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Original Article

Aid and the Control of Tuberculosis in Papua New Guinea: Is Australia's Assistance Cost-Effective?

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Abstract

Australia supports the control of tuberculosis in Papua New Guinea for reasons of aid effectiveness and a desire to decrease the chance of importing tuberculosis to Australia. This paper analyses the case for this support using both cost-utility and cost-benefit analysis. We reach three conclusions. First, Australia directly benefits from its investment in controlling tuberculosis in Papua New Guinea, with a cost of $US 13 million (in 2012 prices) over 10 years earning a net present value of $US 22 million. Second, the longer and more extensive the basic directly observed short course therapy, or basic DOTS, to control tuberculosis, the higher are the returns for Australia. Finally, in addition to surpassing all commonly used benchmarks for being a cost-effective investment for Australia, a basic DOTS expansion also generates a health benefit for Papua New Guinea that compares well as one of the 'ten best health buys' in developing countries.

Key words: tuberculosis, DOTS, Papua New Guinea, aid

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1. Introduction

Tuberculosis (TB) has been in existence for at least 17,000 years (Rothschild et al. 2001). At the point of greatest public concern, in the nineteenth and early twentieth centuries, it caused nearly 25 per cent of all deaths in Europe (Bloom 1994). Mortality since has dramatically decreased, by nearly 90 per cent up to the 1950s, thanks to significant improvements in public health, and later on the arrival of antibiotics (Persson 2010). However, TB still remains a major global health problem, ranking as the second leading cause of death from an infectious disease worldwide, after the human immunodeficiency virus (HIV) (World Health Organization (WHO) 2012a). Moreover, the rise of multi-drug-resistant (MDR TB) and extensively drug-resistant (XDR TB) strains of TB in the 1980s, along with the overlap of TB with HIV infections, led the WHO to declare TB as a global public health emergency in 1993. Despite continuing progress since, including a move to global targets for the reduction in TB cases and deaths, about 9 million new TB cases are detected and 1.5 million people still die from TB every year (WHO 2012a). The prevalence of the disease is also very skewed towards poor developing countries, with 60 per cent of cases in the South-East Asia and Western Pacific regions alone, and another 25 per cent of cases in Africa (WHO 2012a).

Being an airborne communicable disease, TB poses a major threat not only to countries with a high burden of TB but also to the entire world due to the increase in travel and migration. For example, the high prevalence of TB in northern Europe in the eighteenth and

nineteenth centuries caused a disease transmission, due to the effects of migration, to highly susceptible populations in Africa, Asia and the Americas, resulting in epidemics in those populations (Davies 1995). Over the last 50 years, this direction has flipped. The incidence of TB has fallen dramatically in developed countries while it remains high in developing countries, with immigration now more likely from developing to developed countries as global mobility rises. As a result, most of new active TB cases in developed countries occur among foreign-born migrants and travellers to areas with a high TB burden (Gaudette & Ellis 1993; McKenna et al. 1995; Cobelens et al. 2001).

Existing literature tells us that investing in the control of TB overseas brings significant domestic returns (Schwartzman et al. 2005). Yet most of the resources provided for the fight against TB come from poor developing countries (WHO 2012a). Developed countries typically prevent TB by implementing TB screening programs for immigrants overseas, or at ports of entry, or after arrival (Horsfield & Ormerod 1986; Bonvin & Zellweger 1992; Thomas & Gushulak 1995; Binkin et al. 1996; Alvarez et al. 2011). Nevertheless, no matter how aggressive those screening programs can be, the inherent attributes of TB, especially latent TB which is not easy to detect, prove that sustainable and extensive health outcomes are not likely to be achieved unless the epidemic is tackled at its root.

In this article, we focus on the case for Australia investing in the control of TB in its closest neighbour, Papua New Guinea (PNG). This case is particularly interesting due to extensive population mobility and the large gap in living standards, health services and especially TB prevalence between the two countries. Of major importance is the increasing concern in Australia over the potential and ongoing importation of MDR TB from PNG, and a possible outbreak of MDR TB in the near future due (partly) to the frequency of MDR TB observed among PNG patients seeking health care services in Australia (Lumb et al. 2007; Gilpin et al. 2008).

In part, to protect its population, but also for development assistance in terms of improving health outcomes for people in PNG, Australia has implemented some safeguard measures. At its beginning, a few TB clinics were operational, for years, in a treaty region (i.e., islands between PNG and Australia which allow for free movement of traditional inhabitants) to provide diagnosis and treatment of TB patients. These were controversially closed in early 2010, mostly on the grounds of funding shortfalls. Facing domestic pressure after the closure of these TB clinics, the Government of Australia announced a more 'long-term' and comprehensive strategy to strengthen the capacity to cope with TB in Western Province in PNG, which lies across a relatively small stretch of sea from Australia. In particular, Australia's Aid Program has committed to a 10-year strategy 'to ensure effective and sustained TB services' (AusAid 2012). An initial US$ 11.4 million in 2012 prices[1] over 4 years starting from 2012, in particular, was provided by Australia's Aid Program to strengthen TB control in the Torres Strait Islands (TSI).

