uncertainty.

Information in simulator

Subjects were presented to a few graphs and numbers to aid their decision making during the simulation (Appendix E). Financial resource requirements from GPEI focus on contributions needed to eradicate within a set time frame and information about the annual number of polio cases. Similar to financial requirements made by GPEI (2009; 2011; 2012), we have not included information about the vaccination rates needed to eradicate or percent vaccination rate increase costs. Subjects were therefore only informed about perceived incidence at last year and contributions for the whole simulation time.

Perceived incidence is a measure of the severity of a disease. By incidence we mean the number of new cases (infections) per year (Mathers et. al., 2008). The perceived incidence used in the experiment is the true number of incidence with a first order delay with a time constant of one year. A one year information delay is used by Tebbens and Thompson (2009), in their simulations of policy decisions for disease eradication, to portray both the time it takes to receive information about incidences and the time it takes to adjust interventions.

Target group

The experiment was conducted on System Dynamics student from first and second year (master degree) and students taking only some System Dynamics courses. There was also a PhD student participating. We used only System Dynamics students in order to get a uniform reference group.

Hypotheses

In order to find out how the benefits of eradication are perceived, we will test the experiment results to 6 hypotheses:

Hypothesis 1: Lack of coordination has a negative effect on post eradication years

The global management of disease eradication has shown that donor countries are reluctant to contribute if other countries do not (Barrett 2007; 2013). The same behavior is seen in laboratory experiments where subjects are more absorbed by their self-interest of not

contributing more than others rather than cooperation (Cadsby & Maynes, 1999). Hypothesis 1 ought to find out if we will find the same behavior in this experiment:

$H1_o$: Group A post eradication years = country A post eradication years

$H1_a$: Group A post eradication years ≠ country A post eradication years

If $H1_o$ is rejected, there is an "eradiation game" played between country A and the other countries that affect the time it takes to eradicate. Post eradication years count the years from certification. We will use post eradication years in year 19 (end of simulation) as a measure of the time it takes to eradicate.

Hypothesis 2: Self-interest incentives results in faster eradication than using other-regarding incentives

Hypothesis 2 uses the same dependent variable as in hypothesis 1, but here we will compare how information affects the time it takes to eradicate. Government decisions are taken purely on self-interest (Jolly, 2004). However, policy makers misunderstand how disease eradication can be in their self-interest since they tend to focus on short term costs rather than long term benefits (Thompson & Tebbens, 2007).

$H2_o$: Others-regarding post eradication years = self-regarding post eradication Years

$H2_a$: Others-regarding post eradication years ≠ self-regarding post eradication years

By emphasizing (with information) why eradication is the best policy in the country or group's self-interest, we expect the contributions to be higher than emphasizing on others-regarding arguments. $H2_o$ is rejected if information about the incentives to eradicate affects post eradication years.

Hypothesis 3: Self-interest incentives result in higher net benefit than using other-regarding incentives

The rationales behind hypothesis 3 are the same as for hypothesis 2: Short term thinking and misunderstandings of the benefit of eradication makes the other-regarding group perform poorer than self-regarding group.

$H3_o$: Others-regarding net benefit = self-regarding net benefit

$H3_a$: Others-regarding net benefit ≠ self-regarding net benefit

We expect self-interest group to have contributions closer to the optimal than other-regarding by contributing more. $H3_o$ is rejected if information has an effect on net benefit.

Hypothesis 4: Country A expects the expert recommended increase to be shared by all donor countries.

In hypothesis 4, we investigate how much of the expert recommended increase country A will be willing to take compared to group A. The argument behind this is that no countries are willing to increase their contribution more than other countries even though it may be more beneficial to take the whole increase themselves (Barrett 2007; 2013).

$H4_o$: Group A fraction of expert recommended contributions increase = country A fraction of expert recommended contributions increase

$H4_a$: Group A fraction of expert recommended contributions increase ≠ country A fraction of expert recommended contributions increase

We will use the fraction of contribution compared to the expert recommended increase the first 5 years of the simulation as the dependent variable. Group A's contribution will therefor be the fraction of 240 million US$2013. For country A, we will test the range between 80-90 million US$2013, where 80 is the base level and 90 includes the total estimated increase needed. However the total amount of contribution for country A group will fluctuate because of the other countries' oscillating contributions. This comparison allows us to find out how big country A's assumed "fair share" of the increase is compared to group A. If $H4_o$ is rejected, country A is less likely to take the whole increase cost themselves compared to

group A. The net benefit for country A is higher when financing the whole recommended increases themselves than just contributing a fraction of the increase.

Hypothesis 5: Self-regarding incentives result in higher contribution the first 5 years than other-regarding incentives.

In order to test hypothesis 5, we will use the same dependent variable as in hypothesis 4, but by using self-regarding and other-regarding as the independent variables:

$H5_o$: Others-regarding fraction of expert recommended contributions increase = self-regarding fraction of expert recommended contributions increase

$H5_a$: Others-regarding fraction of expert recommended contributions increase ≠ self-regarding fraction of expert recommended contributions increase

The arguments behind this statement are the same as for hypothesis 2: focus on self-interest benefit of eradication will lead to higher contributions than a focus on others-regarding (Jolly, 2004; Thompson & Tebbens, 2007). If $H5_o$ is rejected, there is an effect of information on the amount contributed.

Hypothesis 6: The effect of information is bigger for group A than country A

In the last hypothesis we expect the effect of information to be different between group A and country A treatments. We assume that country A is so absorbed by finding its "fair share" compared to the other countries that an information shift from other-regarding to self-regarding will have less effect than with group A.

$H6_o$: Effect of information on group A = Effect of information on country A

$H6_a$: Effect of information on group A ≠ Effect of information on country A

If $H6_o$ is rejected, group A will have a bigger effect of information shift than country A.

4. Results

32 subjects participated in the experiment, 8 persons in each of the 4 treatments. The result from one subject (treatment SECO) was excluded because the person thought the simulator included a test run before the real experiment. We used the following dependent variable in our analysis: Contributions, post eradication years at year 19 (end of experiment) and net benefit. For participants not reaching cessation by year 19 and thus had 0 post eradication years at year 19, we simulated the model with their contributions one more time in a longer time frame using future policy contributions after year 19. The number of years from year 19 till post eradication year > 0 is used as negative value and is therefore a measure of the extra time to reach cessation.

Figure 4.1 and 4.2 show the annual contributions for the 4 treatments. Post eradication contributions are fixed and not decided by subjects and therefore highlighted with yellow marking. 28 subjects reached post eradication. 5 subjects reached vaccination cessation before year 19; one with treatment SECO, two with OTGR and two with SEGR. Vaccination cessation is highlighted with blue marking in figure 4.1 and 4.2.

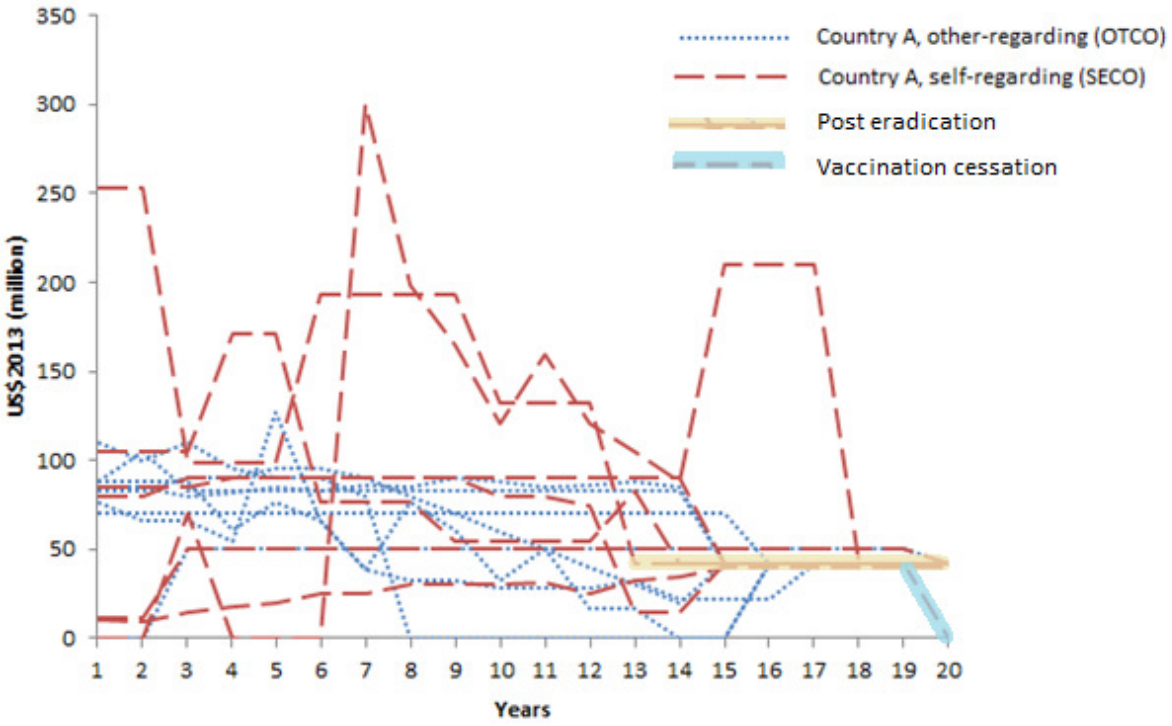

Figure 4.1 Contributions: Country A

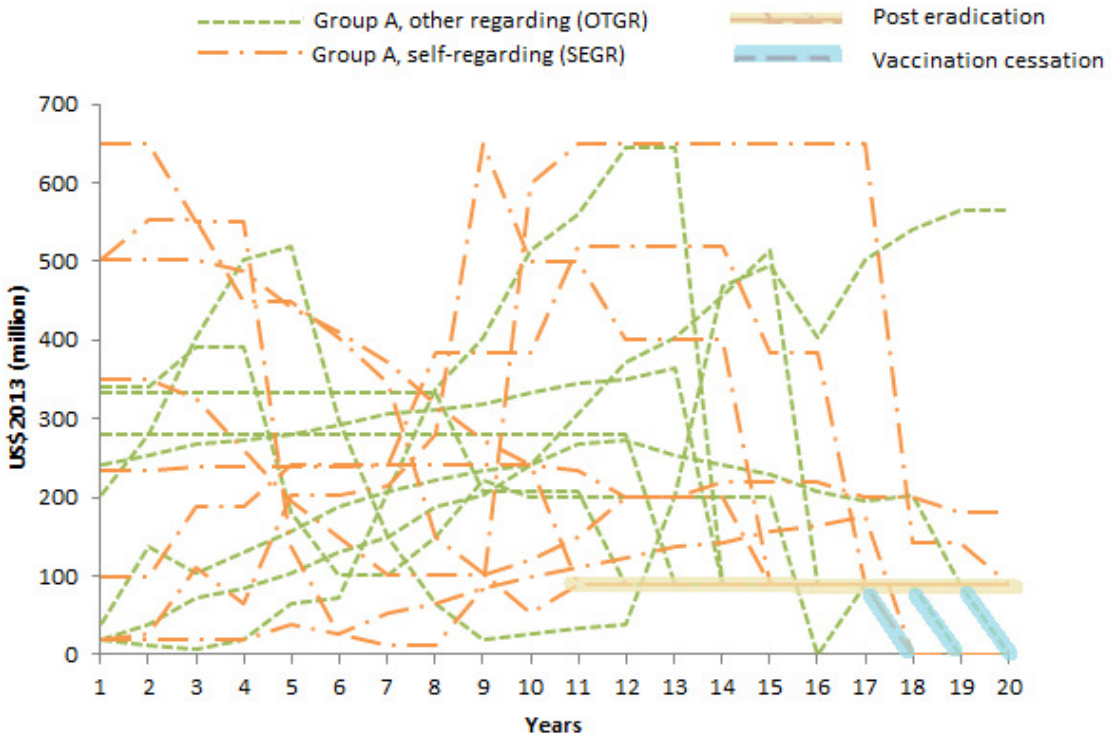

Figure 4.2 Contributions: Group A

Figure 4.3 and 4.4 show the perceived incidence for all subjects. 4 country A subjects experienced outbreaks after making very small contributions from the beginning. 7 group A subjects experienced enormous outbreaks; the biggest with a top of 133 thousand perceived incidences. The difference between outbreak sizes is because in country A, the other countries' contributions will reduce outbreaks. In both cases it takes some time with low contributions before the outbreaks.

