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Supplementary appendix

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Supplement to: Sheehan P, Sweeny K, Rasmussen B, et al. Building the foundations for sustainable development: a case for global investment in the capabilities of adolescents. *Lancet* 2017; published online April 19. http://dx.doi.org/10.1016/S0140-6736(17)30872-3.

Supplementary Appendix

Supplement to: Sheehan P, Sweeny K, Rasmussen R, et al. Building the foundations for sustainable development: a global investment case for investing in the capabilities of adolescents. Submitted to Lancet August 2016, final submission March 2017.

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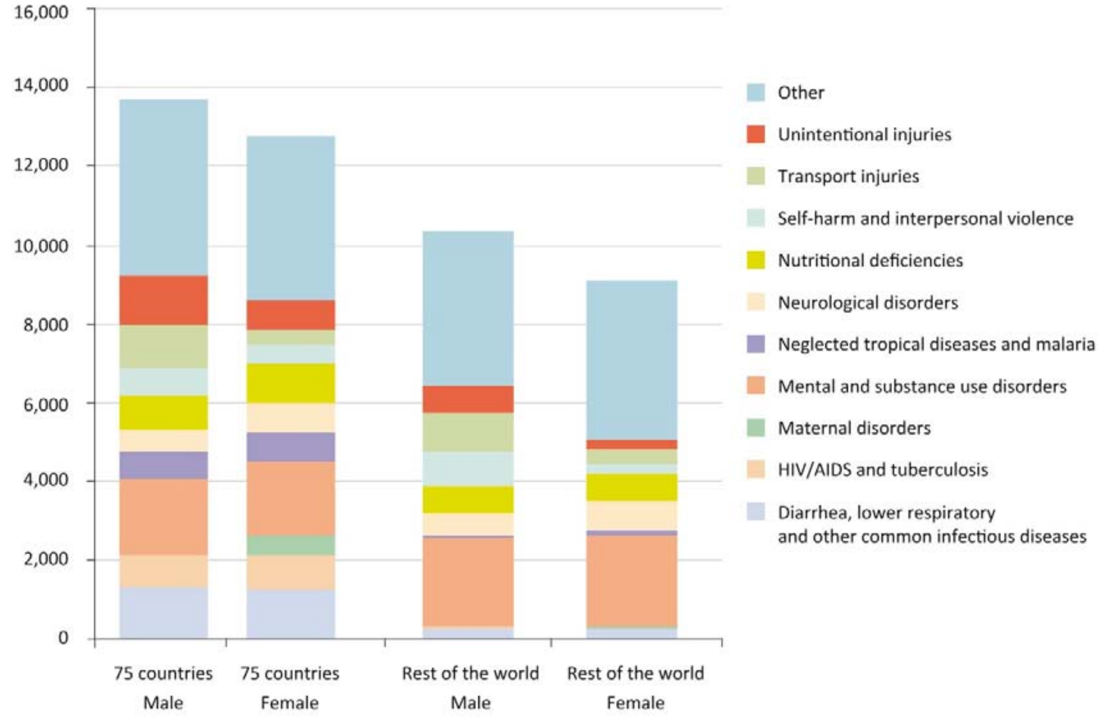
Appendix 1. Incidence Charts and Country Coverage

This appendix presents information on the adolescent burden of disease and indicators of adolescent outcomes.

Figure A1.1 below shows the global burden of disease in 10–19 year olds in 75 developing countries listed in Table A1.1 below.

Figure A1.1 Global burden of disease, 2013, DALY/100,000, 10–19 year olds.



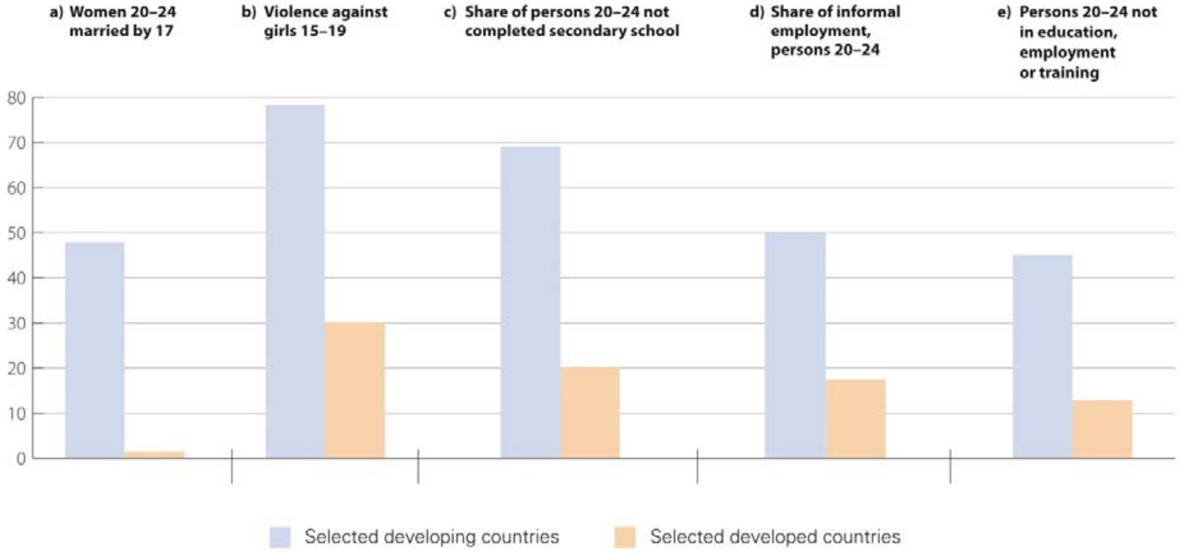
Source: IHME (2015).

Figure A1.2 below presents a summary of indicators of adolescent outcomes.

Details of data presented are as follows:

(a) Percentage of women 20–24 years married/in union by age 17 (2005–2013); data are for 75 developing countries (from UNICEF Global Database) and the developed country is Australia (ABS 2011).
(b) The burden of interpersonal violence for females 15–19 years (2010), disability-adjusted life years (DALYs) per 100,000 (RHS); data are for 75 developing countries and developed is rest of the world (from IHME 2015).
(c) Share of population not completed secondary school; data are for 42 developing countries for persons aged 20–24 years (latest available year) (from ILO 2016) and developed countries are from OECD persons aged 25–64 years (2012) (from OECD 2014).
(d) Informal employment as a share of total employment (latest available year); data are for 56 developing countries for persons aged 20–24 years (from ILO 2016) and developed countries are 30 European countries for persons aged 15 years and over (from Hazans 2011).
(e) Activity status of population 20–24, proportion of young people in neither education, employment nor training; data are for 24 developing countries for persons aged 20–24 years (latest available year) (from ILO 2016) and developed countries are OECD persons aged 15–29 years (2011) (from OECD 2013).

Figure A1.2 Indicators of adolescent outcomes.



Source: Text above figure details sources.

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Table A1.1 Country coverage of analyses and figures

	Income status	OHT analysis	Child marriage	HPV	Education	IPV	Road accidents
		40 countries	31 countries	75 countries	72 countries	74 countries	72 countries
Afghanistan	Low	*	*	*	*	*	*
Angola	Upper middle	*		*		*	
Azerbaijan	Upper middle			*	*	*	*
Bangladesh	Lower middle	*	*	*	*	*	*
Benin	Low			*	*	*	*
Bolivia	Lower middle			*	*	*	*
Botswana	Upper middle			*	*	*	*
Brazil	Upper middle	*		*	*	*	*
Burkina Faso	Low	*	*	*	*	*	*
Burundi	Low			*	*	*	*
Cambodia	Low			*	*	*	*
Cameroon	Lower middle	*	*	*	*	*	*
Central African Republic	Low			*	*	*	*
Chad	Low			*	*	*	*
China	Upper middle	*		*	*	*	*
Comoros	Low			*	*	*	*
Congo	Lower middle			*	*	*	*
Congo, DR	Low	*	*	*	*	*	*
Côte d'Ivoire	Lower middle	*	*	*	*	*	*
Djibouti	Lower middle			*	*	*	*
Egypt	Lower middle	*	*	*	*	*	*
Equatorial Guinea	High			*	*	*	*
Eritrea	Low			*	*	*	*
Ethiopia	Low	*	*	*	*	*	*
Gabon	Upper middle			*	*	*	*
Gambia, The	Low			*	*	*	*
Ghana	Lower middle	*	*	*	*	*	*
Guatemala	Lower middle	*		*	*	*	*
Guinea	Low			*	*	*	*
Guinea-Bissau	Low			*	*	*	*
Haiti	Low	*	*	*	*	*	*
India	Lower middle	*	*	*	*	*	*
Indonesia	Lower middle	*		*	*	*	*
Iraq	Upper middle	*		*		*	
Kenya	Lower middle	*	*	*	*	*	*
Korea, DPR	Low			*		*	
Kyrgyzstan	Lower middle			*	*	*	*
Lao, PDR	Lower middle			*	*	*	*
Lesotho	Lower middle			*	*	*	*
Liberia	Low			*	*	*	*
Malawi	Low	*	*	*	*	*	*
Madagascar	Low	*	*	*	*	*	*
Mali	Low	*	*	*	*	*	*
Mauritania	Lower middle			*	*	*	*
Mexico	Upper middle	*		*	*	*	*
Morocco	Lower middle	*	*	*	*	*	*
Mozambique	Low	*	*	*	*	*	*
Myanmar	Lower middle	*	*	*	*	*	*
Nepal	Low	*	*	*	*	*	*
Niger	Low	*	*	*	*	*	*
Nigeria	Lower middle	*	*	*	*	*	*
Pakistan	Lower middle	*	*	*	*	*	*
Papua New Guinea	Lower middle			*	*	*	*
Peru	Upper middle	*	*	*	*	*	*
Philippines	Lower middle	*		*	*	*	*
Rwanda	Low			*	*	*	*
São Tomé and Príncipe	Lower middle			*	*	*	*
Senegal	Lower middle			*	*	*	*
Sierra Leone	Low			*	*	*	*

	Income status	OHT analysis	Child marriage	HPV	Education	IPV	Road accidents
		40 countries	31 countries	75 countries	72 countries	74 countries	72 countries
Solomon Islands	Lower middle			*	*	*	*
Somalia	Low			*	*	*	*
South Africa	Upper middle	*	*	*	*	*	*
South Sudan	Low			*	*		*
Sudan	Lower middle	*	*	*	*	*	*
Swaziland	Lower middle			*	*	*	*
Tajikistan	Lower middle			*	*	*	*
Tanzania	Low	*	*	*	*	*	*
Togo	Low			*	*	*	*
Turkmenistan	Upper middle			*	*	*	*
Uganda	Low	*	*	*	*	*	*
Uzbekistan	Lower middle	*	*	*	*	*	*
Vietnam	Lower middle	*	*	*	*	*	*
Yemen	Lower middle	*		*	*	*	*
Zambia	Lower middle	*	*	*	*	*	*
Zimbabwe	Low	*	*	*	*	*	*

Appendix 2. Interventions Modelled

This appendix reports on interventions models in all areas used in the main paper.

Table A2.1 Interventions

Area of interventions	Description
Maternal/newborn and reproductive health	
Family planning	Modern family planning methods
Safe abortion	Safe abortion
Management of abortion complications	Post-abortion case management
Management of ectopic pregnancy care	Ectopic case management
Pregnancy care—ANC	Tetanus toxoid (pregnant women)
	Syphilis detection and treatment (pregnant women)
	Modern family planning methods
Pregnancy care—Treatment of complications	Hypertensive disorder case management
	Management of pre-eclampsia (Magnesium sulphate)
Childbirth care—Facility births	Labour and delivery management
	Active management of the 3rd stage of labour
	Management of eclampsia (Magnesium sulphate)
	Neonatal resuscitation (institutional)
	Kangaroo mother care
Childbirth care—Home births	Clean practices and immediate essential newborn care (home)
Childbirth care—Other	Antenatal corticosteroids for preterm labour
	Antibiotics for pPRoM
	Induction of labour (beyond 41 weeks)
Postpartum care—Treatment of sepsis	Maternal sepsis case management
Postpartum care—Treatment of newborn sepsis	Newborn sepsis—Full supportive care
	Newborn sepsis—Injectable antibiotics
Postpartum care—Other	Clean postnatal practices
	Chlorhexidine
Malaria	
	Insecticide treated materials
	Pregnant women sleeping under an ITN
TB	
Diagnosis—DST	Drugs susceptibility testing for first-line drugs: new TB cases
	Drugs susceptibility testing for first-line drugs: previously treated TB cases
HIV/AIDS	
Prevention—Under Programme Costing	Mass media
	Community mobilization
	Youth focused interventions—In-school
	Workplace programs
	Blood safety
	Unsafe injections replaced with AD syringes
	Reduction in number of other injections
	Universal precautions
Prevention—Other	IDU: outreach
	IDU: needle exchange
	IDU: drug substitution
	Interventions focused on female sex workers
	Interventions focused on male sex workers
	Interventions focused on men who have sex with men
	Youth focused interventions—Out-of-school
	Voluntary counselling and testing
	Condoms

	Male circumcision
	PMTCT
	Post-exposure prophylaxis
Care and treatment	ART for men
	ART for women
	Cotrimoxazole for children
	Paediatric ART
Nutrition	
Women of reproductive age and adolescent girls	Intermittent iron-folic acid supplementation (menstruating women where anaemia is public health problem)
Pregnant and lactating women	Calcium supplementation for prevention and treatment of pre-eclampsia and eclampsia
	Nutritional care and support for pregnant and lactating women in emergencies
Mental, neurological, and substance use disorders	
Anxiety disorders	Basic psychosocial treatment for anxiety disorders (mild cases)
	Basic psychosocial treatment and anti-depressant medication for anxiety disorders (moderate-severe cases)
	Intensive psychosocial treatment and anti-depressant medication for anxiety disorders (moderate-severe cases)
Depression	Basic psychosocial treatment for mild depression
	Basic psychosocial treatment and anti-depressant medication of first episode moderate-severe cases
	Intensive psychosocial treatment and anti-depressant medication of first episode moderate-severe cases
	Intensive psychosocial treatment and anti-depressant medication of recurrent moderate-severe cases on an episodic basis
	Intensive psychosocial treatment and anti-depressant medication of recurrent moderate-severe cases on a maintenance basis
	Psychosocial care for peri-natal depression
Epilepsy	Basic psychosocial support, advice, and follow-up, plus anti-epileptic medication
Alcohol use/dependence	Brief interventions and follow-up for alcohol use/dependence
	Management of alcohol withdrawal
Cervical cancer	
HPV vaccination program	Scaled up 2-dose vaccination program for 12 year old females
Education	
Supply expansion of schools	
Target interventions to reduce drop-out	Rural school supply
	Financial transfers
	Free school uniforms
	Child marriage programs
Learning quality enhancements	Better teaching methods including remedial help
	Computer, TV, or radio aided learning
	Malaria prevention
Child marriage	
	Reducing child marriage via increased school retention
	Programs to reduce child marriage within schooling groups
Interpersonal violence against women	
	Intimate partner violence against women and girls
Road safety	
	Behavioural measures: helmet usage, speed compliance, alcohol testing, seat belt use, graduated licensing

Appendix 3. Investment Case for Interventions to Improve Adolescent Health

This appendix reports on the methodology used to estimate the benefits and costs of a number of interventions to improve adolescent health reported in the main article. The interventions considered here are those that address sexual and reproductive health, as well as a range of communicable and non-communicable diseases that are important for adolescent health in low- and middle-income countries.