This article examines whether we have the right framework for making a proper policy choice in Australia's support of the control of TB in PNG. In particular, we ask the following: (i) What would be the returns to Australia in investing in TB control in PNG? (ii) How long and how extensive should the TB program be in order to be the most cost-effective for Australia, both from its own point of view as well as from an Official Development Assistance (ODA) perspective? To answer these questions, we first summarise the results from a TB spread model between South Fly, the southern most district of Western Province, and the TSI. We then present results from the overlay of two economic decision-making approaches, including cost utility analysis (CUA) and cost-benefit analysis (CBA) on the TB spread model. Finally, we briefly discuss the limitations and remaining uncertainties in our analysis that need to be taken into account in the decision-making process.

1. This is equivalent to AU$ 11 million using the average of monthly exchange rates of AUD to USD for the year 2012 provided by the Reserve Bank of Australia (Reserve Bank of Australia 2014).

2. Background

PNG is a resource-rich and largely agricultural economy. The vast majority of Papua New Guineans make their income from self-employment as farmers in the informal sector. One third of the population is poor and almost 90 per cent of the population lives in rural areas (Foster et al. 2009). Since nearly 50 per cent of the total land is mountainous, widely scattered rural communities are often inaccessible. Furthermore, as one of the most culturally diverse countries in the world, PNG has more than 800 distinct languages, spoken by numerous clans. This cultural diversity, coupled with strong allegiance to clan groups rather than to the country as the whole, along with poor infrastructure, makes it hard to achieve nationwide development goals and often hampers the quality of basic services at the point of delivery.

PNG is one of the countries with a very high burden of TB in the Western Pacific region. In 2009, it had an estimated (and likely underestimated) TB prevalence rate of 337 per 100,000, a TB death rate of 26 per 100,000, and a total of 12,306 new TB cases (all forms) (WHO 2011; McBryde 2012). The directly observed therapy, short-course (DOTS)[2] program has been implemented slowly since its inception in 1997, with a coverage of only 14 per cent as of 2007 (WHO 2009b). Due to weak health care services and a lack of supporting resources, the successful treatment rate is only 58 per cent (WHO 2013), much lower than the global target of 85 per cent (WHO 2009b). This, coupled with a high default rate in treatment, likely contributes to the apparently high rate of MDR TB in PNG (WHO 2011).

The control of TB in PNG is of special interest to Australia. Being less than 5 km away, at some points, PNG is its closest neighbour. Furthermore, Australia's TSI, which straddles the border between the two countries, is under a treaty signed between the two countries that allows for the relatively free movement for people of both countries in the region. As Australia has very low incidence of TB and one of the most well-resourced health care systems in the world, there has been an observed and significant number of cross-border health care requests by PNG nationals. High rates of MDR TB notifications among PNG patients seeking health care in Australia have also, as indicated above, raised serious concerns over a possible and ongoing transmission of MDR TB from PNG, and a possible MDR TB outbreak in Australia in the near future (Lumb et al. 2007; Gilpin et al. 2008). These concerns form the backdrop of Australia's support to TB-related programs in PNG.

In part, to cope with this unwanted event, Australia provides about 12 per cent of its annual aid budget to PNG, with one fifth going to the health sector (Foster et al. 2009), and a 10-year strategy to strengthen the capacity to cope with TB in Western Province, which borders with Australia, was launched in 2012. For the first four years, an initial US$ 11.4 million was provided to finance a TB isolation ward and enhance capacity for MDR TB diagnosis and treatment in Daru, to supply MDR TB patients with second-line drugs for 1 year of the required 18-month treatment, along with funding to World Vision to train and supervise TB treatment and workers in South Fly, and for the Western Province Department of Health to conduct regular outreach clinics by boat (AusAid 2012).

3. Theoretical Framework for Economic Evaluation in the Health Sector

CBA is the principal tool for making practical choices in economics. CBA's main criterion is to adopt projects with positive net present values (NPV), or to rank projects by their NPV with future costs and benefits discounted at the social discount rate. In basic terms, NPV is the difference between the present value of all benefits and costs. The challenge to the

2. Being developed and promoted by WHO, DOTS has been widely endorsed by national TB programs. This is the basic package that underpins the WHO-initiated Stop TB Strategy. DOTS has five components, namely (i) political commitment, (ii) diagnosis using sputum smear microscopy, (iii) a regular supply of first-line anti-TB drugs, (iv) a standardised treatment regimen of 6–8 months directly observed by a health worker, and (v) a standard system for recording and reporting the number of cases detected by national TB control program (WHO 2012a).

application of CBA in the health sector is in 'monetising' the benefits and consequences of health interventions. This challenge is not only technical, as values here are hard to measure, but raises significant ethical issues as well, since quantifying human health and life in terms of money is not always appealing to policy-makers and the public.

To address the ethical concerns in putting money values on health benefits, CUA has been developed to aid decision-making in the health sector. CUA differs from CBA in the sense that CUA measures health improvements due to an intervention by a combination of a quality of life measure and life-years saved. To this end, the incremental costs of a program, within this particular point of view, are compared with the incremental health benefits of the program (Drummond et al. 2005). Projects are then selected to maximise health benefits given a budget constraint.

Two commonly used metrics in measuring health consequences in CUA are quality-adjusted life-years (QALY) and disability-adjusted life-years (DALY). First used in 1976, QALY for a single year of an individual's life is a product of 1 year and a health-related quality of a life weight attached to that year of life (Zeckhauser & Shepard 1976). This weight is bounded by [0,1] where 1 represents a year lived with full health and 0 means death. As a variant of QALY, DALY was developed as a measurement unit to quantify the global burden of disease and injury on human populations (Murray & Lopez 1996). DALY has been recommended by WHO for use in generalised cost-effectiveness analysis, which aims to evaluate a wide range of possible health interventions to identify the optimal package of health care services delivered within a fixed budget (Edejer et al. 2003).