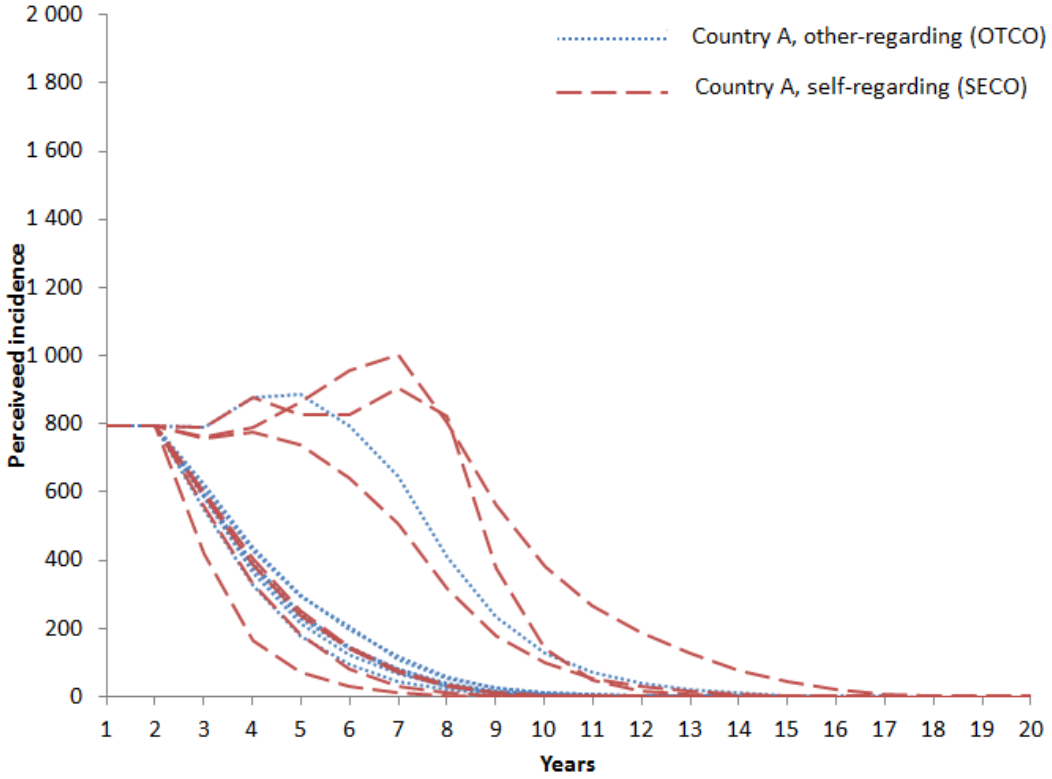

Figure 4.3 Perceived incidence: Country A

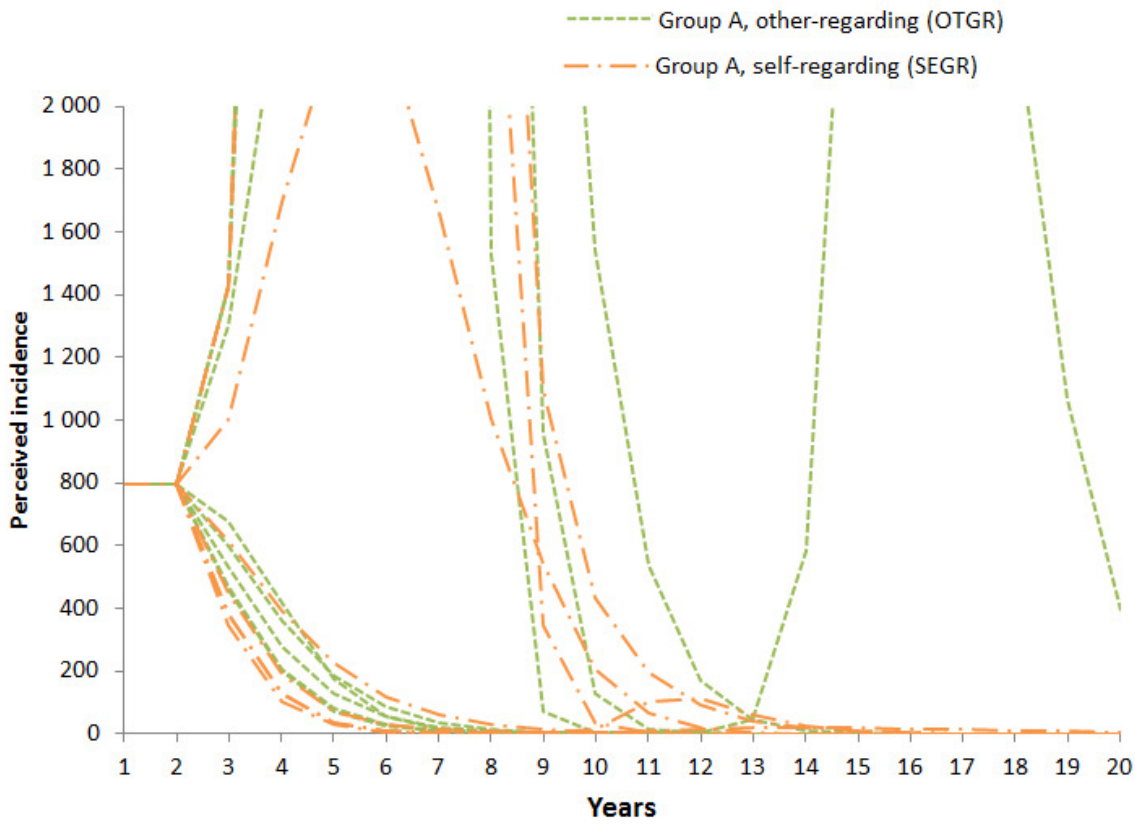

Figure 4.4 Perceived incidence: Group A

Hypothesis 1

Figure 4.5 shows the descriptive statistics for variables tested. From this result we want to find out if there is a significant difference between group A (OTGR and SEGR) and country A (OTCO and SECO) using post eradication years in year 19 as the dependent variable.

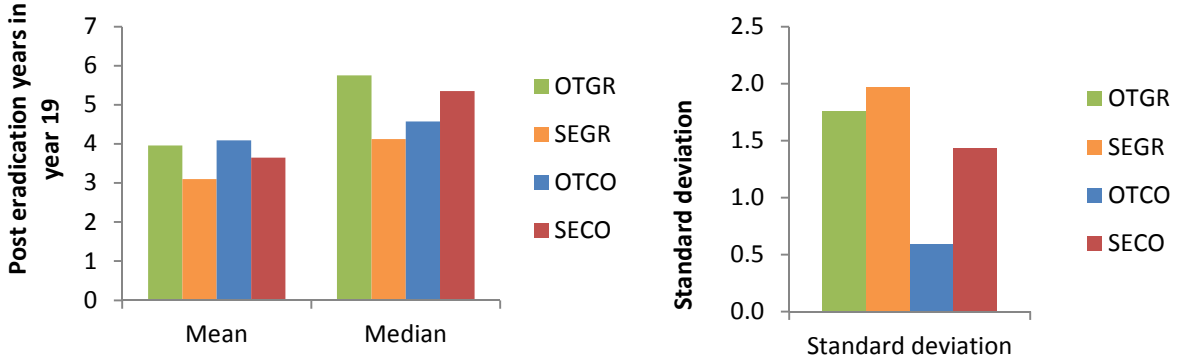

Figure 4.5 Hypothesis 1 and 2: Descriptive statistics

Table 4.1 shows the result of Mann-Whitney U test, alpha level .05. The independent variable 2 is group A and 3 is country A. The test shows that there is no significant difference between group A and country A , $U(16, 15) = 31$, $p = .707$ (two-tailed test). We accept null hypothesis 1.

Table 4.1 Hypothesis 1: Mann-Whitney U test

Ranks

	GROUP_COUNTRY	N	Mean Rank	Sum of Ranks
Post_eradication	2,00	16	16,59	265,50
	3,00	15	15,37	230,50
	Total	31		

Test Statistics[a]

	Post_eradication
Mann-Whitney U	110,500
Wilcoxon W	230,500
Z	-,376
Asymp. Sig. (2-tailed)	,707
Exact Sig. [2*(1-tailed Sig.)]	,711[b]

a. Grouping Variable: GROUP_COUNTRY

b. Not corrected for ties.

Hypothesis 2

Hypothesis 2 uses the same descriptive statistics as in figure 4.5 in order to test information treatments other-regarding (OTGR and OTCO) against self-regarding (SEGR and SECO) using post eradication years in year 19 as the dependent variable.

Table 4.2 Hypothesis 2: Mann-Whitney U test

Ranks

	OTHER_SELF	N	Mean Rank	Sum of Ranks
Total	,00	15	15,60	234,00
	1,00	16	16,38	262,00
	Total	31		

Test Statistics[a]

	Total
Mann-Whitney U	114,000
Wilcoxon W	234,000
Z	-,237
Asymp. Sig. (2-tailed)	,812
Exact Sig. [2*(1-tailed Sig.)]	,830[b]

a. Grouping Variable: OTHER_SELF

b. Not corrected for ties.

Table 4.2 shows the results of the Mann-Whitney U test, alpha level .05. The independent variable 0 is self-regarding and 1 is other-regarding. The test shows that there is no significant difference between self-regarding and other-regarding, $U(15, 16) = 31$, $p = .812$ (two-tailed test). We accept null hypothesis 2.

Hypothesis 3

In hypothesis 3 we want to find out if there is a significant difference between self-regarding (SEGR and SECO) and other-regarding (OTGR and OTCO) on the dependent variable net benefit. Figure 4.6 shows the descriptive statistics used for testing hypothesis 3.

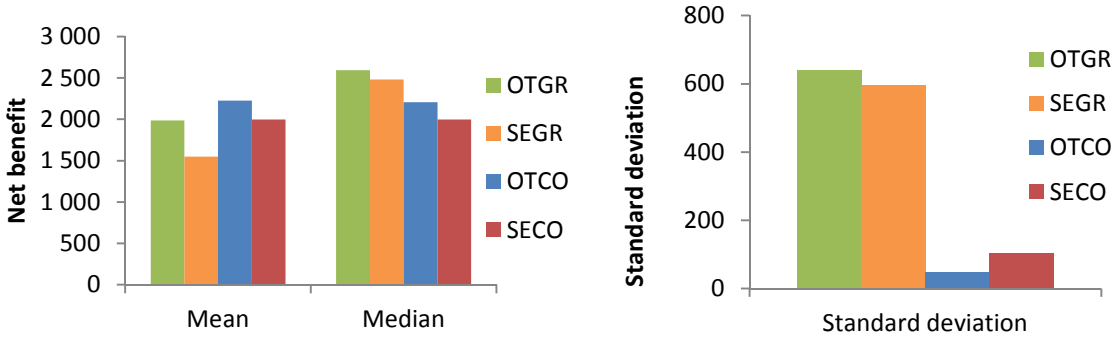

Figure 4.6 Hypothesis 3: Descriptive statistics

Test result of the Mann-Whitney U test, alpha level .05 is shown in table 4.3. The independent variable 0 is self-regarding and 1 is other-regarding. The test shows that there is no significant difference between self-regarding and other-regarding, $U(15, 16) = 31$, $p = .236$ (two-tailed test). We accept null hypothesis 3.

Table 4.3 Hypothesis 3: Mann-Whitney U test

Ranks

	OTHER_SELF	N	Mean Rank	Sum of Ranks
Net_benefit	0	15	14,00	210,00
	1	16	17,88	286,00
	Total	31		

Test Statistics[a]

	Net_benefit
Mann-Whitney U	90,000
Wilcoxon W	210,000
Z	-1,186
Asymp. Sig. (2-tailed)	,236
Exact Sig. [2*(1-tailed Sig.)]	,247[b]

a. Grouping Variable: OTHER_SELF

b. Not corrected for ties.

Hypothesis 4

The descriptive statistics for hypothesis 4 is described in figure 4.7. We want to find out if there is a significant difference between contribution increase in group A (OTGR and SEGR)

and country A (OTCO and SECO). For group A, we compare the contributions the first 5 years to the whole increase of a total 240 million US$2013 (Contributions/expert recommended contributions). For country A, we used a denominator with a range from 80 (baseline) – 90 million (total increase) US$2013 in order to investigate what country A see as a "fair share" of contribution increase compared to group A.

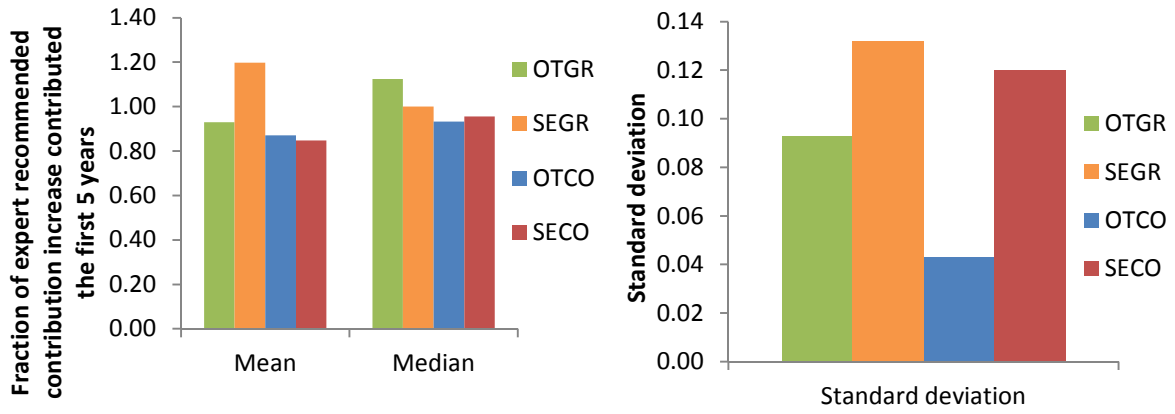

Figure 4.7: Hypothesis 4 and 5: Descriptive statistics

Test results are shown in table 4.4. We have used a Mann-Whitney U test, alpha level .05. The independent variable 2 is group A and 3 is country A. Country A is compared to 89 million US$2013, which is 90 % of expert recommended increase. The test shows that there is a significant difference between group A and country A, $U(80, 75) = 155$, $p = .030$ (two-tailed test). We reject null hypothesis 4.