3.1 Introduction

The approach to the investment case for adolescents is similar to that used in the Global Investment Framework for maternal and child health (Stenberg et al. 2014). That study modelled the effect of a range of interventions aimed at improving reproductive health and reducing maternal, newborn and child deaths using the OneHealthTool (OHT), a software product whose development is overseen by the UN Inter Agency Working Group on Costing, and provided as a product by Avenir Health (2016).

This study also uses the OHT, but the default assumptions within the tool were modified such that they only considered the adolescent age group. Specific interventions included were those that aim to:

- improve the health of pregnant adolescents, as well as adolescent mothers and their newborn children;
- improve sexual and reproductive health among adolescents; and
- reduce adolescent ill health due to communicable diseases such as HIV/AIDS, and non-communicable diseases such as depression, anxiety, epilepsy, and alcohol dependence.

As demonstrated by the Lancet Commission on Adolescent Health and Wellbeing (Patton et al. 2016), these conditions are among the main contributors to the burden of disease among adolescents.

3.2 Methods

Making an investment case for interventions to address adolescent health relies on: (i) being able to specify a set of cost-effective interventions that have been shown to be successful; (ii) being able to identify the target population to which the interventions will be delivered; (iii) specifying what proportion of the target population will receive the intervention; (iv) calculating the cost associated with delivering the intervention; and (v) being able to quantify the impact of the intervention on the particular aspect of adolescent health being considered. Using this information, economic and social benefits can be calculated and compared to the intervention costs in the form of traditional investment metrics such as benefit-cost ratios and internal rates of return.

3.2.1 Specifying interventions to be modelled

This methodology was used in 2013 in making the investment case for reproductive, maternal, newborn, and child health (RMNCH). All the interventions were modelled using the OHT, with the health and cost impacts calculated for two different treatment coverage scenarios (Stenberg et al. 2014).

Since the RMNCH modelling, the scope of the OHT has expanded to include a wider range of diseases and risk factors, with plans to extend this further in the future.

A consequence of the on-going development of the OHT is that the information available to undertake economic modelling is only partially available for some diseases and risk factors. In particular, priority in the development of epidemiological models is dependent on the availability of robust data and models which can be incorporated into the OHT software in a format that would be user friendly for country users, the target audience of the tool being Ministry of Health staff in low- and middle-income countries.

Consequently, the OHT does not currently cover all areas of interest in the study, such as road traffic injuries. Therefore the OHT was only used to model those interventions for which impacts on aspects of adolescent health can be quantified and which can be costed. The final list of the interventions modelled using OHT is given in Appendix 2.

The principal differences between the set of interventions for the adolescent investment case and those used in the RMNCH modelling are that interventions related to child health (i.e. for ages 1 month–5 years) are omitted, and other interventions related to selected non-communicable diseases (depression, anxiety, perinatal depression, alcohol dependence and epilepsy) have been added.

Once a set of interventions has been chosen in OHT, the target population needs to be specified for each intervention. Having done this, the population in need of treatment is determined and then the treatment coverage rates for this population are specified. The impact of interventions is therefore modelled largely as a result of changing treatment coverage rates.

For the different scenarios, the treatment coverage rates in the initial year (2015) were based as far as possible on known current treatment rates. For the base case scenario, these coverage rates remained unchanged across the period to 2030. For the accelerated scenario, target coverage rates in the year 2030 were set based largely on the target coverage rates used in the RMNCH study. The procedure for setting these coverage rates is described in Stenberg et al. (2014, supplementary web appendix, pp. 10–15). Coverage rates for the accelerated scenario for the years between 2015 and 2030 were interpolated using the front-end loaded interpolation setting within the OHT. In the case of non-communicable diseases, the OHT produces estimates for a base case scenario of no change and a scale up scenario based on assumptions about the increase in treatment coverage rates.

An important module within the OHT addresses the impact of modern family planning methods on fertility and health. While the RMNCH study modelled the impact of increased levels of contraception targeted at women of all child bearing ages, the OHT settings for this study only changed the contraception rates for females aged 15–19 years.

For depression and anxiety, the treatment coverage rates used by Chisholm et al. (2016) in modelling the returns to investment in depression and anxiety were used, and extended to the other non-communicable disease modelled, namely perinatal depression, epilepsy and alcohol dependence.

3.2.2 Costs

The approach to estimating the costs associated with scenarios largely follows that for the RMNCH case set out in Stenberg et al. (2014) and estimates incremental costs, i.e. the additional resources required above a certain level of investment. There are two basic kinds of incremental costs, namely:

- Intervention-specific costs which are the costs of increasing intervention coverage above current (2014 estimated) levels of coverage. Costs are estimated as the difference between two scenarios, namely the Accelerated and the Base scenarios.
- Health systems and programme investments: incremental costs are estimated for implementing strategies and activities to strengthen systems and programme delivery above and beyond what is currently estimated to be invested in countries.

As described in Stenberg et al. (2014), the cost of an intervention program has a number of different components. Commodity costs, i.e. the costs associated with the provision of drugs and other supplies, are provided as an output from the OHT. To this were added the other costs associated with the roll-out of an intervention program. These are estimated in a similar way to that in Stenberg et al. (2014) which drew upon updated estimates from the High Level Taskforce for Innovative International Financing of Health Systems (HLTF) (WHO 2010) and related research. These costs are as follows.

(i) Intervention specific costs

These costs were estimated using the OHT, version 4.4.

OHT provides estimates for a specified set of interventions of the commodity costs of drugs and supplies, and the number of outpatient visits and inpatient days.

Cost data within the OHT is not available by age and gender, so commodity costs were allocated using the proportion of adolescents in the target population for each intervention. Some health and fertility outcomes in the OHT are provided by age and gender. Where this was not the case, an allocation method similar to that for costs was used.

The costs of outpatient visits and inpatient days were calculated by multiplying the country-specific and level-specific estimates for service provision of inpatient days and outpatient visits by the country-specific estimated cost associated with a visit and/or an inpatient day, as available through the WHO-CHOICE health service delivery costs database, again adjusted for the proportion of adolescents in target populations.

(ii) Health systems and programme costs

RMNCH programme costs
Programme administration costs include resources required to train health workers, monitor and evaluate programme performance, supervise activities, conduct information campaigns and support general programme management. For the analysis, unit cost estimates were based on those in Stenberg et al. (2014). These unit costs were then multiplied by the number of adolescents to obtain total programme costs.

Following the analysis in Stenberg et al. (2014), it is assumed that 50% of incremental health system costs are allocated towards RMNCH.

These estimates are incremental estimations of resources required to increase coverage from current levels to more accelerated targets.

Adolescent programme costs
Drawing upon Deogan et al. (2012a, 2012b), we include estimated costs by country for improving the quality and accessibility of health services to provide priority health interventions for adolescents. Costs include general programme coordination at national and district level, development and distribution of national standards for Adolescent Friendly Health Services (AFHS) (WHO 2003), in-service training on AFHS, information and communication activities, and upgrade of infrastructure and equipment to adolescent friendly standards. Costs are included for the accelerated scenario only. Unit costs were derived and multiplied by the number of adolescents to obtain total adolescent programme costs.

Logistics
The estimation of costs for logistics draws upon the estimates in Stenberg et al. (2014) to apply mark-up rates to the value of commodity costs in order to approximate resource requirements for expanding the supply chain. The overall approach entails multiplying the total commodity cost by estimates of supply chain logistics as a percentage of the commodity value at the national level.

Infrastructure
Infrastructure costs were calculated in a manner similar to that in Stenberg et al. (2014). For those countries for which data were missing in Stenberg et al., imputed infrastructure costs were developed. Infrastructure costs were allocated to the period 2015–2024 (ten years) as frontloading of infrastructure investments during the first decade is required in order to allow for scale-up of essential health services at primary and tertiary level, including investments in emergency obstetric care to expand access to skilled delivery and effective referral systems.

As was the case for programme costs, 50% of infrastructure costs were allocated towards RMNCH, which was then adjusted by the proportion of adolescents in the population.

Governance
Costs for strengthening functions related to governance were sourced from Stenberg et al. (2014). Updated average annual per capita costs were multiplied by the number of adolescents to derive adolescent specific governance costs.

Health information systems
Costs for health information systems are based on an approach similar to the one described for governance. Additional average annual costs required per capita were estimated and then multiplied by the number of adolescents.

Health financing
Updated costs for the administration of social health insurance (SHI) schemes were estimated from those in Stenberg et al. (2014). The approach used was similar to that for health information systems and governance where average annual per capita costs were derived and multiplied by the number of adolescents.

3.2.3 Health outcomes

The sexual and other health outcomes from modelling interventions with the OHT are usually expressed as the number of deaths and amount of morbidity that occurs for each health condition each year for each age group and sex, where this is available. For reproductive health, other outcomes include fertility rates and numbers of births. For some areas within the OHT, it is possible to obtain health outcomes data by age and sex. In this case the impact on adolescents can be assessed directly. In other areas, this data is for the whole of the population being targeted, in which cases the adolescent proportion was calculated according to that used for allocating costs, based on population proportions.

For each scenario, the numbers of maternal and newborn deaths by cause were extracted from the OHT, as well as the number of stillbirths, the number of HIV deaths, the fertility rate, and number of births. Following the analysis for RMNCH (Stenberg et al. 2014, supplementary web appendix, pp. 31–31), it was assumed that in addition to the number of deaths there would be an associated level of serious disability for both adolescent mothers and their newborn children.

Based on the analysis in Stenberg et al. (2014), it was assumed that for adolescent mothers, the number with serious disability from obstructed labor was 6 times that of the number of deaths, with half of these being unable to work and half able to work at 50% of the productivity of a healthy adolescent. Similarly, the number with serious disability from other maternal disorders was estimated to be twice the number of deaths from this cause divided equally between those unable to work and those able to work at 50% productivity. A similar approach was used to estimate serious disability associated with the causes of newborn deaths. Serious disability from prematurity was assumed to be 1·65 times the number of deaths, from asphyxia 0·9 times and from congenital abnormalities equal to the number of deaths.

For the non-communicable diseases modelled, the impact from the scale-up is expressed in the increase in healthy years lived.

Impact of education interventions on child deaths and births
The interventions to increase educational attainment described in the main paper and in more detail in Appendices 5 and 6 on education and employment result in an increase in the average grades attained by school leavers.

In their study for the Norwegian Agency for Development Cooperation, Schäferhoff et al. (2015) reviewed 6 cross-country studies and 11 single-country studies of the effect of maternal education on infant mortality. The published cross-country studies they identified are listed in Table A3.1 below.

They state that ‘The results of our meta-analysis show that a one-year increment in female education is associated with a 6·5–9·9% reduction in mortality in children younger than 5 years in low- and middle-income countries’. In our modelling, we assume that for each additional year of schooling attained by mothers, the death rate of their children falls by 6·5%.

Multiplying this factor by the increase in average grades attained gives an estimate of the effect of education interventions on the number of child deaths, in addition to those arising from the interventions modelled in OHT.

A reduction in the child marriage rate of 1% will lead to a reduction in births to teenage mothers of 0·88%, where child marriage is defined as marriage before the age of 18.

The education interventions described earlier lead to a reduction in the marriage rate for 15–19 year old females. Multiplying the change in the rate by 0·88 gives the additional reduction in the adolescent birth rate due to education interventions.

This rate is used to adjust the reduction in births due to interventions modelled using the OHT.

Table A3.1 Cross country studies on effect of maternal education on infant mortality

Cross-country studies (macro)	Publication year	Title	Variable	Percentage change estimate(s)
Filmer & Pritchett	1999	Child mortality and public spending on health: how does money matter?	Maternal level of education (categorical)	–9·1%
Jamison, Sandbu & Wang	2016	Why has under-five mortality declined at such different rates in different countries?	Mean years of female education (age 15+)	–3·5%
Wang et al.	2014	Global, regional, and national levels of neonatal, infant, and under-5 mortality during 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013	Mean years of female education (age 15–49)	–9·0%
Gakidou, Cowling, Lozano & Murray	2010	Increased educational attainment and its effect on child mortality in 175 countries between 1970 and 2009: a systematic analysis	Mean years of female education (age 15–44)	–9·5%
Verguet & Jamison	2014	Estimates of performance in the rate of decline of under-five mortality for 113 low- and middle-income countries, 1970–2010	Mean years of female education	–12.8%

Source: Schäferhoff et al. 2015.

3.2.4 Benefits

Economic benefit

Comparing two intervention scenarios enables the number of deaths and amount of morbidity averted to be calculated and compared to the difference in the cost of achieving these outcomes. From the OHT modelling for most of the health areas considered within this study, the economic benefits of interventions preventing deaths occur when people who would otherwise be dead enter the workforce and produce economic output.

A similar benefit occurs for people who would otherwise suffer serious disability that prevents them from working. Again there can be an extended period between the time a death is averted and the time in which the person enters the workforce and becomes fully productive.

As noted earlier, the intervention period is assumed to be 2015 to 2030. The intervention will only benefit those targeted for the intervention during this period. However in most cases, the benefits will extend well beyond the end of the intervention period. This is most obvious where lives are saved by the intervention. If a 15 year old person's life is saved in 2030, the benefit of being alive will commence in 2030 and continue for the rest of that person's life. If the person lives to 75 then the period for the benefits would be 2030 to 2090. The economic benefits arising from being in the workforce will occur in the period 2035 to 2080 if the person enters the workforce at age 20 and retires at age 65.

In this study, the economic modelling of mortality follows for each country the cohort of avoided deaths for each of the years 2015 to 2030. Each cohort is classified by age and sex. As the cohort ages, it is subject to the mortality rates applicable to that age group, sex and year based on estimates from UN World Population Prospects data (2015). The effect of avoided mortality on the labour force is calculated by taking the numbers of deaths avoided by age and gender, and applying a corresponding labour force participation rate for this age, gender and year sourced from the International Labour Organization projections of labour force participation rates (ILO 2016).

The contribution that each of these labour force cohorts makes to economic output is calculated by multiplying the number in each age and sex category by a productivity level that varies with age and year. To do this, the average productivity is first calculated for 2014 by dividing the World Bank estimate of GDP in current US dollars by the labour force in that year (World Bank 2015a).

This average productivity then increases at an annual rate determined by the country's income status.

An analysis of the average annual rate of productivity growth of a set of 176 countries over a number of different time periods between 1990 to 2014 showed that, for low income countries the average growth rate was 2·1%–2·5%, for lower middle income countries it was 2·5%–2·6%, for upper middle income countries it was 1·6%–2·2%, and for high income countries it was 0·6%–0·7% depending on the time period. Productivity was defined as output measured by GDP in constant local currency units (LCU) divided by total labour force, with data sourced from the World Development Indicators database maintained by the World Bank (2015a). Income status of each country for a particular year was sourced from the World Bank Excel file of historical classification (World Bank 2015b). Income status is based on values for GNI (GDP) per capita in US dollars using the Atlas methodology. This converts values in LCUs to US dollars using a conversion factor for any year that is the average of a country's exchange rate for that year and its exchange rates for the two preceding years, adjusted for the difference between the rate of inflation in the country and international inflation; the objective of the adjustment is to reduce any changes to the exchange rate caused by inflation (World Bank 2015c).

Based on this analysis, the modelling assumes that annual productivity growth for low income, lower middle, upper middle and high income countries is 2·1%, 2·5%, 1·6% and 0·7% respectively. Further, it is assumed that the country's income status changes after 15 years. For instance, a country with low income status in 2015 would change to lower middle status in 2030, upper middle status in 2045 and upper status in 2060.

Productivity varies by age, so as a proxy for this the distribution of hourly wage rates by age for Australia for 2014 (ABS 2015) is used. Average productivity for each age group is calculated by multiplying average productivity by the ratio of hourly wage rates for the age group to overall hourly wage rates. The total GDP generated is calculated by summing the GDP produced by each cohort for each year of the period in which they are in the labour force.