While conceptually similar, DALY differs from QALY in a number of aspects. The most notable difference is the disability weight. In QALY, the weight is developed from preferences, either those of the general public or those of patients. In DALY, on the other hand, the weight measures social (not individual) preferences, based on person tradeoff scores from a panel of health care workers who met in Geneva in August 1995. Furthermore, DALY has only seven discrete health values on health states, in addition to death (being 1) and fully healthy (being 0), in contrast to the life quality weight in QALY which is continuous in the range [0,1]. Finally, DALY also gives lower weight to the young and the elderly. (For a detailed discussion on the difference between QALY and DALY, please refer to Drummond et al. 2005 and Sassi 2006.)

Despite the usefulness of CUA in health sector, CBA is still necessary in many cases since it allows for direct comparisons of cost-effectiveness and economy-wide measures of allocative efficiency. In CBA, health outcomes need to be quantified in money. There are three general approaches in doing so: (i) human capital measures, (ii) revealed preference for a health outcome and (iii) stated preferences or 'willingness-to-pay' (WTP) for a health service or outcome. Given problems with often imperfect labour markets in the human capital approach and the context and job specificity needed for revealed preference approaches, WTP appears the most promising in its attempt to measure underlying consumer demand for non-market values and products, such as health care interventions (Drummond et al. 2005). Admittedly, there are some concerns about equity in using WTP, as WTP takes as given the underlying income distribution in the population. However, these concerns should not be an issue in this study as we take the perspective of two countries, namely Australia and PNG, separately in allocating resources to PNG.

4. Costs and Benefits of TB Control for Policy-Making

In this section, we first summarise results from a TB spread model between TSI and South Fly. We then present results from CUA and CBA with a particular focus on (i) what would be the returns to Australia in investing in TB control in PNG, and (ii) how long and how extensive a TB control program should be in order to be the most cost-effective for Australia.

The TB control program in PNG that we consider is an expansion of basic DOTS in South Fly. Basic DOTS, which covers only

infectious (pulmonary) TB cases, is highly recommended in resource-poor countries (WHO 2006b). In PNG, the current level of DOTS coverage is 14 per cent (WHO 2009a). Despite being low, this DOTS coverage level is still likely to be an overestimate for the small, isolated communities of the South Fly district (McBryde 2012). Furthermore, the weak TB control program in PNG, which results in low success treatment and high default rates, coupled with poor clinical practices due to an inadequate health system, limited diagnostic capacity and the lack of availability of drug resistance testing facilities, adds considerable risks to implementing a more sophisticated treatment program, and especially for MDR TB in PNG (WHO 2010b; Lokuge et al. 2012). WHO, in particular, gives specific guidance on rolling out MDR TB treatment as follows: 'In principle, MDR treatment should be introduced only in well-performing DOTS programmes. Before focusing on curing MDR-TB cases, it is critical to "turn off the tap", i.e., to strengthen poor programmes so that they stop giving rise to MDR-TB' (WHO 2010b, p. 18). Therefore, expanding basic DOTS is clearly a top priority and the most reasonable starting point in PNG for the time being.

We consider various levels of basic DOTS coverage expansion as well as various lengths of TB control programs. Expansion levels include 30 per cent, 50 per cent, 65 per cent, 80 per cent and 95 per cent basic DOTS coverage. We assume a lag of 4 years for PNG to reach the 95 per cent coverage level. The time required for fully achieving other expansion levels is somewhere between 0 and 4 years, depending on how extensive the expansion is. In terms of TB program length, it can be as short as 4 years, being in line with the initial funding provided by Australia's Aid Program, or as long as 10 years, 20 years and 30 years.

4.1 Epidemiological Model: Brief Description and Results

We use a metapopulation modelling technique to model the connection in TB prevalence between TSI and South Fly (Hanski & Gilpin 1997; Hanski & Gaggiotti 2004; Keeling & Rohani 2008). The results are based on the model described in Hickson et al. (2012), which is a combination of metapopulation and compartment modelling techniques. The metapopulation technique allows for regions with different attributes, or in this case various burdens of TB, their transmission and access to treatment. This feature of the metapopulation technique is of special importance to our analysis given the large differences between TSI and South Fly in these attributes. Our model has four subpopulations: (i) Papua New Guineans in South Fly, (ii) Papua New Guineans in TSI, (iii) Australians in TSI, and (iv) Australians in South Fly, in order to track population dynamics in South Fly and TSI, as well as the travel between the two regions.[3]

For each subpopulation, each stage of the disease and treatment is encapsulated in six compartments: those susceptible, latently infected, clinically active with only non-pulmonary TB, clinically active with at least pulmonary TB, detected and treated for the first time, and being retreated. The resulting model, combining the metapopulations with the compartments, is in the form of a set of non-linear ordinary differential equations solved using Matlab version R2012b. See Nguyen et al. (2013) for details on equations.

The model was calibrated based on historical patterns and the current situation in PNG and TSI. Some parameter values used in the model were taken from the literature, and some assumptions were made based on what data were available, and in order to simplify the model as much as possible. Details on model calibration, assumptions, parameters and their values are in Hickson et al. (2012). A sensitivity analysis of this model was conducted in Hickson et al. (2011), where it was found that the parameter that most influenced the cumulative number of TB cases was the rate that latently infected patients become clinically active in PNG.