Table 4.4 Hypothesis 4: Mann-Whitney U test

Ranks

	GROUP_COUNTRY	N	Mean Rank	Sum of Ranks
Cont5_89	2.00	80	85.06	6805.00
	3.00	75	70.47	5285.00
	Total	155		

Test Statistics[a]

	Cont5_89
Mann-Whitney U	2435.000
Wilcoxon W	5285.000
Z	-2.024
Asymp. Sig. (2-tailed)	.043

a. Grouping Variable: GROUP_COUNTRY

Hypothesis 5

Descriptive statistics for hypothesis 5 is showed in figure 4.7. In this hypothesis, we want to see if there is a significant difference between self-regarding (SEGR and SECO) and other-regarding (OTGR and OTCO) on the dependent variable fraction of expert suggested amount contributed the first 5 years.

Table 4.5 shows the results of using Mann-Whitney U test, alpha level .05. The independent variable 0 is self-regarding and 1 is other-regarding. The test shows that there is a not a significant difference between self-regarding and other-regarding, $U(75, 80) = 155$, $p = .653$ (two-tailed test). We accept null hypothesis 5.

Table 4.5 Hypothesis 5: Mann-Whitney U test

Ranks

	OTHER_SELF	N	Mean Rank	Sum of Ranks
Cont5_89	0	75	79.69	5977.00
	1	80	76.41	6113.00
	Total	155		

Test Statistics[a]

	Cont5_89
Mann-Whitney U	2873.000
Wilcoxon W	6113.000
Z	-.455
Asymp. Sig. (2-tailed)	.649

a. Grouping Variable: OTHER_SELF

Hypothesis 6

In hypothesis 6 we want to find out if there is a difference on the effect information have on country A and group A using the fraction of base level contribution for the first 5 years as the dependent variable. None of the independent variables have normal distribution; hence we have transformed the data by ranking them. The ranked values are listed in figure 4.8. Ranking resulted in normalized distribution for all independent variables except SEGR, which, has $p = .044$ using Shapiro-Wilk test. We conduct a full-factorial univariate analysis of variance even though the criteria for normal distributions are not met.

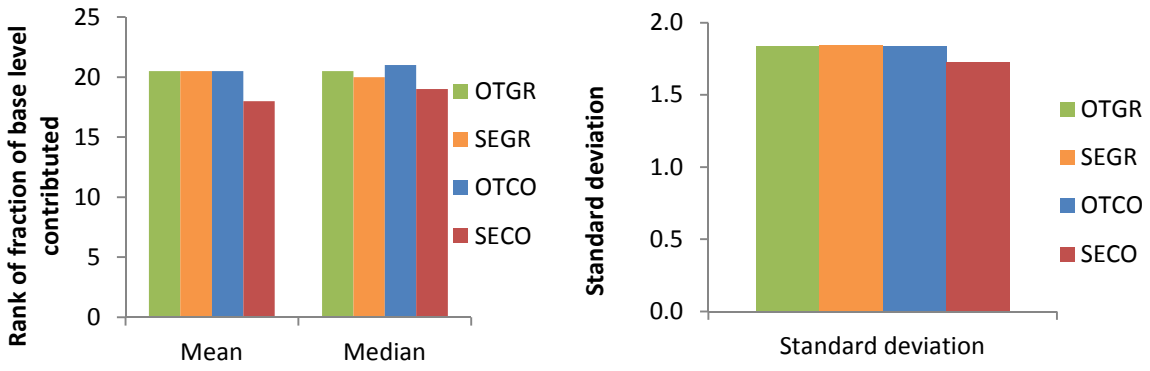

Figure 4.8 Hypothesis 5: Descriptive statistics

Test results using a full-factorial univariate analysis of variance, alpha level .05 are shown in table 4.6. There is not a significant difference between group A and country A on the effect of information (other_self), $U(80, 75, 75, 80) = 310$, $p = .495$. We have also used the same test with untransformed data and got $p = .164$. Figure 4.9 describes the lack of interaction on the ranked data, where group = 2, country = 3, self-regarding = 0 and other-regarding = 1. Country A has a small increase in contribution from self-regarding to other-regarding while the effect is nonexistent for group A. However, the high *p*-value, using both real and ranked values and interpretation of descriptive statistics gives us enough information to accept null hypothesis 6.

Table 4.6 Hypothesis 6: Full-factorial univariate analysis of variance

Dependent Variable: Rank of Cont5_base by All_groups_number

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	169.355[a]	3	56.452	.439	.726
Intercept	61023.103	1	61023.103	474.021	.000
GROUP_COUNTRY	60.345	1	60.345	.469	.495
OTHER_SELF	60.345	1	60.345	.469	.495
GROUP_COUNTRY * OTHER_SELF	60.345	1	60.345	.469	.495
Error	19439.000	151	128.735		
Total	81209.000	155			
Corrected Total	19608.355	154			

a. R Squared = .009 (Adjusted R Squared = -.011)

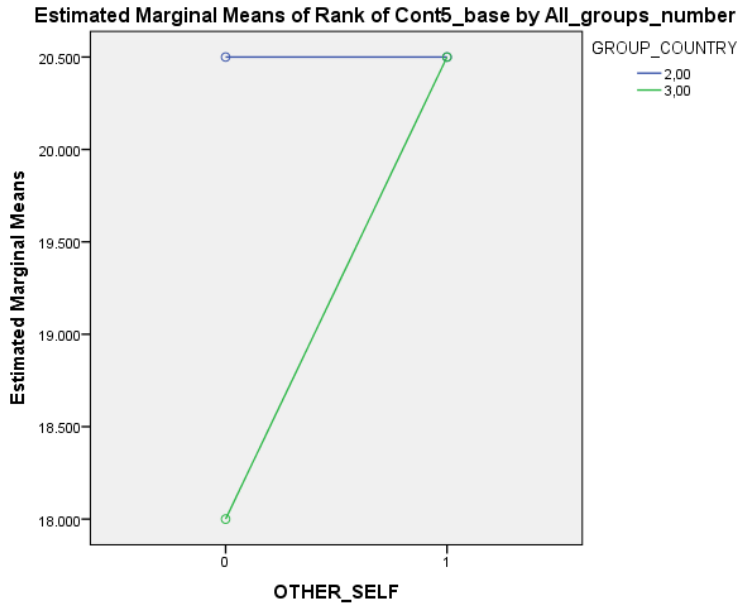

Figure 4.9 Hypothesis 6: Interaction plot

5. Discussion

In this section we will examine the results from the experiment and view the results in the light of other laboratory studies. We will also relate the results to the polio eradication debate and the difficulties of collaboration.

Comparing group A and country A

We have compared group A and country A in two ways: First in hypothesis 1 where we compared how fast the subjects eradicated the disease and secondly in hypothesis 4 where the first 5 contributions were compared to the expert recommended increase. In both hypotheses we expected country A to contribute less than group A. This assumption is supported by game theory in threshold public good arguing that within a group, the members are reluctant to contribute more than their "fair share" even though a higher contribution would be more beneficial. Barrett (2007; 2013) use the "greed factor" seen when donor countries contribute to disease eradication as an explanation of the difficulties of resource mobilization. Laboratory studies show also little cooperation between group members when contributing to a common threshold of public good (Cadsby & Maynes, 1999).

The results showed no significant difference regarding how fast the disease was eradicated. However, there was a significant difference between contribution increases when country A contributed 90% or more of group A's increase. Country A is therefore less willing to take the whole increase itself than group A. Tough the results give us some support for the eradication "game"; the connection is weak since what country A considers its "fair share" is quite high considering that the burden was shared by 5 countries. The weak difference also explains the lack of difference using post eradication years as the dependent variable: Contribution increase shortens the time to eradicate, but model testing shows that the effect of contribution on post eradication years is low and thus making the difference between the treatments lower.

There are two theories for explaining the little difference between country A and group A: First, subjects may be driven by the benefits of eradication rather than adjusting their contributions in proportion to other countries. A considerable reduction of the "greed factor" is inconsistent with evidence from global resource mobilization. During smallpox eradication, policy makers contributed mainly with the insufficient amounts agreed on by the donor

countries rather than raising their effort in line with expert estimations emphasizing the need for a higher short term cost (Barrett, 2007). This argument leads us to the second theory questioning the reliability of explaining real policy maker's decision with laboratory studies performed by students:

Decisions made in the experiment may be more personal motivated rather than focusing on the agenda for the policy maker. When subjects in a public good game are more collaborative than predicted, it can be explained by social and cultural norms or confusion (Andreoni, 1995). Giving money to charity is an example of a social and cultural norm where you will feel good if you contribute and feel guilty if you are not. Although sanctions feel bigger if they come from others, guilt is also experienced when there are no witnesses to your actions (Andreoni, 1995). In the experiment, subjects may have contributed more because they may interpret the game as an incentive to give money to charity rather than a self-regarding investment. Moxnes (2014) investigates the problem of using students to represent the policy makers and thus the general public opinion by comparing what climate policies subjects prefers. Comparing a group of master students to a balanced sample of the population shows that students value long term solutions higher than the general population (Moxnes, 2014). Using students in the experiment may therefor give a wrong impression of how disease eradication is perceived in the general population.

Policy makers' decisions are politically motivated. Using smallpox as an example, the benefits of eradication was unclear for politicians in donor countries leading to little support in favor of eradication. The eradication debate within donor countries was consequently non-present. One reason for making the goal unclear is that the benefit of eradication only affects future generations since the present generation has already been vaccinated. It may be difficult to convey voters to be in favor of a policy that would gain future generations and not themselves. Eradication would also destroy local vaccination companies and thus make eradication not favorable for a domestic group (Barrett, 2007). This supports an idea that even tough contributions are made on behalf of the whole group; they may be smaller than anticipated because of misunderstandings of the benefits of eradication.

We are not able to state if the subjects misunderstand the benefit of eradication or not. The fact that 28 of 31 subjects reached post eradication within the 19 years may indicate a

willingness to eradicate. But subjects may also just "do as they are told" by the expert recommendation without constructing their own policy.

Comparing self-regarding and other-regarding

Hypothesis 2,3 and 5 investigate the difference between two information treatments where "self-regarding" focus on the domestic benefit of eradication and "other-regarding" focus on the responsibility of giving aid to developing countries. We tested the difference between these independent variables using the following depended variables: post eradication years, net benefit and contributions relative to expert recommended increase the first 5 years. We assumed that subjects motivated by self-interest would eradicate faster, have higher net benefit and contribute more money than subjects motivated by others-regarding. In public good games, subjects are driven by their self-interest rather than thinking about the other actors (Jolly, 2004).

However, the result shows that there is no significant difference between self- and other-regarding. One reason why there is a lack of difference may be because others-regarding framing appeals more to the subjects than self-regarding. Giving money to developing countries may feel more important and familiar to the subjects than playing the role as a policy maker (Rege & Telle, 2004). Another reason is that the benefit of eradication is difficult to explain. Even though they are informed that eradication is the best option, it may be difficult to understand that there must be a considerable short term cost in order to enjoy the long term benefit (Thompson & Tebbens, 2007).

Effect of information on treatments

Hypothesis 6 compared the effect of information on country A and group A. We expected that the difference between others-regarding and self-regarding would be bigger in group A than country A. The rationale behind this argument is that policy makers seem to focus more on playing the eradication game with other donor countries rather than grasping the experts' statements of the enormous benefits of eradication (Barrett, 2007). However, the results show that the effect of information is the same for group A and country A. The benefits of eradication are therefore equally understood. There are two explanations for this behavior: Country A is less concerned by other countries' contributions than expected and therefore

have a bigger understanding of the benefits. It can also be explained by that the benefits of eradication is equally misunderstood between country A and group A (Thompson & Tebbens, 2007).

6. Conclusion

In this experiment, we have investigated how game theory and different ways to portray incentives to eradicate affects subjects' contributions and the time it takes to eradicate. The result showed that country A is less willing to increase the total contribution increase recommended compared to group A. But the difference is weak since country A is willing to contribute up to 90% of the group A's increase. In spite of the weak differences, the results stress the importance of collaboration when mobilizing towards a common threshold of public good. Smallpox was eradicated in spite of lack of collaboration .However, smallpox was discovered to be technical easier to eradicate than first estimated (Barrett, 2007). Polio eradication has proven to be technically more challenging than smallpox, generating a higher need for collaboration. In order for polio eradication to succeed, donor countries should commit to binding contributions in a mutual agreement.