The contribution to GDP of each cohort of persons who would otherwise suffer from serious disability is calculated in a similar way as for mortality, using the same assumptions about participation rates and productivity. The contribution of the cohort suffering serious disability is reduced because labour force participation for each age and sex category is set conservatively at 10% lower than that of the corresponding healthy category.

In addition, it is assumed that there is reduction in productivity of 5·3% due to absenteeism and 10.9% due to presenteeism based on the values estimated by Goetzel et al. (2004) for the USA. These values are similar to those reported by Alsono et al. (2011) and Bruffaerts et al. (2012) based on analysis of the World Mental Health Surveys. Similar adjustments were made in Chisholm et al. (2016) in the analysis of depression and anxiety.

Demographic dividend
In calculating the overall benefits from interventions, the benefits arising from the impact of the reduction in high fertility rates on growth in per capita GDP are also included. Such reductions can arise from several of the interventions being studied here: from the sexual and reproductive health measures included in the OHT such as reducing the unmet need for contraception, from the impact of increased education of girls on pregnancy rates, and from reduced child marriage. That there is a strong positive impact is well documented in the literature (for a recent reviews see Canning and Schultz 2012; Ashraf et al. 2013). The demographic dividend measured here consists of increased income per head (GDP per capita) for the population arising from three sets of factors: (1) when the dependent population falls relative to the working population, GDP per capita rises; (2) when the birth rate falls, increased labour supply by women leads to increased GDP; and (3) when rates of population growth slow, the capital resources of society can be devoted to investments increasing productivity, rather than to investments needed to meet the needs of the expanding population.

The estimates of the demographic dividend draw on and adjust the methods of Ashraf et al. (2013) and follow the use of these methods in Stenberg et al. (2014). A revised version of the Ashraf et al. (2013) parameters are used to derive from their model an aggregate relationship between the reduction in the total fertility rate (TFR) and the change in per capita GDP, reflecting the three factors above. This single relationship is applied to the change in the TFR in each country to estimate the impact on per capita GDP and GDP.

Social benefit
It is common when estimating the benefits of improved health to put a value on being alive. This is usually done by estimating the value of a statistical life year. Building on the results of Viscusi et al. (2003), Jamison et al. (2013) estimated the value of a life year as between 1·4 and 4·2 times GDP per capita, averaging 1·6 globally.

Stenberg et al. (2014) modified this approach by assuming the value of a life year of 1·5 times GDP per capita and assuming the economic benefit represented 1 times GDP per capita, leaving a residual value of 0·5 times GDP per capita as the social benefit. Following this approach, a value of 0·5 times the average GDP per capita across 75 developing countries measured in USD is assigned to each healthy life year gained from the interventions to estimate the social benefit of improved health. This value was calculated for the year 2014 and assumed to increase by 1·5% per annum in following years.

The rate of return on investment can be expressed in a number of different but related ways, but benefit-cost ratios are reported here, as they are intuitively easier to understand. Two versions of these ratios are given. The first is for economic benefits alone and is calculated by dividing the net present value (NPV) of the economic benefits from mortality and morbidity avoided by the net present value of the costs of the intervention. The second version adds the economic and social benefits before dividing by costs. NPVs were calculated at a discount rate of 3% as is usual for analysis of health programs. Sensitivity analysis was performed by exploring other discount rates (2%, 5%) around the 3% default rate.

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Appendix 4. The Investment Case for a Human Papilloma Virus Vaccine Program

This appendix reports on the benefits and costs of the introduction of a program to vaccinate adolescent girls against the human papilloma virus, the benefits of which are a large reduction in adult deaths from cervical cancer.

4.1 Introduction

Cervical cancer is the fifth most common cause of neoplasm mortality among women worldwide, accounting for about 235,000 deaths each year (Naghavi et al. 2015). Approximately 80% of worldwide cervical cancers occur in developing nations (Lowy 2012).

Persistent infection by the human papilloma virus (HPV) is a necessary step in the pathogenesis of cervical cancer (Walboomers et al. 1999). HPV also contributes to the pathogenesis of several less prevalent cancers.

There are over 170 different types of HPV. More than 40 types are typically transmitted through sexual contact and infect the anogenital region. Several of these are high-risk HPV types which can contribute to the development of cancer.

The International Agency for Research on Cancer (IARC) has reviewed the evidence on the role of HPV in different cancers. Their meta-analysis of type-specific HPV DNA prevalence in cervical cancer estimated that HPV types 16 and 18 are responsible for 54·4% and 15·9% of cervical cancer respectively, with HPV types 31, 33, 45 52, and 58 are responsible for a further 17·3%. HPV types 6 and 11 are responsible for 0·65% (IARC 2012).

There are currently three types of HPV vaccine available:

- Cervarix (GSK) protecting against HPV types 16 and 18;
- Gardasil 4 (Merck) protecting against HPV types 16, 18, 11 and 6; and
- Gardasil 9 (Merck) protecting against HPV types 16, 18, 11, 6, 31, 33, 45, 52 and 58.

This implies that Cervarix, Gardasil 4 and Gardasil 9 can prevent 70·3%, 70·9% and 88·3% of cervical cancers respectively.

For this study, it is assumed that a vaccine against HPV types 16 and 18 will prevent 70% of cervical cancers.

Current HPV vaccines are prophylactic, not therapeutic; they need to be administered prior to HPV infection. The vaccines were initially recommended for girls before they become at risk of HPV infection, i.e. before they become sexually active.

In 2014, the World Health Organisation (WHO) recommended a 2-dose schedule for a vaccination program (WHO 2014).

The benefits of vaccination with respect to cancer prevention are expected to occur in later life, around ten years after vaccinated cohorts become sexually active. Currently, there has been insufficient time to establish the impact of HPV vaccines on actual health outcomes.

Studies of the feasibility and cost effectiveness of widespread vaccination programs have relied on epidemiological models to predict the alleviation in the burden of cancer based on the impact of the vaccine on the known precursors of HPV-attributable cancers, such as HPV infection and pre-cancerous cervical lesions. Once efficacy of the HPV vaccine had been established, a number of studies were undertaken on the effectiveness and cost effectiveness of widespread vaccination programs.

While there have been a number of studies undertaken for high income countries, individual country studies of the economic and health benefits of HPV vaccination and screening have also been carried out for Kenya, Mozambique, Tanzania and Uganda (Campos et al. 2011), Thailand (Sharma et al. 2012), Brazil (Goldie et al. 2007), Peru (Goldie et al. 2012), Argentina, Chile, Colombia, and Mexico (Goldie et al. 2008a), India (Diaz et al. 2008), Vietnam (Kim et al. 2008), and other low and middle income countries.

The group at the Center for Health Decision Science at the Harvard School of Public Health have developed a complex microsimulation model and undertaken studies in 23 countries for which the required data is available, some of which are listed above. They have also built a simpler model for settings in which there is only limited data (Goldie and Sweet 2013; Goldie et al. 2008b). This has been used to estimate the health and economic outcomes of HPV vaccine in 72 GAVI-eligible countries (Goldie et al. 2008c).

Jit et al. (2014) also developed an Excel-based model to estimate the health and economic effect of vaccination of girls against HPV before sexual debut. They applied this to 179 countries for which sufficient data was available and compared the results to those from 26 individual country estimates and from the study of 72 GAVI-eligible countries (Fesenfeld et al. 2013).

Reviews of these and other studies by Goldie and Sweet (2013), Fesenfeld et al. (2103) and Jit et al. (2014) have concluded that the majority of modelling studies show that HPV vaccination is expected to be cost effective, and particularly beneficial in developing countries, which do not have access to government-funded cervical screening programs. Further to this, Levin et al. (2015) synthesized available epidemiological, clinical, and economic data from China using an individual-based Monte Carlo simulation model of cervical cancer to estimate the distribution of deaths averted by income quintile. They found that the absolute numbers of cervical cancer deaths averted and the financial risk protection from HPV vaccination were highest among women in the lowest quintile and women in the bottom income quintiles received higher benefits than those in the upper wealth quintiles.

4.2 Estimating the Benefits and Cost of an HPV Vaccination Program

The modelling undertaken for this study is based on death rates from cervical cancer that were reported in the Global Burden of Disease Study (GBD) 2013 (IHME 2015). Since GBD 2013 does not report death rates from anal, penile, vulvar and vaginal cancers or other HPV-related conditions separately, our model focuses on the role of HPV vaccination in the prevention of cervical cancer only, and ignores additional protection that the vaccines offer against these other cancers and diseases. The modelling in this study also disregards any possible cross protection against HPV types that are not directly targeted by the vaccine. Therefore, estimates reported here are expected to be conservative, underestimating the likely benefit of HPV vaccination.

The modelling follows closely that used in other investment cases, including for reproductive, maternal, newborn and child health (Stenberg et al. 2014), cardiovascular disease (Bertram et al. 2016) and mental health (Chisholm et al. 2016). The modelling assumes that two doses of the vaccine are given to a proportion of girls aged 12 in each of the years 2015 to 2030.

Consistent with other modelling of the economic benefits of health interventions, it is assumed that the vaccination program begins by only covering a small percentage of the 12 year old cohort but increases rapidly to a target coverage rate which is then maintained for the remainder of the intervention period. Coverage rates in the years between the initial year and the year at which the target rate is achieved are obtained by interpolation.

The default values for coverage rates are 5% for the initial year rising to 90% by year 6 (2020).

The death rates for cervical cancer by age and country for each of the 75 developing countries are taken from the 2013 Global Burden of Disease (GBD) study (IHME 2015).

The model projects country-specific death rates over the modelling period by assuming a constant rate of decrease through to 2100. This decline in death rates can be specified by the user and has a default value of zero. A 0·5% reduction per year in the rate would reduce rates by about 35% over the period.

The number of deaths from cervical cancer for a 12 year old cohort in the absence of the vaccine is calculated by applying the appropriate age specific death rate in the appropriate year to the projected population in that age group in the same year. For instance for the cohort of 12 year olds in 2015, some will die of cervical cancer once they reach the age range of 50–54 years. Taking the age 52 to represent this age group means that there will be some deaths of the 2015 cohort of 12 year olds some 40 years later in 2055.

The percentage of deaths averted due to the vaccine is presumed to be 70%, based on the evidence presented earlier about the efficacy of the vaccine. The number of cervical cancer deaths averted is then calculated by applying this percentage to the deaths calculated as above.

Each cohort of 12 year olds is followed over a period ending 2100. During that time they are subject to a projected age, sex and year specific death rate based on UN projections of population and deaths by age, sex and year (UN 2015).

Once each cohort of 12 year old girls reaches the age of 15 they start to enter the labour force. Age, sex and year specific labour force participation rates projected by ILO (2015) are used to calculate the numbers in the labour force in each year to 2100.

The economic output produced by each cohort is calculated by multiplying the numbers in the labour force by an average productivity value adjusted for age. The average productivity is calculated by dividing World Bank estimates of GDP measured in current USD in 2014 (World Bank 2915a) by the total labour force in 2014 (ILO 2015). Values for years 2015 to 2100 are calculated by assuming this productivity increases at a rate dependent on the income status of the country in that year. The GDP produced by each cohort is summed across cohorts to give the total value of GDP for each of the years from 2015 to 2100. This is then expressed as a net present value (NPV) using a discount rate that can be set in the model. NPV based on default rates of 3%, 5% and 7% are also calculated.

In their calculation of the cost effectiveness of female HPV vaccination in 179 countries, Jit et al. (2014) assumed that the cost of one dose of the vaccine would be: (i) $4·50 in GAVI eligible countries; (ii) the price quoted in the Pan American Health Organization (PAHO) Expanded Program of Immunization Vaccine Prices for PAHO countries currently $8·50; and (iii) the retail US price for high income countries. Analysing studies for Tanzania, Bhutan and Uganda they estimate the program delivery costs to be $4·56 to $5·27 per immunised girl. Based on this they assume delivery costs of $5, $15, and $25 per immunised girl for low, middle and high income countries.

Of the countries studied, 62 are GAVI eligible. Of the other 13 countries, 4 are members of PAHO. The remainder include 4 lower middle income countries, 4 upper middle income countries and 1 high income country (Equatorial Guinea) using the most recent World Bank classification of countries (World Bank 2015b). It was assumed that in rolling out an HPV vaccine program across 75 countries, these latter 9 countries would be able to access the HPV vaccine at PAHO prices.

This suggests that the overall cost per child immunised with two doses might be as set out in Table A4.1.

Table A4.1 Vaccine costs per child immunised, 2-dose program, USD

	World Bank classification	Number of countries	Cost per dose	Cost per 2 doses	Delivery costs	Total unit cost
GAVI	Low income	31	4·50	9·00	5·00	14·00
GAVI	Lower middle income	27	4·50	9·00	10·00	19·00
GAVI	Upper middle income	4	4·50	9·00	15·00	24·00
PAHO	Lower middle income	1	8·50	17·00	10·00	27·00
PAHO	Upper middle income	3	8·50	17·00	15·00	32·00
Other	Lower middle income	4	8·50	17·00	10·00	27·00
Other	Upper middle income	4	8·50	17·00	15·00	32·00
Other	High income	1	8·50	17·00	25·00	42·00

The model used this table to determine for each country the cost per girl vaccinated.

UN population projections (2015) were used to estimate the number of 12 year old girls in each country by year for the years 2015 to 2030. The total cost of the vaccination program each year is obtained by multiplying this number by the coverage rate in that year and by the unit cost of the vaccine. This total cost was then allowed to increase in line with the assumptions made about the annual growth rate in GDP per person in the labour force. The resulting costs are discounted in the same way to produce an NPV for the cost of the vaccination program.

The social benefits associated with the deaths averted by the vaccination program are calculated following a similar procedure to that in Stenberg et al. (2014). The additional social benefit for one life year is expressed as a fraction of GDP per capita. The default value of the fraction is 0.5. Multiplying the life years saved in each year by the average GDP per capita for all 75 developing countries gives the total social benefit generated. This can also be expressed in NPV terms.

Benefit-cost ratios for the economic benefit are obtained by dividing the NPV GDP by the NPV cost. For the economic and social benefit combined the ratio is calculated by dividing the sum of NPV GDP and NPV social benefit by NPV cost.

4.3 Results

The benefit-cost ratios for a range of discount rates for countries classified by income status are shown in Table A4.2 for a 2-dose vaccination program.

Table A4.2 Benefit-cost ratios, economic and social benefits, 2-dose program

	Discount rate		
	2%	3%	5%
2-dose program			
Low	41·6	22·5	8·1
Lower middle	22·8	12·7	4·8
Upper middle	23·7	14·0	5·9
Total	30·7	17·0	6·4
Lower middle excl. India	23·2	12·9	4·9
Upper middle excl. China	16·5	9·6	4·0

The modelling showed a wide variation in benefit-cost ratios among countries and the results are very sensitive to the discount rate used in calculating NPVs. This can be seen in Figure A4.1 which shows the ratios for the 2-dose program for low income, lower middle income and upper middle income countries when only economic benefits are included. Figure A4.2 shows the results when both economic and social benefits are included.

The costs of the program begin to be incurred immediately and over the period to 2030 while most of the economic and social benefits only begin to occur after at least 30 years. The more heavily this stream of benefits is discounted the lower will be the benefit-cost ratio.

Nonetheless, for most countries benefit-cost ratios comfortably exceed 1 at the 3% discount rate typically used in analysing health projects and for the other discount rates used for a sensitivity analysis. For low income countries as a whole, the benefit-cost ratio is 22·5. Similarly the ratios for lower middle income countries are 12·7 and 14·0 for upper middle income countries.