3. The rates of departure and return of Australian and Papua New Guinean nationals to simulate travel between South Fly and TSI were estimated based on data from Department of Immigration and Citizenship (2010). Please see Hickson et al. (2012) or Nguyen et al. (2013) for details.

There are two reasons why we only focus on South Fly and TSI as the representative regions for PNG and Australia, respectively, in our model. First, regions in each country are heterogenous, with South Fly and TSI being among the most disadvantaged in their respective countries. Second, and more importantly, the frequent and relatively unscreened movements between the countries occur mostly between these two communities due to an existing treaty, so that the concerns about TB spread from PNG to Australia centre around this border area.

Given the links between South Fly and TSI in terms of TB incidence and prevalence, expanding basic DOTS coverage in South Fly also delivers direct benefits to TSI. For example, a fall of 12 per cent in TB prevalence in TSI would be achieved if basic DOTS coverage in South Fly was expanded to 95 per cent for 20 years (detailed results are in Nguyen et al. 2013). With this intervention, the results would be even more impressive in South Fly, with TB prevalence being more than halved. These results deserve special consideration given that half of the patients recently detected with MDR TB in Australia came from this cross-border region (Lumb et al. 2007).

4.2 Economic Evaluation

As discussed in Section 3, the cost of an intervention (i.e., expanding the basic DOTS coverage) is the same in CUA and CBA. It includes expenses to cover diagnosis (with sputum smear microscopy and X-rays), health care centre visits, drug supplies for a 6-month treatment course for first-time treated TB patients and an 8-month treatment course for retreated TB patients, as well as program management. Treatment regimens follow WHO's guidelines (WHO 2010b) and drug prices were drawn from Global Drug Facility (2012). Assumptions on the number of health care visits were based on Baltussen et al. (2005). Detailed costs per TB patient are provided in the Appendix 1.

In order to calculate the benefit for CUA, we need not only the distributions of subpopulations in terms of their health states captured in compartments of the epidemiological model, but also their age, gender and life expectancy. Incorporating those details into the model is computationally complicated. Therefore, we kept each subpopulation classified by six health states as described in Section 4.1 intact, with only natural birth rates, natural death rates and the death rates induced by TB related health states being taken into account. Information on age and gender was incorporated into the model results for economic evaluation after the model was solved. Age and gender distributions in TSI are from population projections by Australian Bureau of Statistics (2008), while those for South Fly were obtained from projections by the United Nations (2010). Life expectancy of Australian nationals was taken from the life table 2008–2010 estimated by Australian Bureau of Statistics (2011), while that of Papua New Guinean nationals was drawn from the life table 2011 estimated by WHO (2012b). Finally, the health-related quality of life weight for TB patients used in our article was provided by Tengs and Wallace (2000) while the disability weight was drawn from Murray and Lopez (1994). The numbers of QALY and DALY for each subpopulation in the status quo, and when basic DOTS is expanded, were then calculated using information on health states, age, gender, life expectancy, quality of life and disability weights.

The benefit for CBA was obtained by converting QALY into money using WTP. For TSI, we used a WTP per QALY of US$ 58,766 (in 2012 prices) estimated by Shiroiwa et al. (2010). Since estimates for WTP per QALY are available for only a handful countries in the world, we do not have that information for PNG. Instead, we used gross domestic product (GDP) per capita in PNG of US$ 2,184 for the year 2012 (World Bank, 2014) as a proxy for WTP per QALY in PNG. As discussed in Section 3, using different WTP per QALY could raise concerns about equity since it is always preferred to allocate resources to save QALY in areas where QALY is more valued, namely Australia in this case. Fortunately, this is not a concern for us since we do not consider a joint investment decision for Australia and PNG.

Table 1 Cost per DALY, QALY and NPV (US$ 2012) of Expanding Basic DOTS Coverage in South Fly from the Current Level of 14 Per Cent in South Fly

TB programs		*TSI*				*South Fly*			
Years	*Basic DOTS coverage (%)*	*Total discounted cost (million)*	*NPV (million)*	*Cost per DALY (thousand)*	*Cost per QALY (thousand)*	*Total discounted cost (million)*	*NPV (million)*	*Cost per DALY*	*Cost per QALY*
4	30	1.4	0.34	75	47	1.4	269	18	11
	50	3.0	0.33	84	53	3.0	518	20	13
	65	4.6	–0.60	107	68	4.6	645	26	15
	80	5.8	–1.08	114	72	5.8	746	28	17
	95	6.4	–1.15	113	72	6.4	828	28	17
10	30	3.1	9.8	22	14	3.1	1,170	9.2	5.8
	50	6.4	17	24	16	6.4	2,120	11	6.6
	65	9.8	19	31	20	9.8	2,580	13	8.2
	80	12	21	33	22	12	2,920	14	9.0
	95	13	22	33	22	13	3,180	14	9.0
20	30	5.8	42	10	7.2	5.8	3,080	6.3	4.1
	50	12	73	12	8.1	12	5,410	7.2	4.7
	65	18	83	15	10	18	6,480	9.0	5.9
	80	22	92	16	11	22	7,250	9.8	6.5
	95	23	100	16	11	23	7,830	9.9	6.5
30	30	8.5	93	6.7	4.9	8.5	5,410	4.9	3.4
	50	17	160	7.5	5.5	17	9,340	5.6	3.9
	65	25	185	9.5	7.0	25	11,100	7.1	4.9
	80	30	204	10	7.6	30	12,400	7.7	5.3
	95	33	220	10	7.6	33	13,300	7.7	5.3

DALY, disability-adjusted life-years; NPV, net present values; QALY, quality-adjusted life-years; TB, tuberculosis; TSI, Torres Strait Islands.