Conveying policy makers about the importance of eradication might differ from how the information is presented. However, in this experiment, stressing the fact that eradication is the most cost-effective policy (self-regarding) did neither increase contribution nor give faster eradication. The lack of differences between the treatments may be explained by that students are driven by different incentives than policy makers. It may also be that students either understand the benefit of eradication even though the information does not emphasize it or reversely, the benefit of eradication is so difficult to understand that information emphasizing it will not have an effect.

For country A, playing against constructed countries is artificial and does not in fully extend portray the dynamics of how donor countries affects each other in terms of amount of contribution. For further research, we recommend either that other countries' contributions are a fraction of country A's, or to create a multiplayer game where each subject are in charge of their own countries' contribution. Using a different target group like a sample of the general population or policy makers may also give a different result. Subjects could also have different explanations of the benefit of eradication in order to find out if there are any misperceptions: For example using the eradication of smallpox as an example of the long term benefits having short term costs, or letting the subjects do multiple runs to see if learning has an effect.

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Appendix

Appendix A: Model equations

Only equations for group A treatment are listed. The difference between country A and group A model is described in the method chapter: In country A model, all the 5 countries have their own stock of discounted costs accumulated by a flow of fixed domestic vaccination costs and contributions. Contributions of country A is a number between 0 and 550 million US$2013 and is decided by the subject. Contributions from the other countries are a graph function described in appendix D. Post eradication budget is a fixed budget divided by the five countries with the following fractions: country A: 0.474697, country B 0.078373, country C: 0.083806, country D: 0.106945 and country E: 0.256179.

Group__A_discounted_costs(t) = Group__A_discounted_costs(t - dt) + (Expenditures) * dt
INIT Group__A_discounted_costs = 0
UNITS: US Dollars (USD)
INFLOWS:
Expenditures = IF Years_of__post_eradication > 7THEN 0ELSE
(Contributions_group_A__with_post_eradication+Country_A__v+Country_B__v+Country_C__v+Country_D_v+Country_E__v)*Discount_factor
UNITS: US dollars per year (USD/yr)

Infected_individuals(t) = Infected_individuals(t - dt) + (Infection_above_5_years + Infection_under_5_years - Recovery - Infected_deaths) * dt
INIT Infected_individuals = 15147.813058
INFLOWS:
Infection_above_5_years = IF Susceptibles__individuals_above_5*Force_of_infection*
(Infected_individuals/Population) <1 THEN 0 ELSESusceptibles__individuals_above_5*
Force_of_infection*(Infected_individuals/Population)
Infection_under_5_years = IFSusceptibles__individuals_under_5*Force_of_infection*
(Infected_individuals/Population) <1 THEN 0 ELSE Susceptibles__individuals_under_5*
Force_of_infection*(Infected_individuals/Population)
OUTFLOWS:
Recovery = Infected_individuals/Average__duration__of_infectivity
UNITS: person/yr
Infected_deaths = Infected_individuals*Fractional__death_rate
UNITS: person/yr

Removed_individuals(t) = Removed_individuals(t - dt) + (Routine__immunization + Recovery + Supplement_immunization_activity + Vaccine_derived_infection_recovery - Removed_deaths) * dt
INIT Removed_individuals = 307503891.224588
UNITS: people (person)
INFLOWS:
Routine__immunization = IF Start_post_eradication = 0 THEN
(Routine___vaccination_rate*Births*Efficacy)-
Births*Probability_of_vaccine_derived_infectionELSE
Recovery = Infected_individuals/Average__duration__of_infectivity
UNITS: person/yr

Supplement_immunization_activity = (IF Start_post_eradication = 0 THEN
PULSE((Susceptibles__individuals_under_5*Supplement_vaccination_rate*
Supplement__immunization_activity__efficacy)-(Susceptibles__individuals_under_5*
Supplement_vaccination_rate*
Probability_of_vaccine__derived_infection__after_one_dose),0,
Supplement__immunization_activity__schedule_NID)+
PULSE(((Susceptibles__individuals_under_5*Target_group__fraction_on_regional__imm
unization_day)*Supplement_vaccination_rate*
Supplement__immunization_activity__efficacy)-

Vaccine_derived_infection_recovery =
Vaccine_derived_infected_individuals/Average__duration__of_infectivity

OUTFLOWS:

Removed_deaths = Removed_individuals*Fractional__death_rate
UNITS: person/yr

Start_post_eradication(t) = Start_post_eradication(t - dt) + (Years_after__certifiaction) * dt
INIT Start_post_eradication = 0
UNITS: years (yr)
INFLOWS:

Years_after__certifiaction = IF Years_untill__certification > 3 THEN 1 ELSE 0
UNITS: Unitless

Susceptibles__individuals_above_5(t) = Susceptibles__individuals_above_5(t - dt) + (Aging -
Susceptible__above_5_deaths - Infection_above_5_years -
Non_recipient_vaccine__derived_infection__above_5_years) * dt
INIT Susceptibles__individuals_above_5 = 55354643.595612
INFLOWS:

Aging = Susceptibles__individuals_under_5/Aging_time
UNITS: person/yr

OUTFLOWS:

Susceptible__above_5_deaths =
Susceptibles__individuals_above_5*Fractional__death_rate

Infection_above_5_years = IF Susceptibles__individuals_above_5*Force_of_infection*
(Infected_individuals/Population) <1 THEN 0 ELSESusceptibles__individuals_above_5*
Force_of_infection*(Infected_individuals/Population)

Non_recipient_vaccine__derived_infection__above_5_years = IF
(Susceptibles__individuals_above_5*(Force_of_infection*0.88)*
(Vaccine_derived_infected_individuals/Population)) < 1THEN 0ELSE
(Susceptibles__individuals_above_5*(Force_of_infection*0.88)*

Susceptibles__individuals_under_5(t) = Susceptibles__individuals_under_5(t - dt) +
(Susceptible_births - Susceptible_under_5_deaths - Aging - Infection_under_5_years -
Supplement_immunization_activity - Non_recipient_vaccine__derived_infection__under_5_years) *
dt
INFLOWS:

Susceptible_births = Births-Routine__immunization-Recipient_vaccine__derived_infection
UNITS: person/yr

OUTFLOWS:

Susceptible_under_5_deaths =
Susceptibles__individuals_under_5*Fractional__death_rate

Aging = Susceptibles__individuals_under_5/Aging_time
UNITS: person/yr

Infection_under_5_years = IFSusceptibles__individuals_under_5*Force_of_infection*
(Infected_individuals/Population) <1 THEN 0 ELSE Susceptibles__individuals_under_5*
Force_of_infection*(Infected_individuals/Population)

Supplement_immunization_activity = (IF Start_post_eradication = 0 THEN
PULSE((Susceptibles__individuals_under_5*Supplement_vaccination_rate*
Supplement__immunization_activity__efficacy)-(Susceptibles__individuals_under_5*
Supplement_vaccination_rate*
Probability_of_vaccine__derived_infection__after_one_dose),0,
Supplement__immunization_activity__schedule_NID)+
PULSE(((Susceptibles__individuals_under_5*Target_group__fraction_on_regional__imm
unization_day)*Supplement_vaccination_rate*
Supplement__immunization_activity__efficacy)-

Non_recipient_vaccine__derived_infection__under_5_years = IF
Susceptibles__individuals_under_5*(Force_of_infection*0.88)*
(Vaccine_derived_infected_individuals/Population) <1 THEN 0ELSE
Susceptibles__individuals_under_5*(Force_of_infection*0.88)*

Vaccine_derived_infected_individuals(t) = Vaccine_derived_infected_individuals(t - dt) +
(Non_recipient_vaccine__derived_infection__above_5_years +
Recipient_vaccine__derived_infection +
Non_recipient_vaccine__derived_infection__under_5_years - Vaccine_derived_infection_recovery -
Vaccine_derived__infected_deaths) * dt
INFLOWS:
Non_recipient_vaccine__derived_infection__above_5_years = IF
(Susceptibles__individuals_above_5*(Force_of_infection*0.88)*
(Vaccine_derived_infected_individuals/Population)) < 1THEN 0ELSE
(Susceptibles__individuals_above_5*(Force_of_infection*0.88)*
Recipient_vaccine__derived_infection = IF Start_post_eradication = 0 THEN
PULSE(Susceptibles__individuals_under_5*Supplement_vaccination_rate*Probability_of_v
accine__derived_infection__after_one_dose,0,
Supplement__immunization_activity__schedule_NID)+
PULSE(Susceptibles__individuals_under_5*Target_group__fraction_on_regional__immun
ization_day*Supplement_vaccination_rate*Probability_of_vaccine__derived_infection__after
_one_dose,0.25,Supplement__immunization_activity__schedule_RID)+
Non_recipient_vaccine__derived_infection__under_5_years = IF
Susceptibles__individuals_under_5*(Force_of_infection*0.88)*
(Vaccine_derived_infected_individuals/Population) <1 THEN 0ELSE
Susceptibles__individuals_under_5*(Force_of_infection*0.88)*
OUTFLOWS:
Vaccine_derived_infection_recovery =
Vaccine_derived_infected_individuals/Average__duration__of_infectivity
Vaccine_derived__infected_deaths =
Vaccine_derived_infected_individuals*Fractional__death_rate

Years_of__post_eradication(t) = Years_of__post_eradication(t - dt) +
(Counting_post_eradication__years) * dt
INIT Years_of__post_eradication = 0
INFLOWS:
Counting_post_eradication__years = IF Start_post_eradication = 0 THEN 0 ELSE 1
UNITS: Unitless

Years_untill__certification(t) = Years_untill__certification(t - dt) + (Counting_years__to_certification -
Disruption_of_years_untill_certification) * dt
INIT Years_untill__certification = 0
INFLOWS:
Counting_years__to_certification = Start_counting_years_to_certification
UNITS: Unitless
OUTFLOWS:
Disruption_of_years_untill_certification = iF Start_counting_years_to_certification = 0 THEN
Years_untill__certification ELSE 0

Acute_Flaccid_Paralysis_surveillance_cost_per_child = 0.09
UNITS: usd/person-yr

Acute_Flaccid_Paralysis_surveillance_cost_per_year = Population*
(Percentace_of__population__under_15/100)
*Acute_Flaccid_Paralysis_surveillance_cost_per_child

Aging_time = 5
UNITS: years (yr)

Average__duration__of_infectivity = 0.0958904109589041
UNITS: years (yr)

Baseline_budget = 317659433.7
UNITS: US dollars per year (USD/yr)

Births = Population*Fractional__birth_rate
UNITS: person/year

Contributions = 0
UNITS: US dollars per year (USD/yr)

UNITS: US dollars per year (USD/yr)
Contributions_from_all__countries_including__vaccination_cease = (IF Years_of__post_eradication > 7THEN 0 ELSE Total_contributions)
Contributions_group_A__with_post_eradication = IF Start_post_eradication > 0 THEN Post_eradication_budgetELSE (Contributions*1000000)
Country_A_vaccination_costs_after_70_years_discounted = 6679705046.6
UNITS: US Dollars (USD)
Country_A__v = 228183465.3
UNITS: US dollars per year (USD/yr)
Country_B__v = 20537763.91
UNITS: US dollars per year (USD/yr)
Country_C__v = 37271751.18
UNITS: US dollars per year (USD/yr)
Country_D_v = 57292639.63
UNITS: US dollars per year (USD/yr)
Country_E__v = 40251048.99
UNITS: US dollars per year (USD/yr)
Discount_factor = exp(-Discount_rate*time)
UNITS: Unitless
Discount_rate = 0.03
UNITS: Unitless
Effects_of_infecteds_on_future_country_a_costs = GRAPH(Infected_individuals)
(5.62, 1e+009), (31.9, 1.7e+009), (845, 2.2e+009), (158840, 2.6e+009)
UNITS: US Dollars (USD)
Effects_of_infecteds_on_future_other_countries_costs = GRAPH(Infected_individuals)
(5.62, 7.9e+008), (31.9, 1.4e+009), (845, 1.8e+009), (158840, 2.2e+009)
UNITS: US Dollars (USD)
Effects_of_post_eradication_on__future_other_countries_costs = GRAPH(Years_of__post_eradication)
(0.8, 6.3e+008), (3.70, 3.5e+008), (5.70, 1.5e+008), (6.90, 1.7e+007), (7.00, 0.00)
Effects_of__post_eradication_on__future_country_a_costs = GRAPH(Years_of__post_eradication)
(0.8, 8.5e+008), (3.70, 4.7e+008), (5.70, 2e+008), (6.90, 2.2e+007), (7.00, 0.00)
UNITS: US Dollars (USD)
Effect_of_infecteds_on_future_group_A__costs = Effects_of_infecteds_on_future_country_a_costs+Effects_of_infecteds_on_future_other_countries_costs
Effect_of_post_eradication_years_on_future_group_A_costs = Effects_of__post_eradication_on__future_country_a_costs+Effects_of_post_eradication_on__future_other_countries_costs
Efficacy = GRAPH(Normalized__vaccination__budget)
(0.00, 0.00), (0.0145, 0.6), (0.029, 0.6), (0.0435, 0.6), (0.058, 0.6), (0.0725, 0.6), (0.087, 0.6), (0.102, 0.6), (0.116, 0.6), (0.131, 0.6), (0.145, 0.6), (0.16, 0.6), (0.174, 0.6), (0.189, 0.6), (0.203, 0.6), (0.218, 0.6), (0.232, 0.6), (0.247, 0.6), (0.261, 0.6), (0.276, 0.6), (0.29, 0.6), (0.305, 0.6), (0.319, 0.6), (0.334, 0.6), (0.348, 0.6), (0.363, 0.6), (0.377, 0.6), (0.392, 0.6), (0.406, 0.6), (0.421, 0.6), (0.435, 0.6), (0.45, 0.6), (0.464, 0.6), (0.479, 0.6), (0.493, 0.6), (0.508, 0.6), (0.522, 0.6), (0.537, 0.6), (0.551, 0.6), (0.566, 0.6), (0.58, 0.6), (0.595, 0.6), (0.609, 0.6), (0.624, 0.6), (0.638, 0.6), (0.653, 0.6), (0.667, 0.6), (0.682,
Force_of_infection = 62.63
UNITS: Unitless
Fractional__birth_rate = 0.02
UNITS: 1/year
Fractional__death_rate = 0.02
UNITS: 1/year
Fraction_of_paralytic_cases_per_infected = 0.005
UNITS: Unitless
group__A_net_benefit = (Other_countries_vaccination_costs_after_70_years_discounted+Country_A_vaccination_costs_after_70_years_discounted)-Long_term__group__A_costs
UNITS: US Dollars (USD)
IPV_cost_at_minumum__post_eradication__vaccination_rate = 12.006
UNITS: USD/person