In general, benefits will exceed costs when the rates of cervical cancer are high. Higher rates of labour force participation rates among women will also contribute to higher ratios. In addition, a higher level of GDP per person in the labour force will tend to outweigh the increase in unit cost associated with a country's higher income status.

Because this study only considers the effect on deaths from cervical cancer from immunising girls, it underestimates the benefits from preventing a proportion of other cancers in girls. If all or most girls are immunised against HPV this means that the probability of heterosexual males acquiring HPV is lessened and hence the deaths among males from at least penile and oropharyngeal cancer.

While previous studies have concluded that HPV vaccination programs are generally cost-effective, this study demonstrates that such programs have positive rates of return when considered as an investment project on both economic and social grounds.

Figure A4.1 Benefit-cost ratios, economic benefits, 2-dose program, various discount rates.

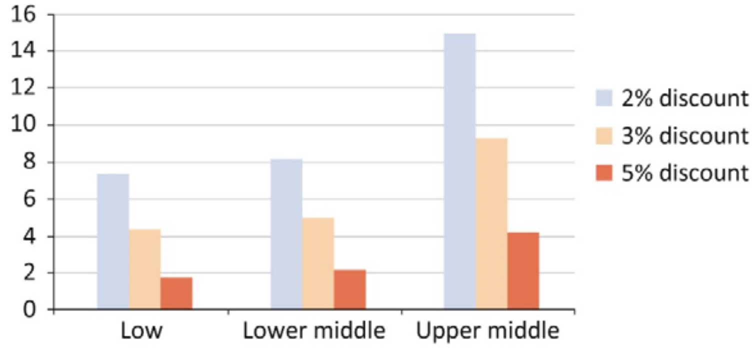
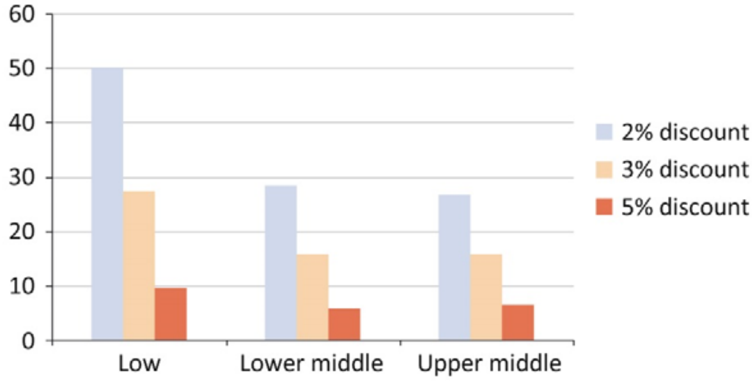


Figure A4.2 Benefit-cost ratios, economic and social benefits, 2-dose program, various discount rates.



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Appendix 5. Technical Aspects of the Education Model

This appendix describes the education model used in the main paper.

5.1 Introduction

The VISES-Education and Marriage Model (VEMM) was developed to provide answers on: a) how investments in adolescent education could improve education outcomes, b) at what costs, and c) what would be the value of those improvements.

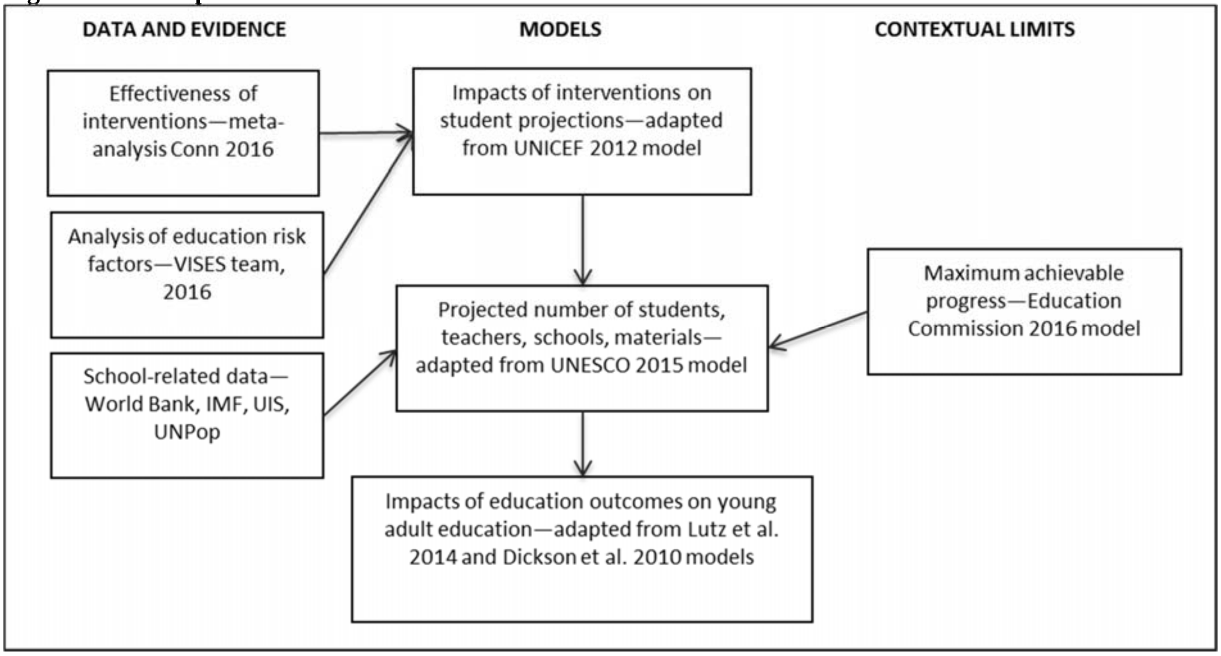
This technical paper provides the background for the new model, as well as describing—in an abbreviated form—the model and the data analysis that underlie the results described in the main report.

The question of how to improve adolescent education is not new, but, with regards to a global outlook for developing countries, models of adolescent (secondary) education until recently took a backseat to primary education. The Declaration of Education for All goals in Dakar, 2000 and the Millennium Development Goals created a need to model how much it would cost to reach the new global education goals. In response, the World Bank and UNESCO developed models to estimate the costs of attaining *primary education for all* children in developing countries by 2015, including some simple assumptions about the quality of schooling (e.g. Bruns et al. 2003; Delamonica et al. 2001; Wils et al. 2010). Later, in preparation for the new Sustainable Development Goals agreed to in Addis Ababa, 2015, UNESCO developed a costing model that includes the costs of achieving *secondary education for all* by 2030 (UNESCO 2015; Wils 2015b). These models all have a common structure: they compute the evolution of student numbers by country up to the attainment of the education goals and multiply those numbers with unit costs based on assumptions regarding teachers, salaries, materials and ongoing support, and school construction.

The limitations of this approach are that it ignores a) whether the projected rates of progress are achievable, b) how much learning improves, c) whether the assumed unit costs include the necessary interventions to improve access and school quality and d) how the outcomes affect adult skills. To answer the main question of our project, namely, which specific interventions could most (cost-) effectively improve adolescent welfare, those four gaps need to be addressed. Fortunately, other streams of research have looked at these issues. Wils and Ingram (2011) and the Education Commission (2016) analyzed feasible historical trends and applied these to education projection and costing models. The Education Commission also developed an approach to modeling learning improvements (Wils forthcoming 2017). UNICEF (2012) developed a model that explicitly includes evidence from research on what types of interventions can improve education outcomes—building on the work in health that UNICEF and the WHO had used to develop the OneHealthTool and the MBB models (WHO 2013; UNICEF 2010). In parallel, researchers in Europe and the US developed demographic models that link school outcomes to improvements in adult education levels, including young adults separately (e.g. Lutz et al. 2007; Wils 2011; Lutz, Butz and KC 2014; Dickson et al. 2010; Dickson et al. 2016; Barakat 2016). The VEMM model hooks these three approaches up to the UNESCO model in a modular fashion, creating a new model out of existing, vetted parts, shown in Figure A5.1 below. Section 5.2 describes the model components and connections in more detail.

As this project is an investment case, not a theoretical exercise, the projected costs and benefits also need to be grounded in data and evidence. The VEMM model is connected to a database of more than 250,000 points, providing the education-related starting conditions for each included country. These data are a compilation from the World Bank, the UNESCO Institute for Statistics (UIS), the IMF, the United Nations Population Division (UNPop), the Education Commission, and national documents to fill in gaps left by the international databases. Regarding the effectiveness of interventions to improve education outcomes, the model includes coefficients from an analysis by Conn (2016), which brings together five meta-analyses (Conn 2014; McEwan 2014; Snilstveit et al. 2015; Nores and Barnett 2010; Rolstad et al. 2005) and produced perhaps the most comprehensive existing review of what works in education. The VEMM model also includes risk factors for adolescent education, namely poverty, rural location and female sex (an approach taken from the UNICEF 2012 model). The VISES team conducted the risk factor analysis. The data and evidence is discussed further in Section 5.3.

Figure A5.1 Components of the VEEM model.



In summary, the VEMM model has the following features:

1. It includes 72 countries, and standard projections of basic provision of education—teachers, classrooms, and materials.
2. Projected improvements in education outcomes—access as well as learning—simulated by the assumed addition of evidence based baskets of interventions.
3. Demographic projection of students and post-school population by age, grade, and marital status for 10-19 year old adolescents and 20 to 24 year old young adults.
4. A marriage component to model the impact of increased schooling on marriage rates and of interventions to reduce child marriage on educational involvement.

5.2 Model Description

The **core of the VEMM model is the projected number of students** by grade and year. Although the focus is on adolescents, the model includes the entire school system starting in grade 1, to get a realistic flow-through from the end of primary into secondary school. This core is taken from the UNESCO (2015) and Wils (2015b) model. The number of students is based on the starting distribution and projected intake, promotion, repetition and dropout rates. In addition to the consideration of sex and grades, the VEMM model added age-by grade, creating a four-dimensional student matrix consisting of sex, grade, age, and time.

In mathematical terms, the projected number of students (*S*) by age and grade is determined by: the repeating students I from the same grade in the previous year and previous age; plus the promoted students (*pr*) from the prior grade in the previous year and the previous age:

$$S_{a,g,t} = S_{a-1,g,t-1} r_{g,t-1} + S_{a-1,g-1,t-1} pr_{a-1,g-1,t-1} \quad (1)$$

For the grade 1 students, intake rates replace promotion in the equation. Intake into grade 1 is projected as the gross intake rate (an exogenously assumed variable) times the population in the official entry age, distributed over age with a consideration of initial over-age entry and an exogenous assumption about the reduction of over-age entry.

Learning levels are included as a single variable, L, to represent the percentage of students in secondary school who attain the minimum learning benchmarks, proxied by reaching the low math score in the PISA and TIMMS (described more in Wils forthcoming 2017).

The **VEMM model considers risk factors** as co-drivers of promotion, dropout, repetition and learning rates, using an adapted version of the education projection model with risk factors developed by UNICEF (2012). Risk factors such as poverty, rural location, female sex, ethnic minority status, disability all increase the probability that an adolescent will leave school prematurely, repeat a grade, or fail to reach learning benchmarks. To capture this effect, the model decomposes dropout (*d*) and repetition rateI (*r*) into a linear equation given by a conInt (*c*), plus the summed effect of risk factors, each of which is the product of the prevalence of the risk factor p_k, and the marginal impact of the risk factor β_k.

$$d/r_{a,g} = c_{a,g} + \sum_k \beta_k p_k \quad (2)$$

The risk factors included in the VEMM model are: poverty, female sex, and rural location. The selection, coefficients and the prevalence of the risk factors are described in the next section. The original equation (1) for student progress uses promotion rates, but these can be computed as the residual of dropout and repetition $pr_{a,g} = 1 - d_{a,g} - r_g$. The equation for learning is similarly decomposed into a constant and risk factor effects.

With this decomposition, a projection of students will change, depending on projected changes in the prevalence of poverty, rural location, and female sex, and on the strength of the coefficients. For future prevalence of poverty, the VEMM model uses the IMF Economic Outlook (2016) and the Education Commission's (2016) projection of GDP per capita growth to 2030; future proportions of rural populations are based on the United Nations population projections (UN 2015); and the prevalence of female sex is assumed unchanged.

Changes in the coefficients for dropout, repetition, and learning assumed to be affected by **levels of investments in interventions**. For this piece, the VEMM model again uses the UNICEF (2012) education projection model. Two examples of intervention effects are: cash transfers reduce dropout by reducing the marginal impact of poverty; community programs for girls reduce the marginal impact of girl sex on dropout.

The intent of interventions is to reduce the *marginal effects* of risk factors on dropout. Other interventions, not considered in this model, could reduce the prevalence of the risk factors. The impact of interventions is the combined effect of: *coverage*—the per cent of the target population receiving the intervention—and the interventions' *effectiveness*. The scale of the interventions is a user-set variable in the model, but the effectiveness is taken from the meta-meta analysis by Conn (2016) and, the VISES team's additional analysis of specific interventions.

As a simple example of how the intervention module works, say that cash transfers have the effect of reducing dropout rates of poor adolescents by 30% annually. If one 100% of adolescents is poor, and 100% receive cash transfers the reduction of dropout rates will be 30 percent. But in most cases, this maximum is not reached because only a portion of adolescents is poor, and because the programs reach only a fraction of those poor adolescents. With this in mind, a general formulation for the impact of a given intervention is:

$$i_{i,k} = c_{i,k} p_k e_i \quad (3)$$

where *i* is the impact of the intervention, *k* is the risk group k, c is the coverage of the intended risk group (percent receiving the intervention), *p* is the prevalence of the risk group in the population, and *e*t is the effectiveness of the intervention for those who receive it.

One group of interventions has a global benefit; these can be scaled up to reach the entire population and reduce the constant in equation (2); other interventions alleviate barriers for particular risk groups and impact the β's in equation (2).

Multiple interventions are often combined in a package. If they are not complimentary, the effect is multiplicative, with each intervention's effect eroded slightly by the impact of other interventions. This effect is formulated as a chain:

$$\hat{\imath} = (1 - i_1) * (1 - i_2) * \ldots * (1 - i_n) \quad (4)$$

where î is the cumulative effect of all the interventions together. The value of î changes over time, depending on the assumed path of scaling up the interventions (effectiveness is assumed to remain constant).

The education model maintains a separate $\hat{\imath}_k$ for each of the three risk groups and for the constant in the dropout equation (above). The combined effect of all four $\hat{\imath}_k$ values determines the future paths of dropout, repetition and learning.

The combined effect of all interventions is to modulate the constant and the betas in equation 2 as follows:

$$d/r_t = d_0 * (\hat{\imath}_{c,d,t} c + \hat{\imath}_{f,d,t} \beta_f p_{f,t} + \hat{\imath}_{p,d,t} \beta_p p_{p,t} + \hat{\imath}_{u,d,t} \beta_u p_{u,t}) \quad (5)$$

where d_t are the projected dropout rates in time t; d_0 is the initial dropout rate; and the subscripts d, f, p, and u denote dropout, female sex, poverty and rural (non-urban) location respectively. Note that both the î effects and the prevalence rates are time-dependent, as they change in the course of the simulation, and the age and grade subscripts have been dropped to simplify the equation.[1]

Finally, all of the above applies only to repetition and learning of the secondary school adolescent students; for younger students, age 5-9, there are simply target-led, user-set assumptions about changes (generally a target for lower values to be reached by a specified target year).