The health benefit from expanding basic DOTS coverage from 14 per cent to any level of interest, at any point in time, is the accumulated difference between the health outcomes, be it in money, DALY or QALY, with the expansion in place and those under the current 14 per cent basic DOTS coverage. Likewise, the corresponding health cost is the cost of expanding the basic DOTS coverage level from the current 14 per cent to the desirable level of expansion. All costs and benefits in our article were discounted at 3 per cent as recommended for the health sector (Weinstein et al. 1996; Edejer et al. 2003). Unless specified, all values in money are in USD in 2012.

Table 1 presents costs per DALY, QALY and NPVs for Australia and PNG. It is important to note that since there is a spillover effect of expanding basic DOTS in South Fly on TSI (Section 4.1), the cost borne by Australia is the combined cost incurred in TSI and in South Fly. For PNG, only the cost incurred in PNG is taken into account. Columns 3 and 7 of Table 1, respectively, present the costs of expanding basic DOTS in South Fly from the Australian and PNG perspectives. While the two costs look virtually the same, there is some deduction in the cost of detecting and treating TB patients in TSI, thanks to basic DOTS expansion in South Fly. The benefit for Australia and PNG, on the other hand, are the accrued benefits to Australian and Papua New Guinean nationals, respectively.

CUA

Costs per DALY and costs per QALY for TSI are presented in columns 5 and 6 while those for South Fly are presented in columns 9 and 10 of Table 1. A similar pattern is revealed for the two regions: the longer the TB program is, the cheaper it is to avert a DALY or to save a QALY. However, it is much more expensive to save a QALY or to avert a DALY in TSI than in

South Fly. For example, it would cost US$ 84,000 to avert a DALY in TSI in comparison with only US$ 20 in South Fly. Furthermore, the length of a TB program has a more substantial impact on the cost per DALY and the cost per QALY in TSI than in South Fly. For example, the cost to avert a DALY in a 30-year TB program is only less than a tenth of that in a 4-year TB program in TSI, while the corresponding comparison is a fourth in South Fly.

There are a couple of factors to consider in these results. First, it takes time for the benefit to be materialised while the cost is required upfront. TB patients need to be treated for 6–8 months. To this end, an intervention needs to be in place for a good while before it has an impact on TB prevalence and TB incidence to generate health benefits. Second, basic DOTS coverage is very low in South Fly, resulting in large health benefits being generated quickly during an intervention. For TSI, on the other hand, the spillover effects from a basic DOTS expansion in South Fly take a much longer time to be effective. It, thus, takes less time for the benefit to 'catch up' with the cost in South Fly compared with TSI.

Against the decreasing trend over time of costs per DALY and QALY, the questions to be asked are whether basic DOTS expansion in South Fly is cost-effective for Australia and over what time period? Looking solely from an Australian perspective, we only count the benefits accrued to Australians while Australia pays for the cost of basic DOTS expansions in South Fly. Using the cost per DALY, a health intervention is considered to be cost-effective for a country when the cost per DALY of the intervention is equal to its GDP per capita (Sachs 2001; Evans et al. 2005). Of course, the lower the cost per DALY is relative to its GDP per capita, the more cost-effective the intervention would be for the country. We use Australia's GDP per capita of US$ 67,442 in 2012 (World Bank, 2014) as the key benchmark. Basic DOTS expansion in South Fly would thus be cost-effective, extrapolating from Table 1 (column 5), if Australia maintains its support for at least 5–6 years, depending on the coverage level, or beyond (detailed results are available upon request). Using the cost per QALY, on the other hand, a health intervention is considered to be cost-effective for a country when the cost per QALY of an intervention is less than or equal to its people's WTP per QALY. The WTP per QALY for Australians is estimated to be US$ 58,766 (Shiroiwa et al. 2010). Comparing the cost per QALY (column 6 of Table 1) with WTP per QALY yields results that corroborate the ones using the cost per DALY.

From an ODA prospective, is TB control in South Fly a good investment for Australia? Yes, indeed, since the cost per DALY in incredibly low, ranging from US$ 5 to US$ 28 (column 9 of Table 1), in South Fly, thanks to large gains of basic DOTS program expansion from its existing low coverage level combined with a prior burden of TB that is high. For this reason, basic DOTS coverage expansion in South Fly is positioned well in the range of the top 10 best 'health buys' in developing countries (Measham et al. 2006).