UNITS: USD/person
Long_term__group__A_costs = IF Years_of__post_eradication > 0 THEN Effect_of_post_eradication_years_on_future_group_A_costs+Group__A_discounted_costsELSE Effect_of_infecteds_on_future_group_A__costs+Group__A_discounted_costs
UNITS: US Dollars (USD)
Normalized__vaccination__budget = (Contributions_from_all__countries_including__vaccination_cease-Acute_Flaccid_Paralysis_surveillance_cost_per_year)/Baseline_budget
Other_countries_vaccination_costs_after_70_years_discounted = 4547715924.39
UNITS: US Dollars (USD)
Paralytic_cases = (Infection_above_5_years+Infection_under_5_years)*Fraction_of_paralytic_cases_per_infected
Perceived_incidence = DELAY(Paralytic_cases,1)
UNITS: person/yr
Percentace_of__population__under_15 = 42.41171
UNITS: Unitless
Population = (Susceptibles__individuals_above_5+Susceptibles__individuals_under_5+Infected_individuals+Removed_individuals+Vaccine_derived_infected_individuals)
UNITS: people (person)
Post_eradication_budget = Post_eradication__routine_vaccination__rate*IPV_cost_at_minumum__post_eradication__vaccin
Post_eradication__efficacy = 0.9
UNITS: Unitless
Post_eradication__routine_vaccination__rate = IF Years_of__post_eradication > 7THEN 0ELSE1
UNITS: Unitless
Probability_of_vaccine_derived_infection = GRAPH(Normalized__vaccination__budget)
(0.00, 0.00), (0.0145, 0.000146), (0.029, 0.000146), (0.0435, 0.000146), (0.058, 0.000146), (0.0725, 0.000146), (0.087, 0.000146), (0.102, 0.000146), (0.116, 0.000146), (0.131, 0.000146), (0.145, 0.000146), (0.16, 0.000146), (0.174, 0.000146), (0.189, 0.000146), (0.203, 0.000146), (0.218, 0.000146), (0.232, 0.000146), (0.247, 0.000146), (0.261, 0.000146), (0.276, 0.000146), (0.29, 0.000146), (0.305, 0.000146), (0.319, 0.000146), (0.334, 0.000146), (0.348, 0.000146), (0.363, 0.000146), (0.377, 0.000146), (0.392, 0.000146), (0.406, 0.000146), (0.421, 0.000146), (0.435, 0.000146), (0.45, 0.000146), (0.464, 0.000146), (0.479, 0.000146), (0.493, 0.000146), (0.508, 0.000146), (0.522, 0.000146), (0.537, 0.000146), (0.551, 0.000146), (0.566, 0.000146), (0.58, 0.000146), (0.595, 0.000146), (0.609, 0.000146), (0.624, 0.000146), (0.638, 0.000146), (0.653,
Probability_of_vaccine__derived_infection__after_one_dose = 4.87805e-05
UNITS: Unitless
Routine___vaccination_rate = GRAPH(Normalized__vaccination__budget)
(0.00, 0.00), (0.0145, 0.01), (0.029, 0.02), (0.0435, 0.03), (0.058, 0.04), (0.0725, 0.05), (0.087, 0.06), (0.102, 0.07), (0.116, 0.08), (0.131, 0.09), (0.145, 0.1), (0.16, 0.11), (0.174, 0.12), (0.189, 0.13), (0.203, 0.14), (0.218, 0.15), (0.232, 0.16), (0.247, 0.17), (0.261, 0.18), (0.276, 0.19), (0.29, 0.2), (0.305, 0.21), (0.319, 0.22), (0.334, 0.23), (0.348, 0.24), (0.363, 0.25), (0.377, 0.26), (0.392, 0.27), (0.406, 0.28), (0.421, 0.29), (0.435, 0.3), (0.45, 0.31), (0.464, 0.32), (0.479, 0.33), (0.493, 0.34), (0.508, 0.35), (0.522, 0.36), (0.537, 0.37), (0.551, 0.38), (0.566, 0.39), (0.58, 0.4), (0.595, 0.41), (0.609, 0.42), (0.624, 0.43), (0.638, 0.44), (0.653, 0.45), (0.667, 0.46), (0.682, 0.47), (0.696, 0.48),
Simulation_stop = TIME
UNITS: years (yr)
Start_counting_years_to_certification = IF Perceived_incidence < 1 THEN 1 ELSE 0
UNITS: Unitless
Supplement_vaccination_rate = GRAPH(Normalized__vaccination__budget)
(0.00, 0.00), (0.0145, 0.0118), (0.029, 0.0235), (0.0435, 0.0353), (0.058, 0.0471), (0.0725, 0.0588), (0.087, 0.0706), (0.102, 0.0824), (0.116, 0.0941), (0.131, 0.106), (0.145, 0.118), (0.16, 0.129), (0.174, 0.141), (0.189, 0.153), (0.203, 0.165), (0.218, 0.176), (0.232, 0.188), (0.247, 0.2), (0.261, 0.212), (0.276, 0.224), (0.29, 0.235), (0.305, 0.247), (0.319, 0.259), (0.334, 0.271), (0.348, 0.282), (0.363, 0.294), (0.377, 0.306), (0.392, 0.318), (0.406, 0.329), (0.421, 0.341), (0.435, 0.353), (0.45, 0.365), (0.464, 0.376), (0.479, 0.388), (0.493, 0.4), (0.508, 0.412), (0.522, 0.424), (0.537, 0.435), (0.551, 0.447), (0.566, 0.459), (0.58, 0.471), (0.595, 0.482), (0.609, 0.494), (0.624, 0.506), (0.638,
Supplement__immunization_activity__efficacy = 0.3
UNITS: Unitless

- Supplement__immunization_activity__schedule_NID = 0.25
  UNITS: Unitless
- Supplement__immunization_activity__schedule_RID = 0.25
  UNITS: Unitless
- Target_group__fraction_on_regional__immunization_day = 0.5
  UNITS: Unitless
- Total_contributions = Contributions_group_A__with_post_eradication
  UNITS: US dollars per year (USD/yr)

Appendix B: Vaccination budget graph functions

Normalized vaccination budget	Routine vaccination rate	Supplement vaccination rate	Probability of vaccine derived infection	Efficacy
0.0000000000	0	0	0	0.00
0.0145005145	0.01	0.011764706	0.000146341	0.60
0.0290010289	0.02	0.023529412	0.000146341	0.60
0.0435015434	0.03	0.035294118	0.000146341	0.60
0.0580020579	0.04	0.047058824	0.000146341	0.60
0.0725025723	0.05	0.058823529	0.000146341	0.60
0.0870030868	0.06	0.070588235	0.000146341	0.60
0.1015036013	0.07	0.082352941	0.000146341	0.60
0.1160041158	0.08	0.094117647	0.000146341	0.60
0.1305046302	0.09	0.105882353	0.000146341	0.60
0.1450051447	0.1	0.117647059	0.000146341	0.60
0.1595056592	0.11	0.129411765	0.000146341	0.60
0.1740061736	0.12	0.141176471	0.000146341	0.60
0.1885066881	0.13	0.152941176	0.000146341	0.60
0.2030072026	0.14	0.164705882	0.000146341	0.60
0.2175077170	0.15	0.176470588	0.000146341	0.60
0.2320082315	0.16	0.188235294	0.000146341	0.60
0.2465087460	0.17	0.2	0.000146341	0.60
0.2610092604	0.18	0.211764706	0.000146341	0.60
0.2755097749	0.19	0.223529412	0.000146341	0.60
0.2900102894	0.2	0.235294118	0.000146341	0.60
0.3045108039	0.21	0.247058823	0.000146341	0.60
0.3190113183	0.22	0.258823529	0.000146341	0.60
0.3335118328	0.23	0.270588235	0.000146341	0.60
0.3480123473	0.24	0.282352941	0.000146341	0.60
0.3625128617	0.25	0.294117647	0.000146341	0.60
0.3770133762	0.26	0.305882353	0.000146341	0.60
0.3915138907	0.27	0.317647059	0.000146341	0.60
0.4060144051	0.28	0.329411765	0.000146341	0.60
0.4205149196	0.29	0.341176471	0.000146341	0.60
0.4350154341	0.3	0.352941176	0.000146341	0.60
0.4495159486	0.31	0.364705882	0.000146341	0.60
0.4640164630	0.32	0.376470588	0.000146341	0.60
0.4785169775	0.33	0.388235294	0.000146341	0.60
0.4930174920	0.34	0.4	0.000146341	0.60
0.5075180064	0.35	0.411764706	0.000146341	0.60
0.5220185209	0.36	0.423529412	0.000146341	0.60
0.5365190354	0.37	0.435294118	0.000146341	0.60
0.5510195498	0.38	0.447058823	0.000146341	0.60
0.5655200643	0.39	0.458823529	0.000146341	0.60

0.5800205788	0.4	0.470588235	0.000146341	0.60
0.5945210932	0.41	0.482352941	0.000146341	0.60
0.6090216077	0.42	0.494117647	0.000146341	0.60
0.6235221222	0.43	0.505882353	0.000146341	0.60
0.6380226367	0.44	0.517647059	0.000146341	0.60
0.6525231511	0.45	0.529411765	0.000146341	0.60
0.6670236656	0.46	0.54117647	0.000146341	0.60
0.6815241801	0.47	0.552941176	0.000146341	0.60
0.6960246945	0.48	0.564705882	0.000146341	0.60
0.7105252090	0.49	0.576470588	0.000146341	0.60
0.7250257235	0.5	0.588235294	0.000146341	0.60
0.7395262379	0.51	0.6	0.000146341	0.60
0.7540267524	0.52	0.611764706	0.000146341	0.60
0.7685272669	0.53	0.623529412	0.000146341	0.60
0.7830277813	0.54	0.635294118	0.000146341	0.60
0.7975282958	0.55	0.647058823	0.000146341	0.60
0.8120288103	0.56	0.658823529	0.000146341	0.60
0.8265293248	0.57	0.670588235	0.000146341	0.60
0.8410298392	0.58	0.682352941	0.000146341	0.60
0.8555303537	0.59	0.694117647	0.000146341	0.60
0.8713999874	0.6	0.705882353	0.000146341	0.60
0.8873152584	0.61	0.717647059	0.000146341	0.60
0.9032761667	0.62	0.729411765	0.000146341	0.60
0.9192827123	0.63	0.74117647	0.000146341	0.60
0.9353348952	0.64	0.752941176	0.000146341	0.60
0.9514327155	0.65	0.764705882	0.000146341	0.60
0.9675761730	0.66	0.776470588	0.000146341	0.60
0.9837652678	0.67	0.788235294	0.000146341	0.60
1.0000000000	0.68	0.8	0.000146341	0.60
1.0162803695	0.69	0.811764706	0.000146341	0.60
1.0326063762	0.7	0.823529412	0.000146341	0.60
1.0489780203	0.71	0.835294117	0.000146341	0.60
1.0653953017	0.72	0.847058823	0.000146341	0.60
1.0818582204	0.73	0.858823529	0.000146341	0.60
1.0983667764	0.74	0.870588235	0.000146341	0.60
1.1149209697	0.75	0.882352941	0.000146341	0.60
1.1578727370	0.76	0.894117647	0.000146341	0.60
1.2102664959	0.77	0.905882353	0.000146341	0.60
1.2636254130	0.78	0.917647059	0.000146341	0.60
1.3179494883	0.79	0.929411765	0.000146341	0.60
1.4216798902	0.8[1]	0.94117647	0.000140244	0.63
1.4312104812	0.8[1]	0.94117647	0.000134146	0.65
1.4407410723	0.8[1]	0.94117647	0.000128049	0.68
1.4502716633	0.8[1]	0.94117647	0.000121951	0.70
1.4598022544	0.8[1]	0.94117647	0.000115854	0.73