The **projected costs** are the sum of the core costs and the intervention costs. The core cost equation is from the UNESCO (2015) model. Total costs are a function of unit costs, which are determined by assumptions about class size, teacher salaries, materials, and school maintenance and construction—in basic terms this equation says that unIcosts (c) are equal to salaries (s) plus a multiplier (*m*) to consider other recurrent costs plus amortized costs per classroom (*sc*), divided by the pupil teacher ratio (*PTR*, assumed equal to the pupil classroom ratio):

$$c = \frac{s*(1+m)+sc}{PTR} \quad (6)$$

The **total intervention cost** (*CI*) is equal to sum of costs for all interventions assumed; and the cost of each individual intervention is equal to the number of students (*n*) receiving intervention *i* at time *t* multiplied by the unit costs of the intervention (*ci*):

$$CI = \sum_i n_{i,t} * ci_{i,t} \quad (7)$$

For the **computation of the investment case,** two scenarios are considered. The first is a base case, where there are no interventions assumed, so education progress remains flat, and the only costs are the basic costs. In the intervention case, education improves along the path resulting from changes to dropout, repetition, and learning failure as a result of interventions, and the costs are both the intervention costs and the increase in base costs due to the higher number of students.

[1] Also, for repetition *and learning* the VEMM model does not consider the marginal effects of risk factors, but the scale of interventions is still limited by the prevalence of the risk factors. The equation for repetition/learning, with subscripts *r/l* for repetition or learning, is:

$$r/l_t = r/l_0 * \hat{\imath}_c \left(1 - p_{f,t}(1 - \hat{\imath}_{f,r/l,t})\right) * \left(1 - p_{p,t}(1 - \hat{\imath}_{p,r/l,t})\right) * \left(1 - p_{u,t}(1 - \hat{\imath}_{u,r/l,t})\right)$$

In addition, for the investment case and the calculations of education's impacts on worker skills and earnings, as well as on early marriage rates, the VEMM model needed to consider how the different schooling outcomes affect the **education levels of adults, in particular, young adults**. For these calculations, the VEMM model computes school leavers (L) and from those, the population by age, sex and highest completed education level. For the school leavers, the VEMM model uses equations from Wils (2011) and for the demographic component, the VEMM model uses the multi-state demographic methodology first proposed by Rogers (1980) and more recently described for education projection in Lutz et al. (2014) and Dickson et al. (2010).

From the projected students, the computation of school-leavers is straightforward as the product of students and the dropout rate:

$$L_{a,g,t} = S_{a,g,t} d_{a,g,t} \quad (8)$$

For the **adult population by education**, the VEMM model uses multi-state demographic methodology. Starting from a base situation with the population distributed by sex, age, and educational attainment, and people transition between educational attainment states as they enter and leave school. The education states included in the VEMM model are: no schooling, in school, left school with primary only, left school with incomplete secondary, and left school with completed secondary.

All people are born into the no schooling category. In the countries in the VEMM model, most transition into school, but some portion never enters school and these remain in the no schooling state even as they age into adults. The never-schooled population is:

$$P_{a,0,t} = P_{a-1,0,t-1}(1 - m_a) - I_{a,t}. \quad (9)$$

Intake is considered possible up to age 12 in the model.

Those who enter school remain in the in school category, progressing through grades according to equation (1), until they leave school at the rate computed from equation (8). The school-leavers enter into one of the three post-school states, depending on the grade they left school, and over time, the left-school population is attenuated by mortality (m):

$$P_{a,g,t} = P_{a-1,g,t-1}(1 - m_a) + L_{a,g,t}(1 - m_a). \quad (10)$$

Finally **marriage is added** through the division of each population-age-sex group into married and un-married according to proportions observed in the household surveys in the benchmark year and assumed fixed over time (thus, educational change is the only avenue modeled for reducing marriage rates)

The sum of the education-specific population groups is equal to the total population.

5.3 Data and Evidence

The education risks for adolescents are high, but particularly higher for married, female, poor, and rural adolescents. The study undertook a **multivariate risk factor analysis** to determine the independent contribution of each of these four risk factors to dropout rate based on household surveys. In total, 49 Demographic Health Surveys (DHS) from 2008–2014 were included in the analysis and 24 UNICEF Multiple Indicator Cluster Surveys (MICS). Five of these could not be used due to missing variables. The micro-datasets were combine into two meta-files, one containing DHS and the second containing all the MICS surveys, with the variables related to the regression—age, sex, location, marital status, relative wealth indices, educational status and derived variables for dropout, school duration, poor status, rural status, and marital-education status.

This dataset was used in a multivariate regression model following Hattori (2014), later adapted by Kan and Wils (2016) with the probability of having left school by age 19 as the dependent variable, and marital status, sex, poor and rural status as the independents. As these are all binary a logit model was used, and the results transformed into marginal effects. The model was run separately for each country. The results are the coefficients for risk-factor equation (3) above.

The study also researched the **evidence of the effectiveness of interventions**, mainly using Conn (2016), but also other earlier analyses. In health, rigorous and repeated testing of new treatments is common to identify effective interventions. In education, this rigorous approach is only recently expanding. In part, the field of education has been held back in this respect by the fact that the delivery modes of any given education intervention can be very varied (meaning that one study is never exactly comparable to another). For example, in the area of distance learning, educationalists have studies on the impacts of programs as diverse as Sesame Street for preschoolers and Telesecundaria, a program for rural secondary schools in Latin America.

To consolidate this evidence, diverse as it is, educationalists turn to meta-analyses, and account for the diversity of studies in groups of interventions in different ways. Some, like recently Glewwe and Mulharidharan (2015) present only the numbers of studies with positive, negative, or no significant results. While this is a useful first step, it is not helpful for the identification of particularly strong or cost-effective interventions. McEwan (2015), Conn (2014) and Snilstveit et al. (2015) utilize the statistical techniques of meta-analysis (e.g. Borenstein et al. 2009) to provide weighted averages of the effects of intervention-groups (the weights are determined by among other things, sample sizes, standard errors, type of study). UNICEF (2012) presented the effectiveness of interventions based on its own compilation of 300+ studies (using an un-weighted approach) to make the investment case for investing in equity in education.

Conn (2016) and the Education Commission (2016) took this intervention research one step further by consolidating five meta-analyses into one meta-meta study on education intervention impacts. These studies found the following interventions to be the most effective at increasing learning and reducing dropout rates: early childhood interventions; mother-tongue or bilingual instruction; multi-level interventions that include community, teachers, and student support; cash transfers; improved teaching methods; improved school infrastructure; schools nearby; remedial education; computer-assisted instruction with teacher support; and some health interventions such as malaria prevention.

Finally the VEMM model is grounded in **detailed country-specific data** that describe the starting position of each country with regards to students by grade, teachers, school buildings, student progression rates, learning outcomes, as well as contextual variables regarding income, poverty, and distribution of the population. The sources of these data are: the UIS (UNESCO Institute of Statistics), Word Bank Development Indicators, the UN Population Division and additional data compiled for the adolescent study. The benchmark data for the model encompasses more than 250,000 data points. The initial conditions provide a comprehensive starting point for each country including the existing student population and its education outputs (progress through school and dropout rates), risk factors for dropout in the adolescent years, and the initial learning levels.

Basic data on the pupil distribution by sex and grade, number of teachers, teacher salary, annual expenditures on materials, and estimates on classrooms, and projections of the school age population are taken from the UNESCO (2015) and the Education Commission (2016) model. Most of these data are from the UNESCO Institute of Statistics (UIS).

Repetition and dropout rates by grade were obtained from UIS data in the UNESCO (2015) model. Because we wanted to include the known effects of age on dropout rates, the grade-specific dropout divided into three groups (5–9, 10–14, and 15+). The patterns for age-specific dropout rates were taken from the same set of household surveys also use for the risk factor analysis. The age adjustments maintain the grade-specific dropout values in the aggregate. DHS and MICS household surveys were also accessed for initial age-distribution within grades, and for the age- and sex-wise initial distribution of the population over education and marital status groups—those with no schooling, those in school, those post-school with primary, post school with incomplete secondary, and post-school with secondary completed, all for never-married or ever-married.

As an estimate of the **learning levels of secondary schooling**, the model uses the proportion of secondary students who attain a minimum level of academic learning, namely the “low” benchmark for mathematics, from PISA and TIMSS. The methodology for these estimates is described in Wils (forthcoming 2017).

Table A5.1 Output of the regression for marginal effects of risk factors on early dropout probability before age 19, for 44 DHS surveys

VARIABLES	Married	s.d.	Girl sex	s.d.	Poor	s.d.	Rural location	s.d.	Observations
Albania	0·325***	(0·0574)	0·0166	(0·0354)	0·145**	(0·0607)	0·349***	(0·0302)	1457
Bangladesh	0·398***	(0·0162)	-0·0808***	(0·0183)	0·295***	(0·0230)	-0·0585***	(0·0186)	4940
Burkina Faso	0·426***	(0·0300)	-0·0262	(0·0323)	0·0710*	(0·0404)	0·0733*	(0·0404)	1769
Burundi	0·578***	(0·0168)	0·0446*	(0·0263)	0·109**	(0·0473)	-0·110***	(0·0407)	2226
Cambodia	0·311***	(0·0126)	0·0455***	(0·0157)	0·200***	(0·0162)	0·108***	(0·0200)	4752
Cameroon	0·531***	(0·0180)	0·0206	(0·0215)	0·177***	(0·0277)	0·0214	(0·0274)	3891
Colombia	0·357***	(0·0162)	-0·130***	(0·0108)	0·263***	(0·0201)	0·0939***	(0·0148)	11209
Comoros	0·577***	(0·0414)	-0·123***	(0·0364)	0·0544	(0·0336)	0·0289	(0·0350)	1368
Congo	0·396***	(0·0360)	0·0288	(0·0361)	0·283***	(0·0455)	-0·139***	(0·0480)	2258
Congo DR	0·494***	(0·0242)	0·208***	(0·0239)	0·0619*	(0·0371)	0·0994***	(0·0336)	4736
Cote d'Ivoire	0·383***	(0·0353)	0·137***	(0·0339)	0·169***	(0·0477)	0·252***	(0·0434)	1647
Ethiopia	0·470***	(0·0246)	-0·0518*	(0·0278)	-0·168***	(0·0543)	0·283***	(0·0501)	3982
Gabon	0·459***	(0·0527)	0·0503	(0·0370)			0·253***	(0·0363)	1879
Gambia	0·507***	(0·0301)	0·00183	(0·0296)	0·157***	(0·0368)	-0·0634*	(0·0352)	2413
Ghana	0·454***	(0·0273)	0·0934***	(0·0237)	0·0145	(0·0306)	0·110***	(0·0284)	2407
Guinea	0·470***	(0·0397)	0·128***	(0·0356)	0·111*	(0·0625)	0·0800	(0·0632)	1526
Guyana	0·256***	(0·0510)	-0·138***	(0·0431)	0·337***	(0·0523)	0·129***	(0·0438)	1038
Haiti	0·603***	(0·0266)	0·0620***	(0·0212)	0·137***	(0·0291)	0·0196	(0.0293)	3664
Kenya	0·556***	(0·0337)	0·0468	(0·0345)	-0·00265	(0·0395)	-0·0220	(0.0515)	2072
Kyrgystan	0·232***	(0·0404)	-0·0707***	(0·0230)			0·0826***	(0.0195)	1551
Lesotho	0·466***	(0·0193)	-0·172***	(0·0246)	0·252***	(0·0279)	0·127***	(0·0357)	2971
Malawi	0·521***	(0·0158)	0·0245	(0·0219)	0·277***	(0·0342)	0·0598*	(0·0361)	5515
Mozambique	0·385***	(0·0220)	0·0202	(0·0257)	0·258***	(0·0305)	0·100***	(0·0285)	2977
Nepal	0·450***	(0·0244)	-0·0445*	(0·0263)	0·219***	(0·0263)	-0·00935	(0·0306)	2673
Niger	0·384***	(0·0306)	-0·0919**	(0·0368)	0·143***	(0·0404)	0·183***	(0·0403)	1188
Nigeria	0·434***	(0·0221)	0·0298**	(0·0123)	0·148***	(0·0116)	0·0702***	(0·0117)	7180
Pakistan	0·279***	(0·0279)	0·0113	(0·0214)	0·169***	(0·0242)	0·0737***	(0·0235)	5055
Peru	0·372***	(0·0257)	-0·0437***	(0·0139)	0·203***	(0·0279)	0·160***	(0·0179)	5566
Rwanda	0·363***	(0·0197)	0·0411**	(0·0182)	0·0671**	(0·0309)	0·00779	(0·0292)	3088
Senegal	0·533***	(0·0359)	-0·00174	(0·0457)	0·0485	(0·0416)	-0·000372	(0·0425)	1484
Sierra Leone	0·530***	(0·0254)	0·161***	(0·0239)	0·0866***	(0·0332)	0·166***	(0·0271)	3363
STP	0·392***	(0·0430)	-0·0736	(0·0549)	0·337***	(0·0467)	0·0945*	(0·0508)	731
Tajikistan	0·194***	(0·0298)	0·177***	(0·0238)	0·0905***	(0·0265)	0·103***	(0·0233)	2230
Tanzania	0·388***	(0·0165)	0·0466**	(0·0228)	0·147***	(0·0325)	-0·00897	(0·0311)	2683
Timor Leste	0·627***	(0·0247)	-0·0450**	(0·0190)	0·131***	(0·0199)	0·142***	(0·0206)	3316
Togo	0·534***	(0·0222)	0·143***	(0·0275)	0·0561	(0·0430)	0·0359	(0·0399)	2132
Uganda	0·465***	(0·0187)	0·0487*	(0·0255)	0·0945***	(0·0314)	-0·0302	(0·0312)	2353
Zambia	0·558***	(0·0159)	0·0719***	(0·0218)	0·324***	(0·0277)	0·0904***	(0·0239)	4597
Zimbabwe	0·287***	(0·0163)	0·0611***	(0·0186)	0·0944***	(0·0197)	0·0164	(0·0201)	2457

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Appendix 6. Employment

This appendix describes the employment model discussed in the main paper.

6.1 Executive Summary

In the modern world, education of good quality, to at least secondary level, is vital for adolescents to develop the capabilities required to live a productive, empowered and satisfying life. But in many developing countries only 30% or less of young people complete secondary school (about 80% do so in developed countries). Thus an important element of this project is to specify interventions to improve the level and quality of schooling in the target countries, to quantify their likely educational outcomes and to assess these interventions as investments, by a cost-benefit analysis which compares their costs to the value of the economic and social benefits generated. The first two of these tasks is undertaken in the education model developed for this project (Appendix 5), while this paper reports on work done on the cost-benefit analysis of the results emerging from the education model.

It is important to distinguish between analyses of the returns to education, which typically involve estimating the return to an individual or a community from, for example, an additional year of schooling or an incremental unit of the quality of education, from a cost-benefit analysis which compares the costs of achieving the improvement in educational outcomes to the benefits generated. There is a vast literature on the various components of the return to education, which we draw on below. Much less research has been undertaken on the cost-benefit analysis of large-scale educational interventions, especially in studies covering many countries. In a rigorous assessment of a specific program, the Perry preschool program in the USA, Heckman et al. (2010) found benefit-cost ratios for the program between 7 and 10, for a 3% discount rate. A rare recent example is of a study covering many countries is Psacharopoulos (2014), who attempts a preliminary cost-benefit analysis of the post-2015 education targets and found a range of benefit-cost ratios from 4 to 37 for various elements assessed for developing countries.

This paper describes the simple model developed to estimate the impact on national GDP levels of improvements in educational outcomes arising from specific interventions, as analysed by the education model. This work draws on three strands of the recent literature on the economic impact of education. The first is the macroeconomic literature linking educational outcomes, both years of schooling and quality outcomes, to GDP growth at the national level. This strand establishes long term average relationships, covering both private and public benefits and after the interaction of supply and demand. The second strand is the earnings return to schooling literature, which provides estimates of the (private) wage earnings return to an additional year of schooling, to better quality schooling or to improved cognitive skills acquired through schooling. The third strand is the role of education in allowing adolescents to move into good quality employment. This strand starts from the importance of relatively low wage informal employment (own account workers and contributing family helpers) in developing countries, and the fact that such jobs are more likely to be held by individuals with limited education.