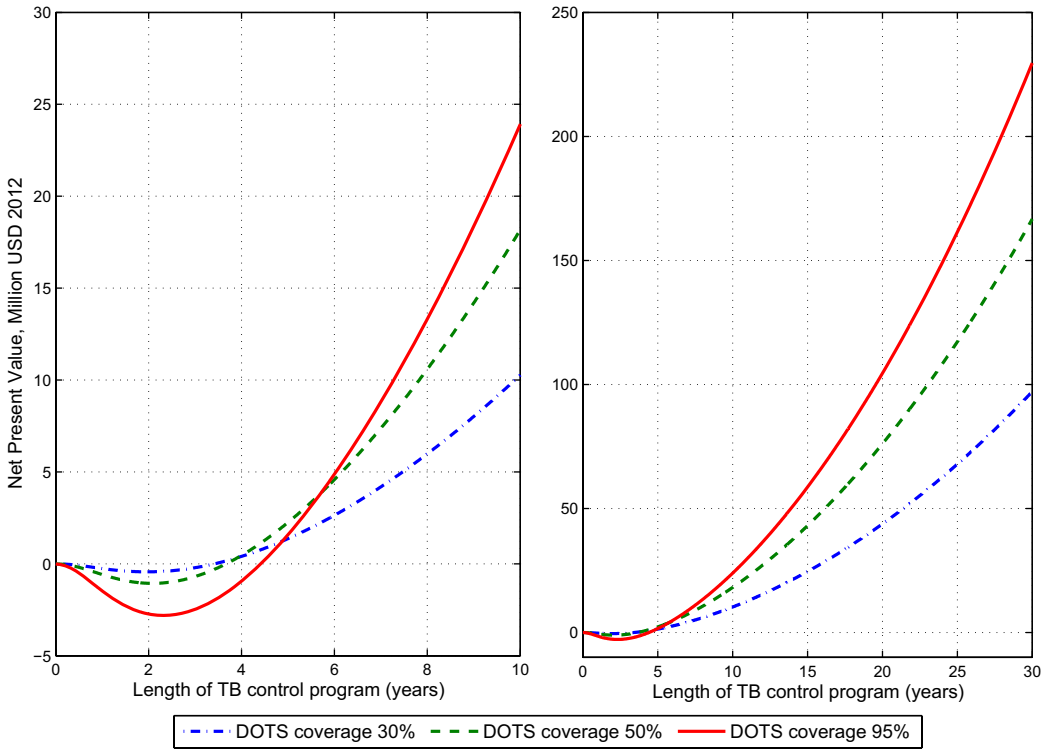
Finally, should PNG itself invest in TB control in South Fly? Both cost per DALY and QALY suggest that this investment is very cost-effective for PNG as well. However, an open question remains as to whether this relatively poor country can afford this investment?

CBA

Having the same cost as in CUA, CBA has its benefit obtained by converting QALY into money using WTP. NPVs for TSI are presented in column 4 while NPVs for South Fly are in column 8 of Table 1. For programs that run beyond 4 years, NPVs for TSI and South Fly exhibit the same pattern: the longer the TB program or the more extensive the basic DOTS expansion is, the higher is the NPV. This pattern is also revealed in Figures 1 and 2.

One distinctive feature for TSI is that the more extensive the basic DOTS expansion in South Fly is, the larger the losses that would occur if Australia stops funding the expansion after 4 years (Table 1, column 4). This result stems from the high start-up costs and likely delay to get required facilities and human resources ready to widely expand basic DOTS

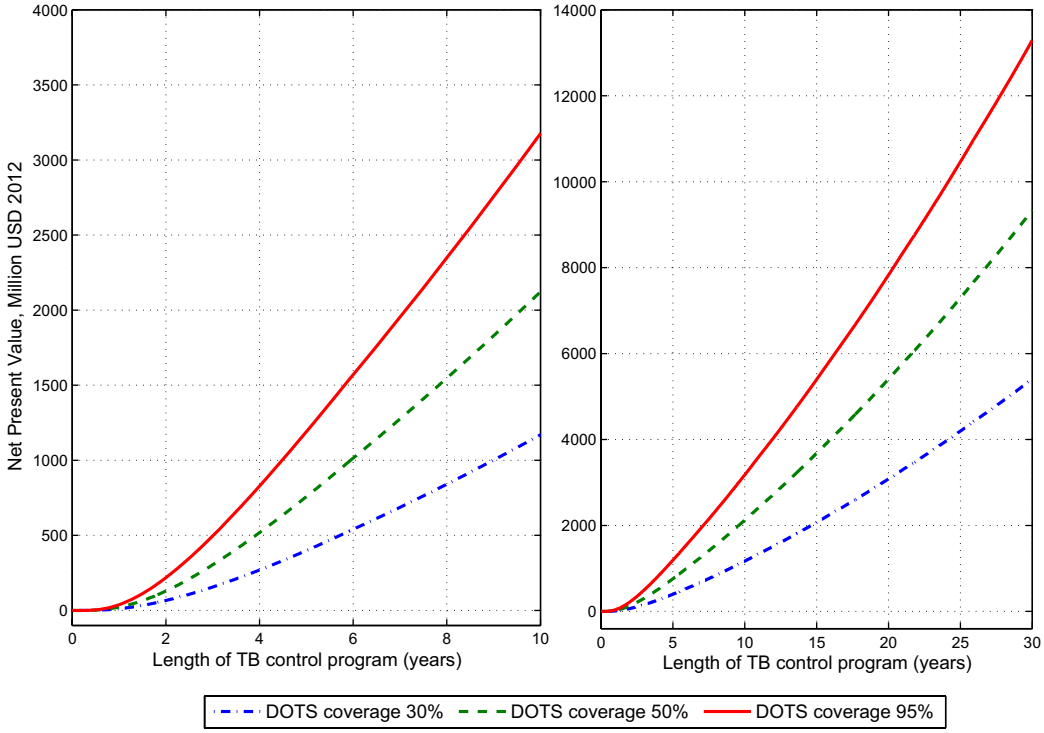
Figure 1 NPV of Expanding Basic DOTS Coverage in South Fly from the Current Level of 14 Per Cent for Australia (Left Panel for Years 0–10; Right Panel for Years 0–30)



coverage. This high start-up cost only pays off in the long run. Indeed, only from the sixth year of the program does the NPV generated from the 95 per cent basic DOTS coverage dominate the NPVs generated by all other lower levels of coverage (Figure 1, left panel). Suppose, for example, Australia continues to support the expansion for 10 years, as promised, it would cost Australia about US$ 13 million in total or US$ 1.3 million per year to expand basic DOTS coverage to 95 per cent in South Fly. In return, the NPV generated would be about US$ 22 million. On the other hand, for the same program length, the cost would be halved for a 50 per cent basic DOTS expansion, but the corresponding NPV would be only US$ 17 million.