1.4693328454	0.8[1]	0.94117647	0.000109756	0.75
1.4788634364	0.8[1]	0.94117647	0.000103659	0.78
1.4883940275	0.8[1]	0.94117647	9.7561E-05	0.80
1.5482442233	0.81	0.952941176	9.7561E-05	0.80
1.6091128209	0.82	0.964705882	9.7561E-05	0.80
1.6709998203	0.83	0.976470588	9.7561E-05	0.80
1.7339052213	0.84	0.988235294	9.7561E-05	0.80
1.7978290241	0.85	1	9.7561E-05	0.80
1.8446145221	0.86	1	9.7561E-05	0.80
1.8524192623	0.87	1	9.7561E-05	0.80
1.8603228833	0.88	1	9.7561E-05	0.80
1.8683253852	0.89	1	9.7561E-05	0.80
1.8764267679	0.9	1	9.7561E-05	0.80
1.8846270314	0.91	1	9.7561E-05	0.80
1.8929261758	0.92	1	9.7561E-05	0.80
1.9013242010	0.93	1	9.7561E-05	0.80
1.9098211070	0.94	1	9.7561E-05	0.80
1.9184168938	0.95	1	9.7561E-05	0.80
1.9271115615	0.96	1	9.7561E-05	0.80
1.9359051100	0.97	1	9.7561E-05	0.80
1.9447975394	0.98	1	9.7561E-05	0.80
1.9537888496	0.99	1	9.7561E-05	0.80
1.9628790406	1	1	9.7561E-05	0.80

[1]

Normalized vaccination budget	**3 OPV vaccination rate**	**1 IPV, 2 OPV vaccination rate**
1.4216798902	0.7	0.1
1.4312104812	0.6	0.2
1.4407410723	0.5	0.3
1.4502716633	0.4	0.4
1.4598022544	0.3	0.5
1.4693328454	0.2	0.6
1.4788634364	0.1	0.7

Appendix C: Domestic vaccination costs for donor countries

	United States (country A)	United Kingdom (country E)	Japan (country D)
Births 2011[2]	4322000	761000	1073000
3 IPV cost per dose in combination vaccine US$2013[3]	12,95	12,95	12,95
Unvaccination costs US$2013[3]	3,1067	3,1067	3,1067
Wastage [3]	0,05	0,05	0,05
Doses	3	3	3
Immunization coverage[3]	0,94	0,94	0,94
Cost per polio immunized child[3]	50,1126	50,1126	50,1126
Population 2011[4]	311587816	62752472	127817277
Proportion of population under 15 2011[4]	19,73	17,54	13,20
Population under 15	61480018,8	11008754,27	16870172,56
AFP cost per child US$2013[3]	0,4	0,4	0,4
AFP cost US$2013	24592007,52	4403501,71	6748069,023
Annual vaccination cost	203591457,8	35847547,28	50544570,61

	Germany (country C)	Canada (country B)
Births 2011[2]	699000	388000
3 IPV cost per dose in combination vaccine US$2013[3]	12,95	12,95
Unvaccination costs US$2013[3]	3,1067	3,1067
Wastage [3]	0,05	0,05
Doses	3	3
Immunization coverage[3]	0,94	0,94
Cost per polio immunized child[3]	50,1126	50,1126
Population 2011[4]	81797673	34483975
Proportion of population under 15 2011[4]	13,28	16,39
Population under 15	10861915,57	5651741,101
AFP cost per child US$2013[3]	0,4	0,4
AFP cost US$2013	4344766,228	2260696,44
Annual vaccination cost	32926984,96	18277067,47

[2] UN Population Division 2013

[3] Tebbens et. al., 2006

[4] World Bank 2014

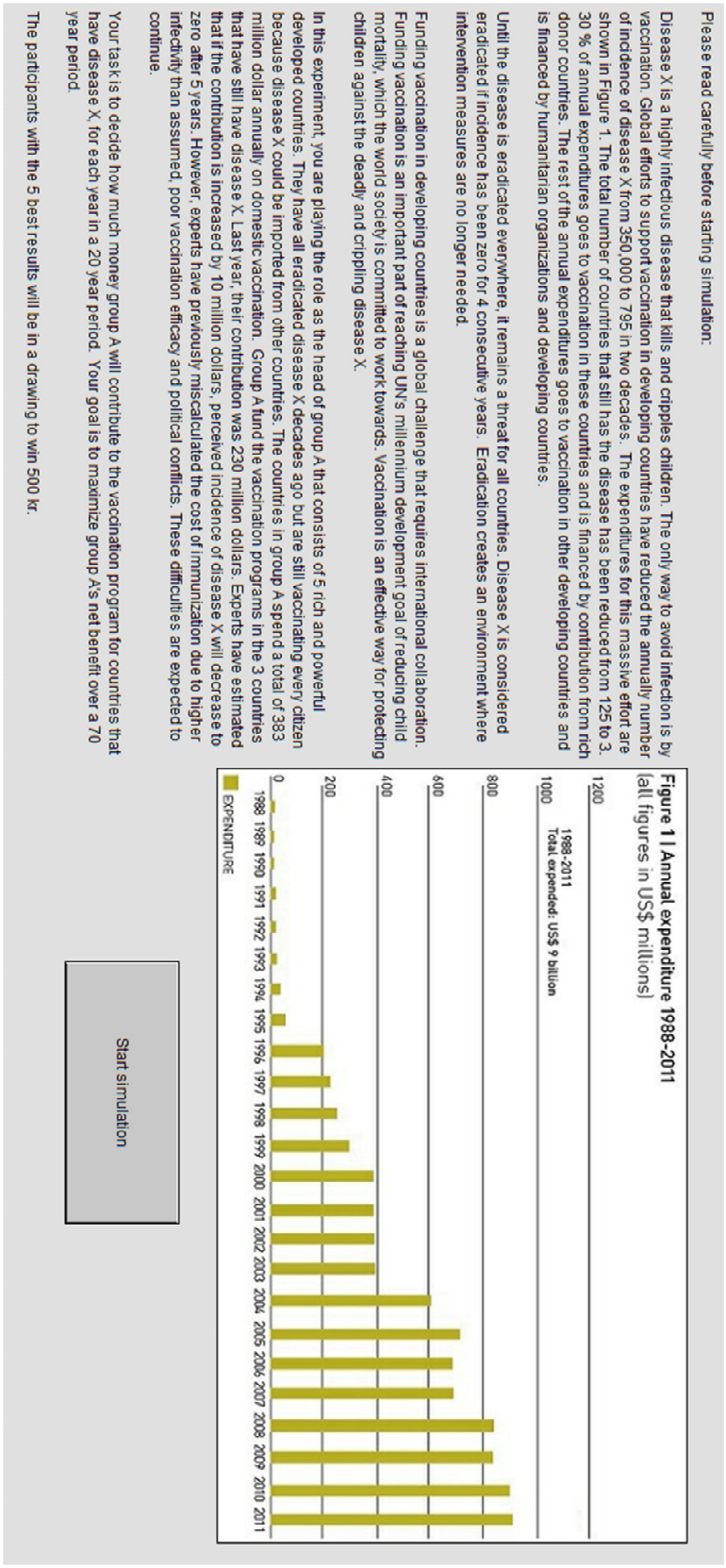
Appendix D: Country B, C, D and E contributions

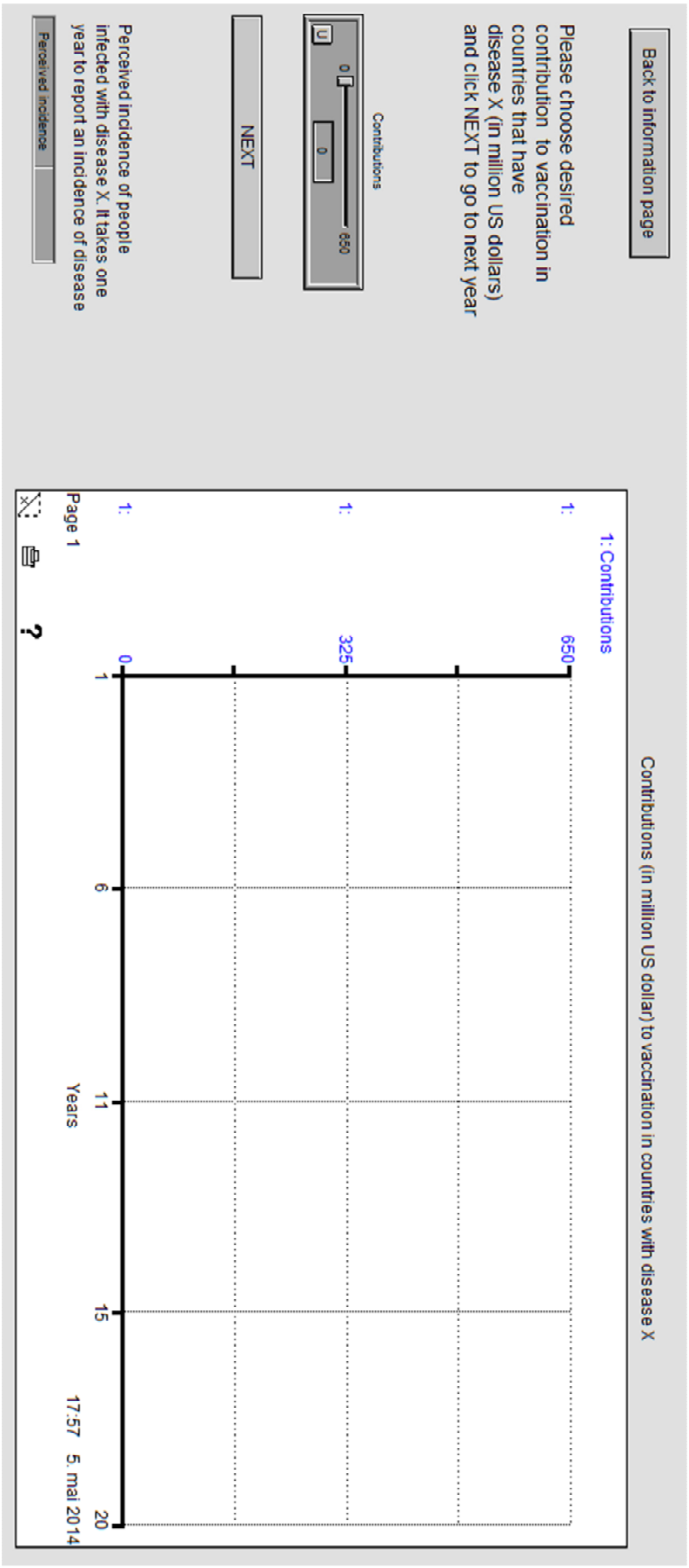
Year	Country B contributions	Country C contributions	Country D contributions	Country E contributions
0	29,929	31,3594	43,2933	43,385
1	22,5603	28,6897	38,2347	77,7112
2	29,4807	27,1383	38,4546	44,7589
3	22,5306	24,4369	19,2015	66,4661
4	19,1063	14,268	37,2519	67,2959
5	30,2869	24,203	18,0113	56,891
6	31,6064	22,5422	45,0361	96,4255
7	33,9049	32,4905	17,362	114,331
8	35,7976	21,7861	36,5337	87,8784
9	31,8119	32,0057	45,9432	42,6337
10	33,977	30,6739	28,157	74,0083
11	18,9261	16,2464	45,7377	67,5455
12	33,4037	33,7068	46,557	86,7509
13	35,1217	31,3854	47,2195	75,308
14	34,8931	29,9402	45,3865	90,695
15	36,2906	38,945	34,6414	118,411
16	34,0508	22,9623	18,6689	87,751
17	35,9415	19,7398	38,8074	85,6003
18	22,0236	36,8284	34,4731	75,3447
19	32,1705	21,3918	29,5355	91,9467
20	30,9409	20,2338	38,8429	57,3109
21	35,0618	18,0667	35,8021	43,4644
22	13,9486	23,6366	28,1307	70,8028
23	36,0539	21,0456	29,6788	82,2403
24	17,6667	36,0096	28,9293	50,4535
25	26,5828	13,5379	45,7498	86,3885
26	12,9524	33,458	41,982	112,822
27	18,2165	15,1292	22,0047	91,4991
28	30,0017	16,2845	21,8003	92,5807
29	34,1289	18,602	20,7344	97,6322
30	14,6287	21,621	45,3035	111,679
31	25,4473	28,2367	33,6004	117,559
32	22,7127	22,0418	35,3696	116,542
33	28,2868	36,5344	43,6181	41,8839
34	33,5311	15,7332	19,5434	112,926
35	34,8109	37,255	50,2166	102,655
36	17,981	19,8962	47,1883	66,9695
37	13,3774	27,1383	26,9925	46,7935
38	22,5985	37,3829	49,9313	105,749