The interventions which are employed in the education model, including measures to reduce child marriage and hence keep girls in school longer, have been described in the main paper and in Appendix 5. We developed a model drawing on three outcomes from the education model resulting from these interventions (additional years of schooling, improved quality of schooling and increased secondary completions). The impact model includes four channels through which these improved education outcomes and the enhanced human capital to which they give rise influences economic activity, relative to the unchanged policy base case:

- (i) increased years of schooling lead to higher productivity and higher earnings in employment;
- (ii) improvements in the quality of education also lead to higher productivity and earnings in employment;
- (iii) a rise in secondary school completions leads to an increase in the relative share of formal employment and a decline in the share of informal employment; and
- (iv) an increase in secondary completions also leads to a rise in the population which is employed.

The parameters of this model are based on our assessment of the existing literature and on some limited empirical work on the link between secondary completions and employment type. Account is taken of the fact that changes in employment type will reflect demand and structural factors in addition to the increased supply of better educated workers. The central focus of the model is on the educational and employment characteristics of successive 20 year old cohorts, with the activity of each cohort traced through the life cycle having regard to different levels of productivity by age. For each country the projected population by age and sex is an exogenous input to the education model, and the educational status of the 20–24 year old cohorts as generated by that model is used here. The analysis is undertaken for the 72 developing countries. The education interventions are gradually scaled up from 2016 to 2030 and are held at the 2030 level until 2050. For each cohort, however, the benefits of better education persist well beyond the period of schooling.

The initial results imply that, consistent with the literature, improved educational outcomes have a major impact on long term GDP. But these impacts take considerable time to build up—it typically takes close to a decade before the GDP impact becomes positive—and they vary considerably across countries. If a country takes major initiatives to increase the level and quality of schooling of its young people, this involves them staying longer in school. Not only are the costs of the initiatives, and of having more pupils at school, considerable but the nation also bears an initial GDP cost because more young people are at school rather than at work. It is only after successive cohorts leave school and enter the labour force with enhanced skills and human capital that the economic benefits of better education are felt. The magnitude of this effect, and the cost and effectiveness of the education initiatives, varies across countries. These factors influence the variations in benefit-cost ratios across countries reported in this paper.

6.2 The Issue

Better education contributes in many ways to improving the welfare of young people over their life-cycle. For girls, better schooling often leads to later marriage and to fewer adolescent pregnancies, to improved health outcomes for both mother and child and to a lower birth rate overall. More generally, it assists the empowerment of women, leading to more equal participation in marriage and in the community as a whole. For boys, a variety of parallel benefits are evident, including reduced violence, lower injury levels and improved long-term health and community involvement.

These impacts are important, and pursued elsewhere in this project, but the effect of better education on the earnings and productivity of individuals and on the economic growth of the nation as a whole is also critical. This paper concentrates on this issue, starting from the estimates produced in the education model (Wils 2015) of the improved schooling outcomes—in terms of years of schooling, school quality and secondary completions—which might be achieved in the developing countries by specified interventions.

The body of this paper is in four parts. In this section, the vast literature about educational outcomes and productivity, earnings and growth is briefly reviewed, and possible approaches defined. Section 6.2 outlines the structure of the simple model that is drawn from this review, to estimate the impact of improvements in school outcomes in the developing countries on GDP in those countries. Section 6.3 describes how the parameters of the model are determined, and how this model draws on the outputs of the educational model. Finally, Section 6.4 provides some illustrative results from a sample of countries and discusses the limitations of this model.

6.2.1 Three potential approaches

Here we concentrate on three strands of the literature, and the different approaches which they might suggest. The first is the link between education and GDP growth at the aggregate level, the second is the impact of better education on the earnings of individuals and the third relates to the specific characteristics of employment in developing countries, especially the extent of informal employment in those countries.

Macroeconomic measures of the impact of increases in the quantity or quality of education on GDP
There is a long history in economics of studying the impact of education and of human capital more generally on economic growth, partly in the context of seeking to explain the existence of sharp differences between countries in GDP per capita levels and hence in living standards. A valuable review of some of this literature, from an educational perspective, is to be found in Thomas and Burnett (2015). The modern literature started from Mankiw, Romer and Weil's demonstration (1992) that introducing a human capital variable based on educational attainment much improved the predictive power of the Solow/Swan growth model. While some 'single factor' analyses have continued, this literature quickly expanded into an analysis of the role of human capital as one of the many factors that shape cross-country differences in GDP per capita and growth rates (Barro 1997, 2013; Hall and Jones 1999; Gleaser et al. 2004). Much of this analysis has made use of successive generations of the Barro and Lee cross-country database (2013), and has focused on years of schooling as a measure of educational attainment. Recently

there has been increasing emphasis on the growth effects of improving the quality of educational outcomes (Barro 2013; Hanushek and Woesmann 2015a, 2015b).

While this macroeconomic literature is vast, and there are many voices dissenting on various aspects, the central conclusion is that there are very high returns in terms of higher GDP or higher GDP growth to improvements in both educational outcomes measured in years of schooling and in educational quality measured by test scores. It is also widely agreed that the role of education stands in addition to that of other factors which contribute to higher growth (such as economic and social institutions and convergence in technologies), and that the role of education can be seen as, at least in part, a causal one in generating growth as a response to improved educational outcomes.

For example, Barro (2013) found that the return through higher GDP to an additional year of schooling for adult males is about 19% for a sample of approximately 100 countries, and that the effect was about twice as large for the poor countries in the sample as for the sample as a whole. In his regressions the dependent variable is the average rate of growth over 1965–95, estimated for each country as the average of growth rates over each of the three decades covered. The schooling variable, which was included with a range of other independent variables, was the average level of school attainment at secondary school or above for adult males 25 years and over at the beginning of the period (that is, in 1965), but he detects no significant returns to schooling in a parallel analysis for females. The emphasis on the primary role of post-primary education is reinforced in other studies (such as Lutz et al. 2008 which used a distinct data set), but the null return for females is not generally reported in other studies, many of which are carried out on data for all persons.

Examples of recent work exploring the impact of improved educational quality are noted above. Barro (2013) adds test score measures to the regressions reported above, for 43 of the 100 countries and with only one value for each country, for different years over the period. This single value is assumed to be representative of earlier and later values for the country concerned. When a science score is added to the basic regressions, Barro finds a substantial quality effect and that the years of schooling variable remains significant but at a lower level.

In a series of studies over a decade or so, Hanushek and Woessmann have assembled comparative data across countries on test scores. In their latest studies (2015a, 2015b), they used average test scores over 1964 to 2003 in mathematics and science for 50 countries, from primary through to the end of secondary school, as a measure of human capital. They then ran simple regressions relating the long-run growth in per capita GDP for these countries (measured as the average annual growth rate over 1960–2000) to the opening level of GDP per capita and to human capital, measured as either the opening years of schooling or the test scores variable. They found that the explanatory power of this equation was raised sharply when the test score variable replaces the opening years of schooling variable, but results with other explanatory variables included were not reported. The scale of the effect reported by Hanushek and Woessmann is substantial—evaluated at the mean they find that a one standard deviation (about 10%) increase in test scores increases the GDP growth rate by about 0·2 percentage points per annum.

These estimates are typically done at a highly aggregated level for a large number of very different countries over an extensive historical period. While they can be (and have been) criticised in terms of both data and methodology, they undoubtedly point to a strong, long term link between education and growth. Being estimated on long term aggregate outcomes, they must be taken to incorporate the interaction of supply and demand factors and to take account of both private and public returns. We take them as providing a strong context in which our model is developed, but seek more specific relationships for incorporation in the model.

Estimates of the impact of increases in the quantity or quality of education on GDP on earnings or productivity
Given the diversity of the economic benefits that education brings, some part of these benefits will be private, captured by the individuals who receive the enhanced education. However a significant component will not be captured privately, but consists of public benefits. A better educated population will enable new technologies to be more quickly absorbed and utilised, businesses to hire better trained staff and to expand, and governments to provide improved health and other services. Thus a second approach is to start with the private returns to education, and look for other ways of taking account of the public returns.

There is again a massive literature on the private returns to schooling, and specifically on the returns of increased earnings arising from additional schooling. Much of the literature uses the simple model proposed by Mincer (1974), in which the log of earnings is a function of completed years of schooling and of experience (proxied by age, and inserted in both level and quadratic form). This simple model has been found to both successful and robust across a wide range of countries, both developed and developing. Consistent measures of the returns to schooling for a wide range of countries are available in Montenegro and Patrinos (2012), and many studies provide rate of return to schooling estimates for individual countries. Montenegro and Patrinos find that the mean return to an additional year of schooling is about 10%, that it is somewhat higher for females than males and that it is higher for tertiary education than for other levels of education. Their 2014 paper provides estimates of the earnings return to an additional year of schooling, for both males and females and for three levels of education, for about 160 countries. These estimates are used here.

While there have been important recent macroeconomic studies on the impact of the quality of schooling, the microeconomic literature relating quality measures for earnings or productivity is much more limited, especially for developing countries. Student test results (such as PISA or TIMSS) have only recently become available for many developing countries, and have not been widely used in wage studies. As a result other measures of cognitive or other skills are used, which may reflect both quantity and quality of schooling effects. A summary of the results of some studies is provided in Table A6.2 below. In a recent paper, Hanushek et al. (2015) explore the return to skills for 22 OECD countries using new international data from the Programme for the International Assessment of Adult Competencies. Their central finding is that a one standard deviation increased in cognitive skills implies on average a 17·8% increase in earnings, implying an elasticity of earnings with respect to skills of 0·8–1·0. The authors noted that this finding varied substantially by country, being higher in countries with high levels of wage inequality, such as the USA. Several studies find that the contribution of cognitive skills to earnings is lower in developing than in developed countries.

The structure of employment in developing countries

While powerful, the two approaches summarised above take no account of the actual structure of employment and education in developing countries. A third approach is to seek to understand further the ways in which improved educational attainment impacts on the level and nature of employment in developing countries, and on the productivity and earnings of workers.

In many developing countries only a small proportion of the population of working age are in regular wage jobs, with an employment contract defining wages and other conditions. On the other hand, reported unemployment in such countries is often low, as many individuals are active as family helpers (often in agriculture) or own-account workers, while many others are not in the labour force, being neither in employment nor in education and training (i.e. NEET). The individual's level of education is an important factor influencing their labour force status.

In a seminal paper *Educational Attainment and Employment Outcomes,* the Understanding Children's Work Programme (a cooperative programme of ILO and the World Bank) highlights twelve themes, many of which are closely related to our project (UCW Programme 2013). These themes are drawn from an analysis of 12 developing countries across the full spectrum of development. The employment themes generally relate to employment for persons aged 25–34 years. In summary form, these are as follows:

- (i) There is a positive correlation between education levels and participation rates for 8 of the 12 countries, with the exceptions being the poorest countries.
- (ii) Male participation rates are higher than female rates for young workers in all 12 countries.
- (iii) Gender disparities in participation rates are highest for lower education groups.
- (iv) Unemployment tends to be higher among the more educated, except in Brazil and Argentina.
- (v) Education makes it more likely that young people can secure wage jobs.
- (vi) Self-employment is more common among those with lower education.
- (vii) Educated young adults are less likely to be employed in agriculture, with higher shares of non-agricultural employment.
- (viii) Employment in the services sector is strongly positively correlated with education levels.
- (ix) Employment in manufacturing is most common among less educated young adults.
- (x) Education increases the chances of gaining employment with an employment contract.
- (xi) The poorly educated tend to work part-time.
- (xii) Substantial returns to education (in terms of higher wages) are evident for all 11 countries for which wage data are available.

(xiii) Young males earn more that young females in all the 11 countries, but the gender gap generally falls with education.

Further analysis of the structure of labour market involvement in developing countries is provided in Kapsos and Bourmpoula (2013), ILO (2014), Shehu and Nilsson (2014), Sparreboom and Staneva (2014) and in the *Global Employment Trends for Youth* report released by the ILO in October 2015 (ILO 2015). A key distinction here is between formal and informal employment (also sometimes called non-vulnerable and vulnerable employment). Using the latter terminology, Sparreboom and Staneva (2014) write:

> Vulnerable employment consists of the sum of the status groups of own-account workers and contributing family workers, while non-vulnerable employment comprises employers and employees. Own-account workers and contributing family workers are less likely to have formal work arrangements, and are therefore more likely to lack elements associated with decent work, such as adequate social security and recourse to effective social dialogue mechanisms. Vulnerable employment is often characterized by inadequate earnings, difficult conditions of work that undermine workers' fundamental rights, or other characteristics symptomatic of decent work deficits. (p. 10)

Data on employment by type are available only for a limited number of countries; the available data for 20–24 year olds in 24 countries from the ILO statistics website are summarised in Table A6.1. This table shows the proportions of the 20–24 year old population (excluding those in school) in each of formal and informal employment and NEET, for females and males across countries. For females (using unweighted means) only about 42% of this age group were in work, and of these just over one third were in formal employment with nearly two thirds in informal work. For boys the proportions were somewhat higher, with 53% in employment and nearly 50% of those in formal employment. The proportions of the 20–24 year old population in formal and informal employment differ substantially across countries, with the formal share tending to be higher in countries with higher secondary completion rates and GDP per capita, such as Mexico and Brazil.

Table A6.1 Distribution of activity status, females and males aged 20–24 years, selected countries and latest available year, % of non-school population

	Females			Males		
	Formal employment	Informal employment	NEET	Formal employment	Informal employment	NEET
	(% of non-school population)			(% of non-school population)		
Tanzania	4·0	18·3	77·7	7·3	14·0	78·7
Ethopia	5·2	47·4	47·4	6·7	42·5	50·7
Uganda	1·6	5·4	93·0	9·5	25·6	64·9
Madagascar	9·0	51·4	39·6	10·9	42·2	46·8
Rwanda	4·1	25·5	70·4	8·7	19·2	72·1
Togo	9·5	47·2	43·2	12·3	41·8	45·9
Cambodia	32·8	53·2	13·9	35·8	58·1	6·1
Cameroon	4·6	52·3	43·1	13·4	40·0	46·6
Bangadesh	4·7	17·4	77·9	22·2	32·1	45·7
India	9·1	18·7	72·2	24·2	33·3	42·5
Indonesia	24·7	15·3	60·0	38·5	23·3	38·1
Kyrgyzstan	14·3	36·1	49·6	18·4	39·1	42·6
Mexico	29·9	7·4	62·7	49·5	10·3	40·2
Peru	17·0	16·0	67·0	24·1	17·0	58·8
Brazil	44·3	6·6	49·1	61·1	10·8	28·1
Liberia	2·7	48·2	49·1	7·0	36·7	56·3
South Sudan	4·9	38·4	56·7	7·1	28·0	64·9
Tajikistan	24·7	10·6	64·7	38·3	11·5	50·2
Zambia	23·7	63·7	12·6	24·6	66·2	9·2
Sudan	3·8	8·7	87·5	19·1	18·3	62·6
Bolivia	25·6	14·7	59·7	41·9	24·0	34·1
Guatemala	27·7	12·3	60·0	60·8	18·6	20·6
Egypt	16·5	5·9	77·6	15·8	5·7	78·5
Azerbaijan	13·8	32·1	54·1	21·1	33·1	45·7
Unweighted mean	**14·9**	**27·2**	**57·9**	**24·1**	**28·8**	**47·1**

Source: ILO Labour Statistics database.