Two questions are motivated by Australia's recent 10-year commitment to assist with TB control in Western Province, where South Fly is located, with an initial funding of US$ 11.4 million for the first 4 years. First, is a 10-year commitment optimal? The answer is likely negative. Stopping the support after 10 years would be unwise since major added benefits from the intervention will only be generated, in a clear exponential manner, beyond 10 years, producing substantive net gains (Figure 1, right panel). For example, if Australia funded the basic DOTS expansion to 95 per cent for 20 instead of 10 years, the cost of the support would be almost doubled, increasing from about US$ 13 million to US$ 23 million. However, the NPV from a 20-year program is roughly US$ 100 million, almost four times higher than the NPV of US$ 22 million from a 10-year program (Table 1, column 4). Indeed, Australia would probably be better off committing to the program in perpetuity since the program cost keeps falling while the program benefit keeps increasing beyond the program break-even point of year 5–6. Although the exact timing of the break-even point is sensitive to the assumption of a 4-year lag for PNG to reach the 95 per cent coverage level

Figure 2 NPV of Expanding Basic DOTS Coverage in South Fly from the Current Level of 14 Per Cent for PNG (Left Panel for Years 0–10; Right Panel for Years 0–30)



discussed earlier, the main results that are in favour of the program being place in perpetuity remain.

The second question is whether the initial US$ 11.4 million for the first 4 years would be enough to control TB in Western Province? The cost for expanding basic DOTS coverage in South Fly to 95 per cent for 4 years is US$ 6.4 million. Suppose the cost of expanding basic DOTS in other parts in Western Province is similar to that in South Fly, as are the parameters required for the epidemiological model, then the required cost for expanding the basic DOTS in Western Province is about US$ 19.2 million. That is, the cost is in proportion to population size, with the total population of Western Province being three times as much as that in South Fly. As a result, if Australia wants to expand basic DOTS in Western Province to 95 per cent coverage for 4 years, it needs to increase its current funding commitment by about US$ 7.8 million (or AU$ 7.25 million). It is also worth noting that our required funding estimate is only for treating TB drug-sensitive (pulmonary) patients, not for any of MDR TB cases that Australia would also like to target.

From PNG's perspective, it is also clear from Figure 2, as well as Table 1 (column 8), that the longer and the more extensive the basic DOTS expansion is, the higher are the NPVs that are generated. The same open question as above remains.

5. Conclusion

Our study has attempted to analyse the case for the assistance provided by Australia for the control of TB in PNG. By overlaying two economic decision-making approaches, CUA and CBA, on a TB spread model between the two neighbouring regions of these two countries, it is able to shed light on the likely costs and benefits of this investment. The results show that this assistance is clearly effective in controlling TB, and thus achieving one of the

Millennium Development Goals, since the cost per DALY averted in PNG is positioned well in the range of the top 10 best health buys in developing countries, regardless of the length of the program. Further, the longer the assistance is, the more effective it would be. The findings also indicate that Australia can only benefit from this investment if it continues the support the program for at least 6 years. In fact, it would be optimal for Australia to provide this support in perpetuity.

With these results in mind, there are at least three issues worth exploring in the decision-making process. First, it would be useful to further investigate the local estimates for parameters used in our costing, and to some extent the TB spread model. The cost of running an effective TB program and extending its coverage in South Fly, in particular, is likely to be large given the weak state of health services and the health system there. Little information other than available estimates from other similar developing countries is available for us to take this issue into account. Second, there is a need to investigate collaborative opportunities in controlling other infectious diseases, such as HIV and malaria, to enhance allocative efficiency and avoid the otherwise inevitable crowding-out of resources allocated to those diseases. Finally, patients' attitudes, culture and local practices need to be further investigated as they are found to have a profound effect on the success of TB programs (Thiam et al. 2007).

May 2014.

Appendix 1: Cost Per TB Patient under Different Basic DOTS Coverage in PNG, US$ 2012

			South Fly			*TSI*		
Coverage	*Cost item*	*Q'ty*	*Unit cost*	*T1*	*T2*	*Unit cost*	*T1*	*T2*
14%	Program management and supervision[a]			57	57		711	711
	Diagnosis							
	Smear test[b]	30	4.1	122	122	21.6	649	649
	X-ray[c]	9	10.1	91	91	48.4	435	435
	Monitoring diagnosis							
	Smear test[b]	6	4.1	24.5	24.5	21.6	130	130
	Drugs[d]			43.7	177		43.7	177
	Health centre visits[e]	43	10.3	441		28	1,206	
	Health centre visits[e]	59	10.3		605	28		1,654
	Total cost per patient			779	1,076		3,174	3,756
30%	Program management and supervision[a]			221	221		711	711
	Diagnosis							
	Smear test[b]	30	4.1	122	122	21.6	649	649
	X-ray[c]	9	10.1	91	91	48.4	435	435
	Monitoring diagnosis							
	Smear test[b]	6	4.1	24.5	24.5	21.6	130	130
	Drugs[d]			44	177		43.7	177
	Health centre visits[e]	43	10.3	441		28	1,206	
	Health centre visits[e]	59	10.3		605	28		1,654
	Total cost per patient			944	1,241		3,174	3,756
50%	Program management and supervision[a]			402	402		711	711
	Diagnosis							
	Smear test[b]	30	4.1	122	122	21.6	649	649
	X-ray[c]	9	10.1	91	91	48.4	435	435
	Monitoring diagnosis							
	Smear test[b]	6	4.1	24.5	24.5	21.6	130	130
	Drugs[d]			44	177		43.7	177