39	33,0977	22,0357	39,6167	64,5385
40	30,6447	17,1754	46,6048	106,87
41	32,8154	36,9545	46,8902	78,0765
42	24,27	18,1917	26,4707	101,753
43	30,0805	15,9611	24,6791	96,8155
44	30,1959	32,5397	27,6558	43,0551
45	22,2659	22,8133	33,5291	108,418
46	31,8018	25,3824	36,0912	122,051
47	15,4332	19,8091	31,5606	60,5053
48	27,5822	28,9866	20,7752	41,1325
49	31,0182	33,0105	44,189	119,199
50	16,7413	38,5683	40,6958	97,8969
51	14,7843	33,8341	37,3385	60,7922
52	15,2826	25,0103	26,9455	62,7681
53	31,5084	39,7793	26,4482	114,356
54	26,4186	16,3264	22,379	117,897
55	31,1124	24,0835	19,4513	49,5902
56	29,7829	30,7579	38,6424	50,9833
57	30,0782	14,572	32,6068	71,8494
58	32,1553	32,9508	21,2468	52,9278
59	26,1114	20,8527	20,6438	80,665
60	27,8869	14,8721	17,6212	102,615
61	34,9099	18,72	36,4171	81,4967
62	19,5063	28,7015	38,1849	92,8936
63	18,1168	26,9533	42,2844	63,5122
64	35,4508	27,9091	32,8083	87,6618
65	21,9205	36,5162	43,1115	106,8
66	28,383	26,2507	40,1559	89,8719
67	32,9949	16,23	42,5737	62,2865
68	36,2525	30,0105	22,7938	55,1831
69	26,6589	28,9627	17,7842	77,8388

Appendix E: Experiment interface

Group 1: Others regarding, group A (OTGR)




Back to information page
Please choose desired contribution to vaccination in countries that have disease X (in million US dollars) and click NEXT to go to next year
Contributions
0
650
0
NEXT
Perceived incidence of people infected with disease X. It takes one year to report an incidence of disease
Perceived incidence
Contributions (in million US dollar) to vaccination in countries with disease X
1: Contributions
650
325
0
1
6
11
15
20
Years
Page 1
17:57 5. mai 2014

Group 2: Self-regarding, group A (SEGR)

Please read carefully before starting simulation:

Disease X is a highly infectious disease that kills and cripples children. The only way to avoid infection is by vaccination. Global efforts to support vaccination in developing countries have reduced the annually number of incidence of disease X from 350,000 to 795 in two decades. The expenditures for this massive effort are shown in Figure 1. The total number of countries that still has the disease has been reduced from 125 to 3. 30 % of annual expenditures goes to vaccination in these countries and is financed by contribution from rich donor countries. The rest of the annual expenditures goes to vaccination in other developing countries and is financed by humanitarian organizations and developing countries.

Until the disease is eradicated everywhere, it remains a threat for all countries. Disease X is considered eradicated if incidence has been zero for 4 consecutive years. Eradication creates an environment where intervention measures are no longer needed.

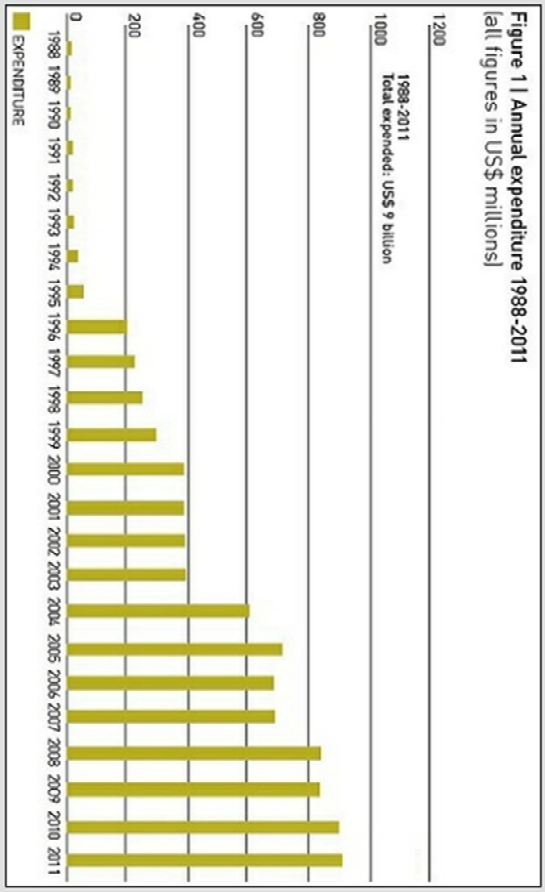
Global eradication is the most cost-effective and permanent way to protect country A against importing disease X. No single country can be safe from disease X until all countries are free of the disease and the disease is eradicated.

In this experiment, you are playing the role as the head of group A that consists of 5 rich and powerful developed countries. They have all eradicated disease X decades ago but are still vaccinating every citizen because disease X could be imported from other countries. The countries in group A spend a total of 383 million dollar annually on domestic vaccination. Group A fund the vaccination programs in the 3 countries that still have disease X. Last year, their contribution was 230 million dollars. Experts have estimated that if the contribution is increased by 10 million dollars, perceived incidence of disease X will decrease to zero after 5 years. However, experts have previously miscalculated the cost of immunization due to higher infectivity than assumed, poor vaccination efficacy and political conflicts. These difficulties are expected to continue.

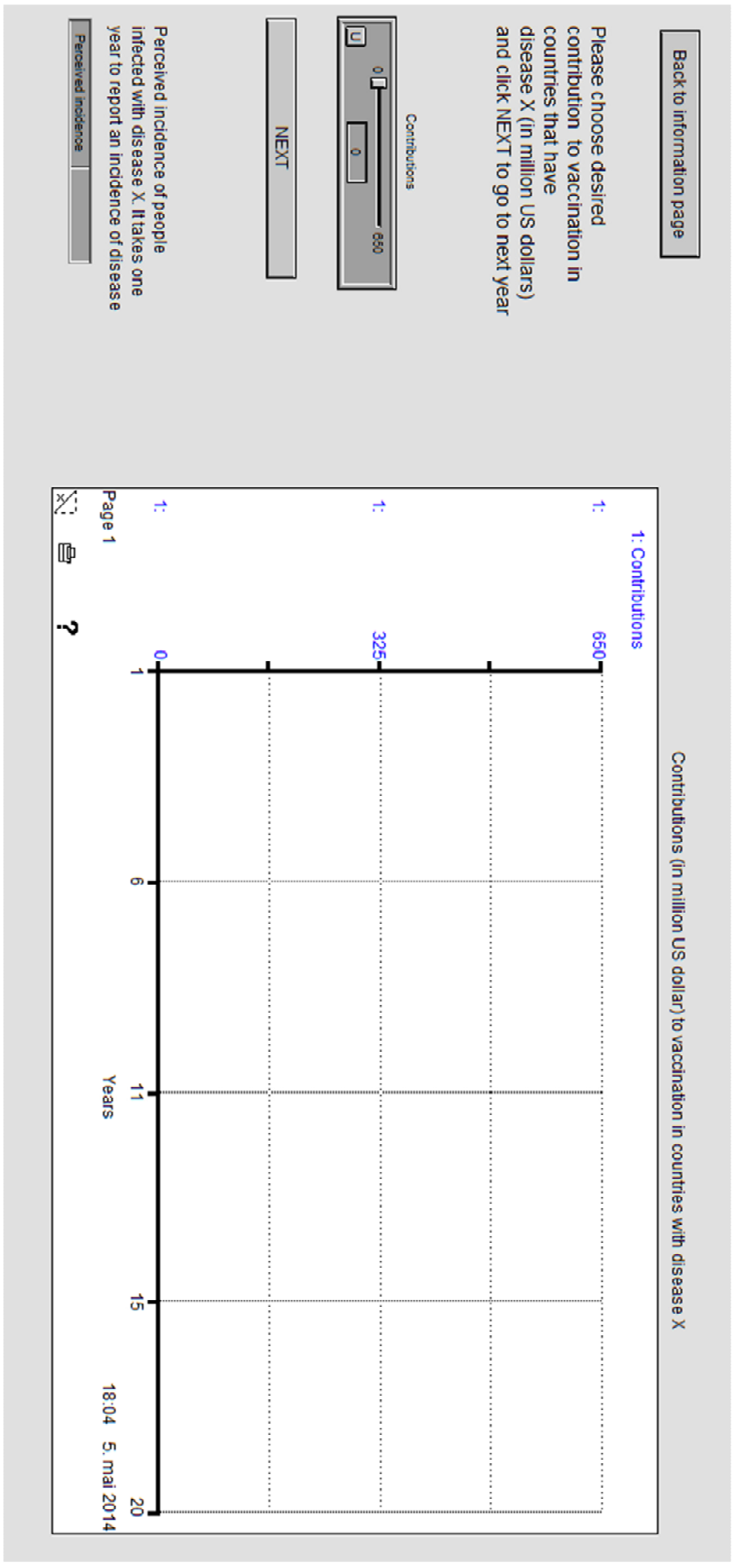
Your task is to decide how much money group A will contribute to the vaccination program for countries that have disease X, for each year in a 20 year period. Your goal is to maximize group A's net benefit over a 70 year period.

The participants with the 5 best results will be in a drawing to win 500 kr.

Figure 1 | Annual expenditure 1988-2011
(all figures in US$ millions)



Start simulation


Back to information page
Please choose desired contribution to vaccination in countries that have disease X (in million US dollars) and click NEXT to go to next year
Contributions
0
650
0
NEXT
Perceived incidence of people infected with disease X. It takes one year to report an incidence of disease
Perceived incidence
Contributions (in million US dollar) to vaccination in countries with disease X
1: Contributions
650
325
0
1
6
11
15
20
Years
Page 1
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Group 3: Others regarding, country A (OTCO)

Please read carefully before starting simulation:

Disease X is a highly infectious disease that kills and cripples children. The only way to avoid infection is by vaccination. Global efforts to support vaccination in developing countries have reduced the annually number of incidence of disease X from 350 000 to 795 in two decades. The expenditures for this massive effort are shown in Figure 1. The total number of countries that still has the disease has been reduced from 125 to 3. 30 % of annual expenditures goes to vaccination in these countries and is financed by contribution from rich donor countries. The rest of the annual expenditures goes to vaccination in other developing countries and is financed by humanitarian organizations and developing countries.

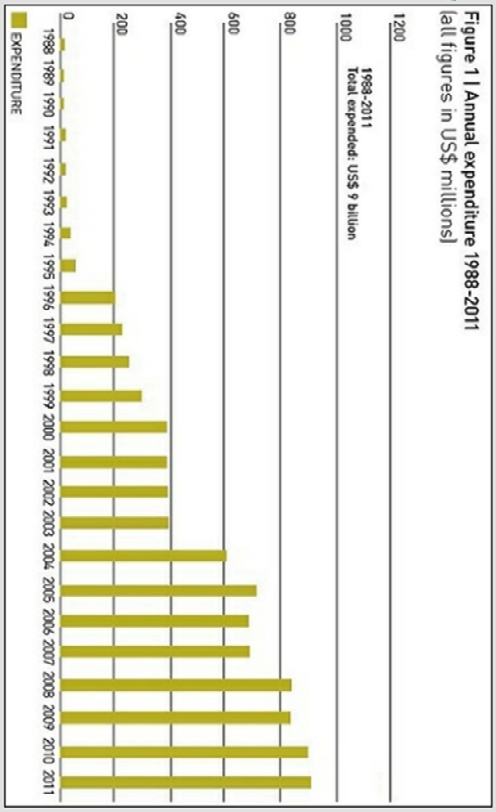
Until the disease is eradicated everywhere, it remains a threat for all countries. Disease X is considered eradicated if incidence has been zero for 4 consecutive years. Eradication creates an environment where intervention measures are no longer needed.

Funding vaccination in developing countries is a global challenge that requires international collaboration. Funding vaccination is an important part of reaching UN's millennium development goal of reducing child mortality, which the world society is committed to work towards. Vaccination is an effective way for protecting children against the deadly and crippling disease X.