While analysis of the data is complex, the propositions of UWC (UCW Programme 2013) are generally supported in the literature: better educated young people are more likely to find formal employment, especially in the services sector, and less educated young people are more likely to obtain various forms of informal employment (non-wage or part-time work or self-employment). Labour force participation rates, and hence the level of employment, is also likely to be higher among more educated workers. Estimates of these effects are included in the model.

6.3 Structure of the Model Used in this Analysis

The impact model includes four channels through which better education influences economic activity, relative to the unchanged policy base case:

(i) increased years of schooling lead to higher productivity and higher earnings in employment;
(ii) improvements in the quality of education also lead to higher productivity and earnings in employment;
(iii) a rise in secondary school completions leads to an increase in the relative share of formal employment and a decline in the share of informal employment; and
(iv) an increase in secondary completions also leads to a rise in the population which is employed.

The formal structure of the model is detailed below.

The model is designed to estimate the effect of changes in educational outcomes relative to an unchanged policy base case defined in the educational model and with an exogenous value of GDP and GDP per capita for each country. The ratio of value added for cohort *i* in country *j* in year *k* ($VA_{i,j,k}$) in the intervention case relative to the base case, for a given level of productivity weighted employment ($E^{P}_{i,j,k}$, covering formal and informal employment), is assumed to be a function of both the average level of completed years of schooling for that cohort and of the average quality of the schooling which the cohort has received, both relative to base case values. Thus $VA_{i,j,k}$ is written as:

$$VA_{i,j,k} / VA^{B}_{i,j,k} = E^{P}_{i,j,k} * \Delta S_{i,j} (1+\alpha) * \Delta Q_{i,j} (1+\beta) \qquad (1)$$

where $VA^{B}_{i,j,k}$ is the value added per capita of cohort *i* in country *j* in year *k* in the base case, $E^{P}_{i,j,k}$ is the productivity weighted level of employment, $\Delta S_{i,j}$ is increase in the average completed years of schooling achieved by that cohort in that country, α is the return to an additional completed year of schooling, $\Delta Q_{i,j}$ is the increase in the average quality of schooling in country *j* for the period relevant to cohort *i* and β is the elasticity of average productivity in employment with respect to school quality. For simplicity the parameters α and β are assumed to be invariant across formal and informal employment.

Total employment consists of formal employment (E^{F}), defined here as covering employees and employers, and informal employment (E^{INF}), which covers own-account workers and contributing family helpers. We assume that the level of these two forms of employment change from the opening level in relation to the increase in secondary school completions from the base level, as given by:

$$E^{F}_{i,j,k} = f^{F}_{0} * E_{i,j,0} + \gamma_{F} * \Delta SEC_{i,j,k} * POP^{NS}_{i,j,k} \qquad (2) \quad \text{and}$$

$$E^{INF}_{i,j,k} = f^{INF}_{0} * E_{i,j,0} + \gamma_{INF} * \Delta SEC_{i,j,k} * POP^{NS}_{i,j,k} \qquad (3)$$

Here f^{F}_{0} and f^{INF}_{0} are the base case shares of employment in the two forms respectively, $POP^{NS}_{i,j,k}$ is the population in the cohort in question not in school and γ_{F} and γ_{INF} are the coefficients relating the increase in secondary completions relative to the base case to the share of the non-school population in the cohort in question that is in the different types of employment. The right hand terms in (2) and (3) thus give the change in each form of employment arising from the interventions, and hence relative to the base case.

With γ_{F} positive and γ_{INF} negative, equations (2) and (3) define the effect of rising secondary completions in terms of increasing formal employment and reducing informal employment. If γ_{F} is greater than γ_{INF} this will imply that increased secondary completions lead to an overall increase in employment, as some persons are drawn from being neither in school or in employment to one or other form of employment.

As discussed below, the average productivity in informal employment is assumed to be 50% of that in formal employment, which leads to the following expression for productivity weighted average employment across the two employment types:

$$E_{i,j,k} = E^{F}_{i,j,k} + 0.5 * E^{INF}_{i,j,k} \quad (4)$$

Combining expressions for the change in the different types of employment relative to the base case from equations (2) and (3) with (4) and substituting the result into (1) gives an expression for the ratio of value added for cohort *i* in country *j* in year *k* in the intervention case relative to the base case as follows:

$$VA_{i,j,k}/ VA^{B}_{i,j,k} = [(\gamma_F*\Delta SEC_{i,j,k}* POP^{NS}_{i,j,k}) + 0.5*(\gamma_{INF}*\Delta SEC_{i,j,k} * POP^{NS}_{i,j,k})] *\Delta S_{i,j} (1+\alpha)*\Delta Q_{i,j} (1+\beta) \quad (5)$$

Thus the change in total value added as a result of the educational interventions is given by:

$$\Delta VA_{i,j,k} = (VA_{i,j,k}/ VA^{B}_{i,j,k} - 1) * VA^{B}_{i,j,k} \quad (6)$$

Equations (5) and (6) summarise the overall model which we use to assess the impact of improved educational outcomes on GDP for the target countries. The application of the model, including the specification of appropriate values for the key parameters, is discussed in Section 6.4 below.

6.4 Parameter Specification and Application of the Model

The application of the model starts from the output of the education model, comparing the base case with the outcomes from the intervention case using six interventions: increased supply of rural schools, instruction in an understood language, interactive teaching, enhanced teacher incentives, more remedial teachers and increased use of female teachers. These six are chosen from a wider menu of interventions available as a result of an initial analysis of the cost-effectiveness of the various interventions. As described in Appendix 5, the interventions are scaled up from 2016 to 2030 and maintained at the 2030 level until 2050.

While the education model generates a range of outcomes resulting from these interventions, this analysis makes use of three results for females and males aged 20–24 years, namely years of completed schooling, average school quality and the proportion of the population which has completed secondary school. The estimate of the population of 20–24 year olds who are not in school is also used, as is an exogenous estimate of GDP per capita for each country and year.

The application of the model is summarised in Box A6.1, and the key parameters used are summarised in Box A6.2.

Box A6.1 Summary of model application

1. Productivity effect from increased average years of schooling
The average productivity of the employed 20–24 year old age group, in each year of the base case, is assumed to be equal to overall GDP per capita, set to 1. For each country and each year, the average completed years of schooling for 20–24 year olds is calculated for the base case and for the intervention case, and the increased number of years calculated.

The estimate of the returns to an extra year of schooling from Montenegro and Patrinos (2012) from the latest year) is then applied to the years of schooling, to get a figure for annual productivity relative to the base of 1. For the initial run this figure is applied to both formal and informal employment for a given country.

For a given 20–24 year old cohort this gives a series for productivity in each year relative to the base case of 1.

2. Productivity effect from increased school quality
Average school quality, as a factor increasing the productivity of 20–24 year olds, is assumed to increase with school quality, as measured by the average school quality index, but with a five year lag.

The productivity of 20–24 year olds (derived from 1. above) is further increased, after a five year lag, by the percentage increase in the school quality index, relative to the base, with and initial elasticity of 0·2.

This gives a series for 20–24 year old productivity, relative to the base case, after taking account of both the years of schooling and quality effects.

3. Productivity effects of employment type and increased employment
Individual productivity is also affected by the type of employment in which an individual is engaged, and especially formal employment (FE) or informal or non-formal employment (NFE).

Starting again from the basis that base 20–24 year old productivity is 1 in each year, we estimate starting FE/NFE/NEET shares for each country. It is also assumed in the initial run that the average productivity in informal employment is 50% of that in formal employment.

Beginning with the opening shares, and using parameters relating the rise in secondary completion to the change of the share of the 20–24 year old population in each state, we track the evolution of the 20–24 year old population in each year in FE/NFE/NEET states. In these calculations we use 50% of the estimated impact from the regression equations, to allow for both demand and supply effects.

This allows us to calculate both the implied change in average 20–24 year old productivity as a result of employment structure change and the increase in employment.

With both factors applied to the series from point 2 above, this gives a series for 20–24 year old productivity allowing for increased years of school and of school quality, and also for structural employment effects, as well as a measure of the increased employment resulting from the shift from NEET.

4. Calculation of increased GDP
For the calculation of changes in GDP over time the 20–24 year old group is assumed to be uniform, so that the same percentage changes apply to 20 year olds. The analysis of successive cohorts over time thus focuses on 20 year olds.

The productivity series derived in point 3 above is multiplied by GDP per capita in the base case, and by the percentage increase in employment, to derive GDP produced by 20 year olds in the intervention case, for each country and year. For the base case GDP is base case GDP per capita multiplied by base case employment.

For both the base case and the intervention case the GDP produced by successive generations of 20 year olds as they age is calculated out to 2050.

The difference between the intervention and base case results for each year is the additional GDP in that resulting from the investment in education affecting successive cohorts.

Box A6.2 Parameters used in estimating the economic impact of improved educational outcomes

Effect	Education outcome used	Impact Parameters	
		Formal employment	*Informal employment*
Earnings return to additional schooling (α)	Additional completed years of schooling of 20–24 year olds (males and females separately).	Overall country-specific return to secondary schooling, for males and females separately, for the latest year in the Montenegro and Patrinos (2012) study.	The same elasticity is used for informal as for formal employment.
Returns to increased average quality (β)	Average school quality Index. Apply to all school leavers aged 20–24 years.	An elasticity of productivity with respect to school quality of 0.2 is used. See text.	The common elasticity of productivity with respect to school quality of 0.2 is used for informal employment.
Impact effects of better educational outcome on employment shares (γ_F and γ_{INF})	Increase in secondary completions, for 20–24 year olds, male and females separately.	For each one percentage point increase in the secondary completion rate, the increase in the share of formal employment. Here 50% of the estimated figures from Table A6.2 are used, that is 0.16 ppts for females, and 0·23 ppts for males.	For each one percentage point increase in the secondary completion rate, the reduction in the share of informal employment. Here 50% of the estimated figures from Table A6.2 are used, that is 0·16 ppts for females, and 0·22 ppts for males.

Several issues need to be discussed in relation to Box A6.2. In terms of the earnings return from additional completed years of schooling, for formal employment we use the values from the Montenegro and Patrinos (2012) study for secondary schooling, for males and females separately and for the latest year for which estimates are available. The variable is specified in terms of the percentage increase in earnings/productivity for each additional year of schooling. Although the available information is much more limited for the impact on the informal sector, Ackah et al. (2014) find, for example, that the impact of increased education on earnings from informal work in Ghana is substantial and highly significant, and of a level comparable to that in the formal sector. Here we make the assumption that the impact of higher schooling on productivity in the informal sector is the same in percentage terms as in the formal sector, but of course much lower in absolute terms because the base level of productivity is lower (see below).

Most of the research on the impact of school quality has been done at the macroeconomic level, as exemplified by the Barro and Hanushek and Woessmann studies cited above. As noted above, the macroeconomic studies of Hanushek and Woessmann imply that a 10% increase in test scores increases the rate of growth of GDP by 0·2 percentage points. This results means that the elasticity of the level of GDP with respect to school quality increases over time, as the higher growth rate generates continuing increases in the level of GDP. Their result implies an elasticity of 0·18 after 10 years, 0·38 after 20 years and 1·02 after 50 years. As also previously noted, in their microeconomic studies they find an elasticity of GDP with respect to skills of 0·8–1·0 for 22 OECD countries, but with a significant range across countries. The literature on returns to cognitive skills in developing countries is restricted to a relatively limited number of countries: Ghana, Kenya, Morocco, Pakistan, South Africa and Tanzania. The available estimates of the impact of cognitive skills on outcomes suggest strong economic returns within developing countries. The summary of estimated returns to a standard deviation increase in cognitive skills is provided in Table A6.2 below, but it is not easy to derive an elasticity estimate from these data.

Table A6.2 Estimated returns to a one standard deviation increase in cognitive skills

Country	Study	Estimated effect
Ghana	Glewwe (1996)	0·14–0·17
Ghana	Jolliffe (1998)	0·05–0·07
Kenya	Boissiere, Knight & Sabot (1985); Knight and Sabot (1990)	0·19–0·22
Pakistan	Alderman, Behrman, Ross & Sabot (1996)	0·12–0·28
Pakistan	Behrman, Ross & Sabot (2008)	0·25
South Africa	Moll (1998)	0·34–0·48
Tanzania	Boissiere, Knight & Sabot (1985); Knight & Sabot (1990)	0·07–0·13

Having regard to the fact that these skills measures will reflect elements of both the quantity and quality of education, and of the general finding that the return to skill tends to be lower in developing than in developed countries, we take a conservative course here by assuming that the elasticity of productivity or earnings with respect to school quality is 0·2, that is that a 10% increase in school quality leads to a 2% increase in productivity, across both formal and informal employment.

In terms of the impact of education on the type of employment gained, there is a significant number of mainly individual country studies, focusing particularly on the impact of education on the move into formal employment from informal employment and not so much on entry into informal employment from being unemployed or outside the labour force. Many studies (e.g. Marcouiller et al. 1997; Pagan and Tijerina-Guajardo 2000; Packard 2007; Arias and Khamis 2008; Tegoum 2009) have found that more education increases the probability of formal rather than informal work. Adams et al. (2013) examined the impact of education on entry into informal employment, and for four out of five countries studied in sub-Saharan Africa found significant effects of increased education on informal employment.

The γ_F and γ_{INF} parameters, measuring the impact of an increase in the share of the 20–24 year old population that had completed secondary school on the shares of that population in formal and informal employment, are critical parameters for the model. In the light of these studies, but with very limited data available, we explored the relationship between these two variables for the countries for which data are provided in Table A6.1. The results are shown in Table A6.3. These results imply that, for females, a one percentage point (ppt) increase in the secondary completion rate leads to a 0·32 ppts rise in the formal employment share and an offsetting reduction of 0·32 ppts in the share in informal employment. For males the increase in the formal share is 0·46 ppts while the decline in the informal share is 0·24 ppts, implying a significant rise in overall employment as some part of the rise in formal employment is met by a reduction in NEET. It is not reasonable to assume that these correlations entirely reflect the impact of increase supply of secondary graduates on employment structure, but that this latter change also reflects demand and other factors that increase both formal employment and education completions. For this reason we use coefficients of only 50% of the value shown in Table A6.3 in the model. The coefficients from Table A6.3 imply that there is no net increase in employment for females, as the transition is entirely from informal to formal employment, while there is a net increase in employment for males.

Table A6.3 Coefficient values and test statistics, simple regressions of secondary completion rate against employment types, 20 countries

Dependent variable	Secondary completions variable			Equation adjusted R^2
	Coefficient	t stat	p value	
Females				
FE share	0·32	3·54	0·00	0·45
NFE share	–0·32	2·09	0·06	0·19
Males				
FE share	0·46	4·59	0·00	0·59
NFE share	–0·24	3·54	0·00	0·17

Source: Estimates of the authors.

Another key parameter, on which only limited data are again available, is the relative levels of productivity and earnings in formal and informal employment. Two pieces of evidence are available. The ILO (2014) reports average annual wage income of temporary/informal workers as a share of the average annual wage income of permanent/formal employees for eight countries, only one of which (South Africa) is in Africa. The ratios range from about 35% in Uruguay to about 75% in the Philippines, with an unweighted mean close to 40%. Shehu and Nilsson (2014) provide data for 16 countries on the average hourly wage of formally and informally employed youth (paid employees) in the informal sector and in formal employment. The unweighted mean ratio of informal to formal earnings across the sample is 66%, but for three African countries the figure is less than 50%. Because this measure covers only paid employees in the informal sector it is likely to overstate the ratio of income from working in the informal sector relative to the formal sector. With this limited information, and consistent with adopting a conservative stance, in the model we use a fixed figure of 40% for all countries. This will understate the ratio for some countries, and country-specific estimates would clearly be preferable.