			South Fly			TSI		
Coverage	*Cost item*	*Q'ty*	*Unit cost*	*T1*	*T2*	*Unit cost*	*T1*	*T2*
	Health centre visits[e]	43	10.3	441		28	1,206	
	Health centre visits[e]	59	10.3		605	28		1,654
	Total cost per patient			1,124	1,421		3,174	3,756
65%	Program management and supervision[a]			665	665		711	711
	Diagnosis							
	Smear test[b]	30	4.1	122	122	21.6	649	649
	X-ray[c]	9	10.1	91	91	48.4	435	435
	Monitoring diagnosis							
	Smear test[b]	6	4.1	24.5	24.5	21.6	130	130
	Drugs[d]			44	177		44	177
	Health centre visits[e]	43	10.3	441		28	1,206	
	Health centre visits[e]	59	10.3		605	28		1,654
	Total cost per patient			1,387	1,684		3,174	3,756
80%	Program management and supervision[a]			810	810		711	711
	Diagnosis							
	Smear test[b]	30	4.1	122	122	21.6	649	649
	X-ray[c]	9	10.1	91	91	48	435	435
	Monitoring diagnosis							
	Smear test[b]	6	4.1	24.5	24.5	21.6	130	130
	Drugs[d]			44	177		44	177
	Health centre visits[e]	43	10.3	441		28	1,206	
	Health centre visits[e]	59	10.3		605	28		1,654
	Total cost per patient			1,533	1,830		3,174	3,756
95%	Program management and supervision[a]			839	839		711	711
	Diagnosis							
	Smear test[b]	30	4.1	122	122	21.6	649	649
	X-ray[c]	9	10.1	91	91	48	435	435
	Monitoring diagnosis							
	Smear test[b]	6	4.1	24.5	24.5	21.6	130	130
	Drugs[d]			44	177		44	177
	Health centre visits[e]	43	10.6	454		28	1,206	
	Health centre visits[e]	59	10.6		624	28		1,654
	Total cost per patient			1,575	1,878		3,174	3,756

Notes: T1: infectious TB patient treated for the first time; T2: infectious TB patient retreated. Costs only occur in these two compartments. The consumer price indices (CPI) for Australia and PNG are obtained from World Bank (2014) while exchange rates are from the Reserve Bank of Australia (2014).

(a) Costs for program management and supervision per patient are from Baltussen et al. (2005), where details of the approach for estimating those costs are discussed in Evans et al. (2005). We use data for Sear-D (Bangladesh, Bhutan, Democratic People Republic of Korea, India, Maldives, Myanmar, Nepal, Timor Leste) as data are not available for Australia or PNG or for anywhere else in the Pacific region. As data are available for only DOTS coverage levels of 50 per cent, 80 per cent and 95 per cent in Sear-D, we use an extrapolation method to estimate the program management and supervision cost for other DOTS coverage levels.

(b) and (c) Diagnosis is based on an assumption that one per 10 TB suspects presenting to the health centre is tested smear-positive (WHO 2010a; Baltussen et al. 2005). Since each suspect is tested with three smear tests, this means that 30 smears are used to detect one smear-positive case. The remaining nine remain suspected case and are tested with an X-ray. This means for every case that is tested smear-positive, nine X-rays are performed which will detect the x number of smear-negative cases. The number of X-rays used for case detection of x smear-negative cases is then equal to 9*smear-positive cases detected (and is independent of x). Monitoring diagnosis is based on (Baltussen et al. 2005). Unit costs for smear tests and X-rays are from (WHO 2006a, table 2, p. 58), where prices for PNG and Australia are, as a proxy, given by the average prices for Indonesia and America for 2001–2003 and 2001–2002, respectively, which in turn are inflated by the CPI indices of PNG and Australia to obtain 2012 prices.

(d) The regiment for T1 is based on the recommendation 1.1 in (WHO 2010b, p. 32): 6-month treatment with 2-month intensive and 4-month continuation phases. As we do not take into account multi-drug resistance tuberculosis and the drug susceptibility testing equipment is not available in PNG (Lumb et al. 2008), we use recommendation 7.3.2 (WHO 2010b, p. 40) for T2: 8-month treatment of first-line drugs. Drug costs are based on Global Drug Facility (2012) first-line drug calculation sheet, version 13/7/2011, which uses the lowest possible price per product the Global Drug Facility is able to provide under the current agreement with its suppliers, accounting for freight, insurance and other fees. Quantities of drugs per patient are calculated based on the average weight band of 40–54 kg.
(e) We use assumptions from Baltussen et al. (2005) on the frequency of health centre visits as there is no clear standard by WHO. The cost per health centre visit is from WHO estimates of unit costs for patient services for 14 Global Burden of Disease Regions (WHO, 2014).
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