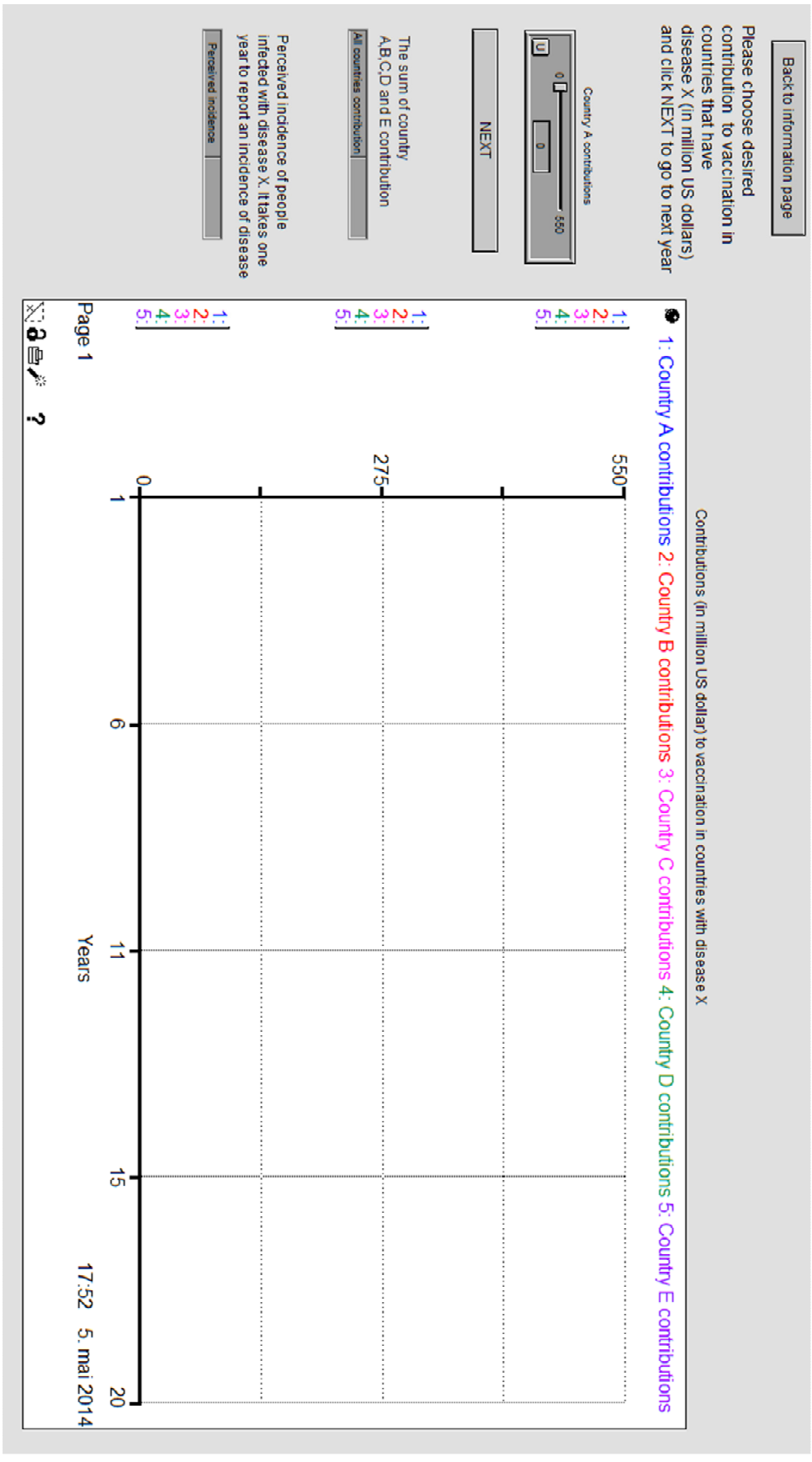
In this experiment, you are playing the role as country A, which together with country B, country C, country D and country E represents a group of rich and powerful developed countries. They have all eradicated disease X decades ago but are still vaccinating every citizen because disease X could be imported from other countries. Country A spends 228 million dollars per year on domestic vaccination. This group of developed countries funds the vaccination programs in the 3 countries that still have disease X. Last year, their total contribution was 230 million dollars. Country A's contribution was 80 million dollars. Experts have estimated that if the total contribution is increased by 10 million dollars, perceived incidence of disease X will decrease to zero after 5 years. However, experts have previously miscalculated the cost of immunization due to higher infectivity than assumed, poor vaccination efficacy and political conflicts. These difficulties are expected to continue.

Your task is to decide how much money country A will contribute to the vaccination program for countries that have disease X, for each year in a 20 year period. Your goal is to maximize country A's net benefit over a 70 year period.

The participants with the 5 best results will be in a drawing to win 500 kr.



Start simulation


Back to information page
Please choose desired contribution to vaccination in countries that have disease X (in million US dollars) and click NEXT to go to next year
Country A contributions
0
550
0
NEXT
The sum of country A,B,C,D and E contribution
All countries contribution
Perceived incidence of people infected with disease X. It takes one year to report an incidence of disease
Perceived incidence
Contributions (in million US dollar) to vaccination in countries with disease X
1: Country A contributions 2: Country B contributions 3: Country C contributions 4: Country D contributions 5: Country E contributions
550
275
0
1
6
11
15
20
Years
Page 1
17:52 5. mai 2014

Group 4: Self-regarding, country A (SECO)

Please read carefully before starting simulation:

Disease X is a highly infectious disease that kills and cripples children. The only way to avoid infection is by vaccination. Global efforts to support vaccination in developing countries have reduced the annually number of incidence of disease X from 350,000 to 795 in two decades. The expenditures for this massive effort are shown in Figure 1. The total number of countries that still has the disease has been reduced from 125 to 3. 30 % of annual expenditures goes to vaccination in these countries and is financed by contribution from rich donor countries. The rest of the annual expenditures goes to vaccination in other developing countries and is financed by humanitarian organizations and developing countries.

Until the disease is eradicated everywhere, it remains a threat for all countries. Disease X is considered eradicated if incidence has been zero for 4 consecutive years. Eradication creates an environment where intervention measures are no longer needed.

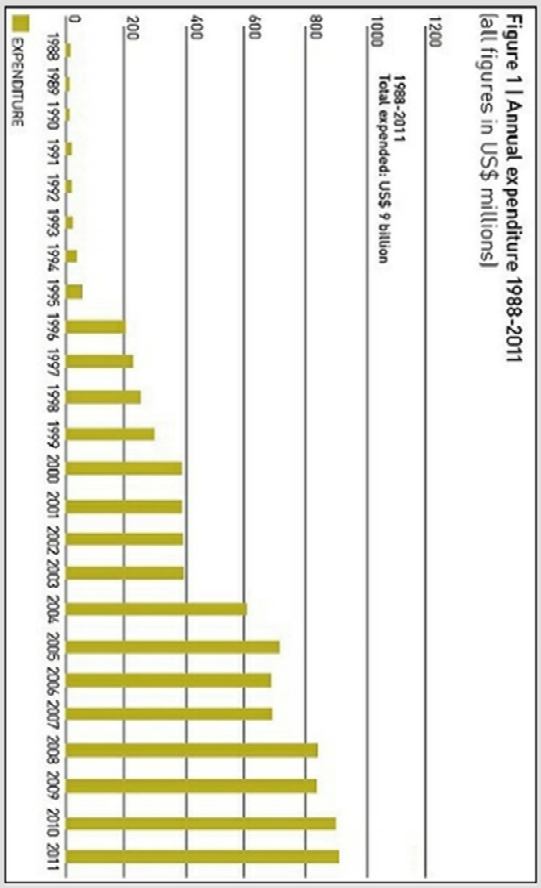
Global eradication is the most cost-effective and permanent way to protect country A against importing disease X. No single country can be safe from disease X until all countries are free of the disease and the disease is eradicated.

In this experiment, you are playing the role as country A, which together with country B, country C, country D and country E represents a group of rich and powerful developed countries. They have all eradicated disease X decades ago but are still vaccinating every citizen because disease X could be imported from other countries. Country A spends 228 million dollars per year on domestic vaccination. This group of developed countries funds the vaccination programs in the 3 countries that still have disease X. Last year, their total contribution was 230 million dollars. Country A's contribution was 80 million dollars. Experts have estimated that if the total contribution is increased by 10 million dollars, perceived incidence of disease X will decrease to zero after 5 years. However, experts have previously miscalculated the cost of immunization due to higher infectivity than assumed, poor vaccination efficacy and political conflicts. These difficulties are expected to continue.

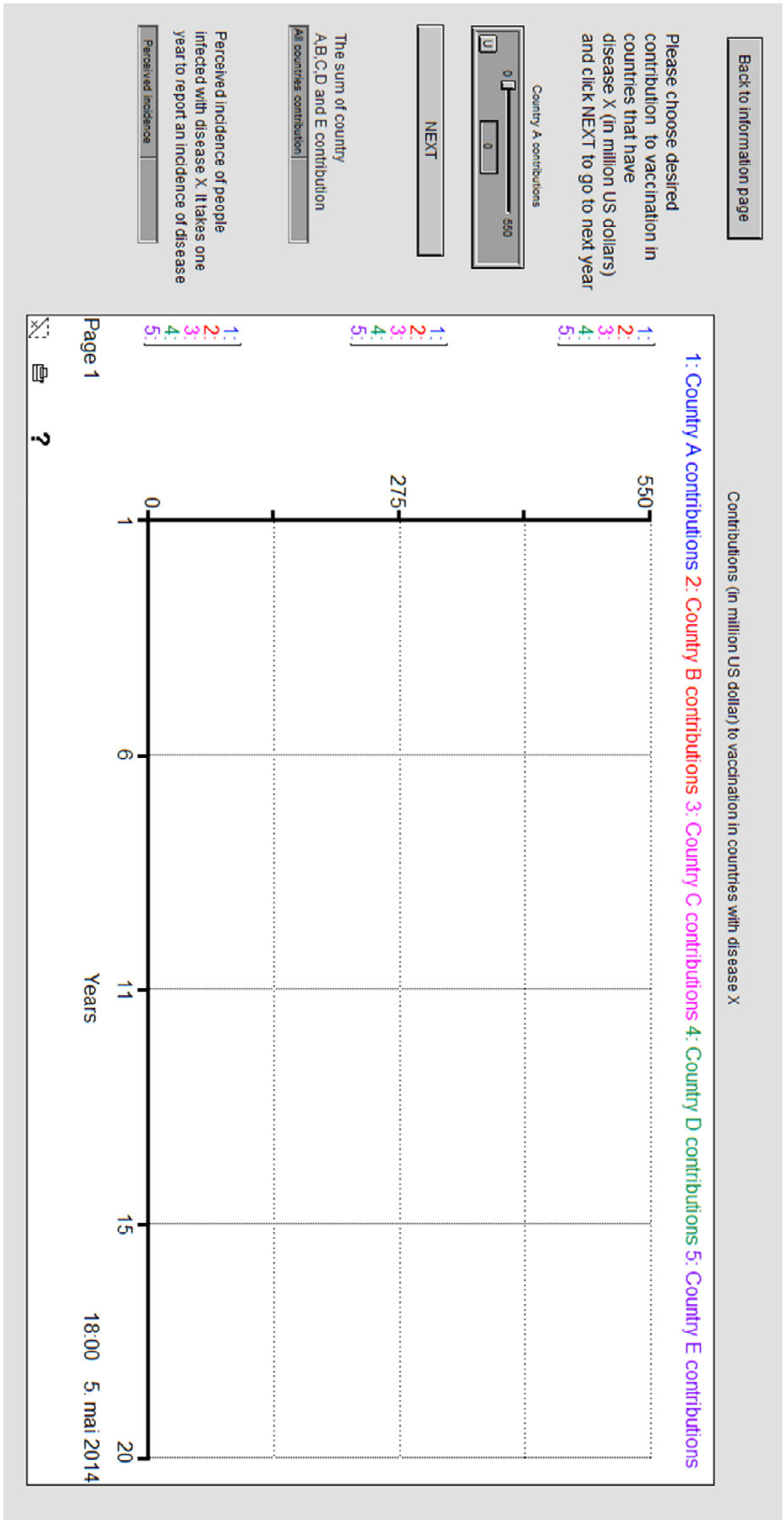
Your task is to decide how much money country A will contribute to the vaccination program for countries that have disease X, for each year in a 20 year period. Your goal is to maximize country A's net benefit over a 70 year period.

The participants with the 5 best results will be in a drawing to win 500 kr.

Figure 1 | Annual expenditure 1988-2011
(all figures in US$ millions)



Start simulation


Back to information page
Please choose desired contribution to vaccination in countries that have disease X (in million US dollars) and click NEXT to go to next year
Country A contributions
0
0
550
NEXT
The sum of country A,B,C,D and E contribution
All countries contribution
Perceived incidence of people infected with disease X. It takes one year to report an incidence of disease
Perceived incidence
Contributions (in million US dollar) to vaccination in countries with disease X
1: Country A contributions 2: Country B contributions 3: Country C contributions 4: Country D contributions 5: Country E contributions
550
275
0
1
6
11
15
20
Years
Page 1
18:00 5. mai 2014