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Appendix 7. Child Marriage

This appendix outlines the methodology and assumptions employed in estimating the results of the impact of specific interventions to delay early marriage as well those broader education interventions discussed in Supplementary Appendix 5 with an impact on early marriage. This involved linking the outcomes of existing models of education, health and employment rather than constructing a further separate model.

7.1 Literature Review

The analysis reflects a thorough search of both peer reviewed and grey literature to identify the evidence for interventions and their outcomes to reduce child marriage in low and middle income countries. In the peer reviewed literature search, PUB MED and Web of Science were searched. The initial search for ("child marriage" or "early marriage") produced 502 results in Web of Science and 547 in PUB MED. Both these results were refined to the terms (impact* or intervention* or trial* or evaluation*) resulting in 172 results in Web of Science and 244 in PUB MED. These two sets were combined (416 articles) and 80 duplicates were identified and removed leaving a total of 336 possibly relevant articles. The abstracts of this set were reviewed and 62 were identified (30 in Web of Science and 32 in PUB MED). A final set of 14 articles was chosen. There were a range of reasons to exclude articles, including: they were related to prevalence and not interventions, they focussed on sexual reproductive health (SRH) education rather than regular primary and secondary education; or they focused on the determinants of child marriage rather than interventions to prevent child marriage.

The grey literature was searched on Google Scholar and university library catalogues, and by visiting relevant websites of national and international agencies, such as the UNFPA and the UN, international NGOs, research institutes and networks on violence against women and girls (as child marriage is a form of violence against girls), such as the ICRW and the Population Council. We then hand searched the literature based on citations in the identified articles in both the peer reviewed and grey literature. We undertook an additional search of the grey literature particularly looking for evidence from the Indian sub-continent where child marriage rates are high.

Several of the studies indicated a strong relationship between child marriage and lower educational outcomes and reduced levels of literacy (in particular Nguyen and Wodon 2012c, 2014; Lloyd and Mensch 2008; Kalamar et al. 2016; Field and Ambrus 2008), which in turn leads to reduced economic participation (Chaaban and Cunningham 2011). As such, we identified articles that considered interventions to increase attendance at secondary schools (including cash transfers, support to remain in school, provision of school uniforms, increasing rural school supply). Other interventions, that targeted early marriage included group training programs including support to stay in school (Erulkar and Methungi 2009) or life skills training (Pande 2006; Amin 2011).

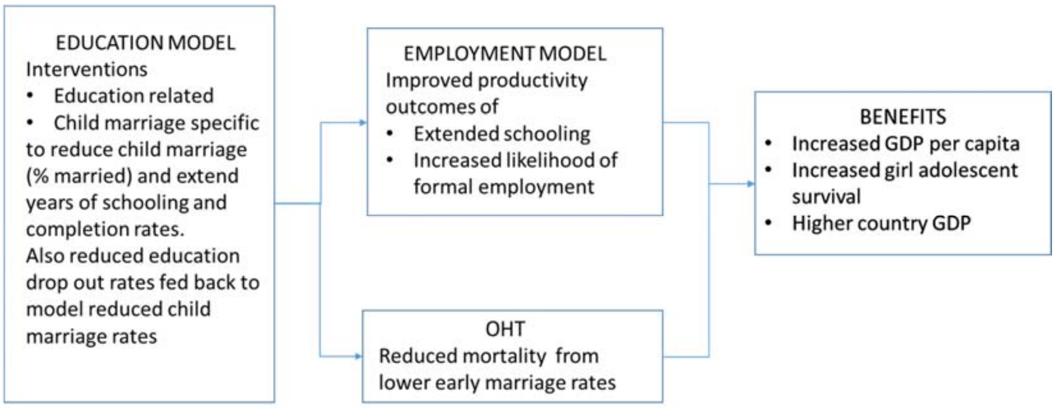
Kalamar et al. (2016) assessed and ranked interventions according to the strength of the evidence, depending on whether they were grounded in theory, if the intervention was first pilot tested to assess feasibility and acceptability, whether and what kind of training personnel involved in the interventions received, what steps were taken to prevent cross-over or contamination between intervention and control groups, the duration of the intervention and whether and how randomization of the intervention and/or evaluation took place (p. 516). Interestingly, all the interventions deemed to be of high quality included either those involved in increasing school attendance (e.g. school vouchers, cash transfers for school attendance, provision of uniforms) or life skills training and group education, all of which were found to have an impact on delaying marriage. However, Kalamar et al. (2016) also reported two unintended effects of the interventions. These included the intervention in Bangladesh, which while successful in increasing the age at marriage, also led to higher dowry payment among the intervention girls because of their older age. The other program in Zimbabwe provided support for students to stay at school, but led to those in the control group being denied access to school till they paid school fees (p. 520). The first instance particularly indicates the importance of changing community attitudes while engaging in efforts to reduce the incidence of child marriage.

We particularly considered studies that provided the costs of interventions (such as Erulkar and Methangi 2009; Duflo et al. 2006; Sewall-Menon and Bruce 2012) and their impacts (Baird et al. 2010; Khandker et al. 2003).

7.2 Introduction to the Estimation of Benefits

Reducing early marriage rates delays first pregnancy, with multiple beneficial health outcomes, and increases the likelihood of staying at school (UNFPA 2013; Nguyen and Wodon 2012a, 2012b). Nguyen and Wodon (2012a) summarise the results of several studies and suggest that for girls aged 15 to 24, child marriage and pregnancies count, depending on the country, for between 5% and 33% of dropouts (Lloyd and Mensch 2008). A South African study by Grant and Hallman (2008) shows that most girls 14–19 who become pregnant drop out of school (74%) and only 29% return. Staying at school longer and higher secondary completion rates in particular, increase the likelihood of a higher productivity job in the formal sector (Field and Ambrus 2008) (see Table A7.1). An attempt is made to evaluate the overall outcomes of these quite complex relationships by linking the cost and benefit estimates from the education, health and employment models. The sections below describe the methodologies and assumptions employed to estimate these outcomes.

Figure A7.1 Estimating child marriage benefits.



7.3 Education

Two relevant sets of interventions were included in the education model. One was a set of attendance interventions (including rural school supply, improvements in school infrastructure, and cash transfers to the poor, see Appendix 5) which have a marked effect on child marriage (Baird et al. 2010; Khandker et al. 2003). These were a product of the meta-analysis (Conn 2016) described in Supplementary Appendix 5 (Section 5.3), to determine the appropriate education interventions. The education intervention programs designed to reduce dropout from school had a joint impact on the marriage rate and education outcomes. There was no information on which to apportion these costs (for girls only) between the primarily education benefits and the reduction in marriage rates. Instead, we apportioned the costs based on the country-specific reduction in the proportion of married girls completing secondary school.

The other set of interventions modelled were designed to reduce early marriage. We distinguished between two programs. One was a group learning 'Life Skills' program, which includes rights and responsibilities of women, health and hygiene, marriage, family planning, pregnancy, and motherhood (Sewall-Menon and Bruce 2012). In one such Indian study (Pande et al. 2006), the proportion of marriages to girls younger than age 18 dropped from 80·7% to 61·8% over a four-year period, compared to no significant change in the control area. The other intervention was modelled on a broad based Berhane Hewan type program aimed at reducing the prevalence of child marriage, through a combination of group formation, support for girls to remain in school and community awareness (Erulkar and Muthengi 2009). Erulkar and Muthengi (2009) have shown a large impact of the Berhane Hewan in delaying younger age (10–14), but the proportion in the 15–19 age group has risen. The odds ratio of girls in the 10–14 year age intervention group of staying at school was 3·0 times the control group. By delaying marriage, these programs reduce the school dropout rate and increase secondary school completion rates. In addition, there is a feedback loop, which in the model delays age of marriage for those remaining in school. The Life Skills program was costed at $31·50 per girl based on the Ishraq program and a community mobilisation program for rural girls costed at $80 (Sewall-Menon and Bruce 2012). As with the education costs, these cost were adjusted by country specific GDP/capita to allow for different cost levels in each country.

The outputs for each country from the education model included school leavers by year and the numbers completing secondary education.

7.4 Health

The lower early marriage rates arising from the education interventions result in delayed first pregnancy, with consequential benefits for mother and child, in particular reduced rates of mortality (UNFPA 2013). These benefits are in addition to those modelled using the OHT and described in Appendix 3 to reduce adolescent pregnancy. It has not been possible to model a number of the broader benefits of lower early marriage rates for morbidity, such as obstetric fistula, lower levels of STDs, etc. It is assumed that there are no additional health costs arising from the lower marriage rates. This reduced level of mortality for the mother was converted to an economic and social benefit by using GDP per worker and half GDP per capita, respectively, as discussed elsewhere in this paper.

7.5 Employment

The outcomes of the lower marriage rates arising from the interventions in the education model, namely a higher number of school leavers with increased years of education and an increased number of leavers having completed secondary school, are inputs for each country to the employment model discussed in Appendix 6. The employment model estimates increased productivity arising from increased average years of schooling, education quality improvement and the increased likelihood of employment in the formal sector as discussed in Appendix 6 (Chaban and Cunningham 2011). These benefits are quantified using GDP per worker for each country for which data are available.

7.6 Results and Sensitivity Analysis

The benefit-cost ratios (BCRs) are calculated based on total employment and health benefits as a ratio of the total costs of the education interventions relevant to reducing early marriage rates as discussed above. The table below shows the relevant BCRs by country income group for intervention investments for the period 2015–2030. The net present values of the costs and benefits were calculated using discount rates of 3% and 5%. Results were only available for the 31 countries with results from the OHT and further restricted to those countries with data for marriage between 15 and 19 years old. At 3% discount rate, the total NPV of the intervention costs for the 31 countries, including both those for child marriage only and the relevant education interventions is $162 billion. The largest component is the two child marriage interventions totalling $109 billion. The remainder is the cost of education interventions which have an impact on child marriage rates. Although there is significant variation between countries, as indicated by the high standard deviations, overall estimated BCRs are high on average for the 31 countries at 5·7 for a discount rate of 3%, and declining to 3·5 at 5%.

Table A7.1 Benefit-cost ratios for the impact of education and child marriage interventions arising from health and employment benefits

Country group	Discount rates	
	3%	5%
Low income (n=14)	6·9 (3·9)	4·3 (2·6)
Lower middle income (n=15)	4·1 (4·7)	2·5 (3·0)
Upper middle income (n=2)*	8·9 (2·6)	6·0 (1·9)
Total (n=31)*	5·7 (4·6)	3·5 (3·0)

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Appendix 8. Intimate Partner Violence

This appendix details the methodology and assumptions employed in the IPV model used to estimate the results presented in Panel 3 in the main paper. These are heavily constrained by the limited data and it is not possible to generate preferred BCRs. Given the limited literature on evaluating IPV intervention programs, the model tests the implications for benefit-cost ratios (BCRs) for rolling out intervention programs to women aged 15–19 to reduce IPV, using a range of values for the effectiveness and implementation costs of such intervention programs, drawn from the literature and other data sources. We further use the model to clarify the data limitations and the areas in which further work is urgently needed.

8.1 Literature Review

This analysis reflects a thorough search of both peer reviewed and grey literature for evidence of interventions and their outcomes to reduce IPV in women and girls in low and middle income countries. In the peer reviewed literature, we searched for journal articles in PubMed and Web of Science using selected terms (after initial trials), for IPV ("intimate partner violence" or "interpersonal violence" or "domestic violence" or "gender-based violence") and interventions and impacts (intervention or interventions or impact or impacts). Combining these two sets of terms, identified 6092 journal articles in Web of Science and 4036 in PubMed. The search was further narrowed in both databases with the terms (women and girls) producing 193 articles in Web of Science and 92 articles in PubMed. These sets were then combined and 48 duplicates removed leaving a total of 237 articles. Of the 237, 40 studies were initially found to be relevant and included interventions addressing social/cultural norms in low and middle income countries, including India, Bangladesh, Zimbabwe, South Africa, Eastern Africa, Iran, Uganda, Sub-Sahara, Nepal, and Kenya. In addition, further records were identified from references in these articles, articles citing these articles and advice from selected expert authors identified in these articles.

Studies relating to high income countries were excluded. Several were not relevant as they referred to impact on children's health or intellectual development, or were looking at the impact of substance abuse, or at factors related to illegal drug use. Others articles looked at prevalence of violence against women or economic violence.

In addition, the grey literature was searched on Google Scholar and university library catalogues, and by visiting relevant websites of national and international agencies such as the UN, the WHO, international NGOs, research institutes and networks on violence against women and girls networks, such as the ICRW and STRIVE, and the Population Council. We also utilised advice from experts contacted and identified articles from references in the grey literature previously identified.

We proceeded on the conceptual understanding of violence referred to as the ecological model of violence, which suggests that there is no single factor that causes interpersonal violence, but instead that it is a function of various factors interacting at different levels that result in the acceptability of violence, particularly against women and includes factors such as the acceptance of traditional gender roles/norms; normative use of violence and the unequal positon of women and poverty. A number of earlier studies (Heise et al. 1999; Heise and Garcia-Moreno 2002; Jewkes, Sen and Garcia-Moreno 2002) established the importance of shifting social norms and empowerment of women and girls in preventing IPV (see WHO 2010, pp. 32, 36; WHO 2002, p. 113).

A second search was done to identify studies of interventions for victims of IPV which had at least a 2-year follow-up. This was to gather evidence of the duration of the effectiveness of interventions. Again using Web of Science and PubMed databases, the terms ("intimate partner violence" or "interpersonal violence" or "domestic violence" or "gender-based violence") and (program or trial or evaluation or impact or intervention) and (follow-up) and (year) were searched in both databases with PubMed producing 103 articles and Web of Science 253, a total of 356 articles. These results were combined and 70 duplicates were found and removed, leaving a total of 286 articles. All abstracts of these articles were reviewed and a total of 14 articles were selected and further investigated. Ten of these were studies where the interventions were ongoing, they did not address IPV, or they did not study adolescents, leaving 4 relevant articles.

8.2 Data Sources

The 2013 Global Burden of Disease study provides, for the first time, estimates of the adverse effects of IPV, which reflect some of the complexity of the health consequences of IPV involving mental health, HIV/AIDS and injuries from interpersonal violence. IPV is treated as a risk with population attribution risk factors generated to estimate the impact of IPV on mental health, HIV/AIDS and injuries from intimate partner violence. The data are available for women aged 15–19, but not those aged 10–14 (Murray et al. 2015). The availability of these global, comparable country-based estimates of the burden imposed by intimate partner violence in the form of DALYs, YLLs and YLDs affords an opportunity to undertake an economic evaluation of IPV interventions using other relevant parameters available from the literature. The model developed for this study utilises the best available data from the literature. Some of these parameters are derived from the grey literature. Others come from the limited number of studies evaluating IPV interventions in the peer reviewed literature. The shortcomings of these data sources are acknowledged.

8.3 The Costs of IPV to Individuals and the Community

The costs of IPV to individual victims and the community in general are both economic and social. The economic costs to the individual victim reflect a reduced ability to work due to consequential ill health, injury or death, and are categorised as indirect but tangible. Social costs, the broader costs of IPV to family and the community, are indirect and intangible. Direct costs are those imposed on the community in the form of medical assistance, policing, legal services, and other justice system and care costs (Day et al. 2005; Morrison and Orlando 2004; Buvinic and Morrison 1999). These direct costs raise complex issues. While they are costs to the community, they are also income to other parties and because of this complexity not covered in this study.

Put more formally, total costs of IPV (T) are the sum of the value of reduced working time (W), and social costs (S):

$$T = W + S \quad (1)$$

The estimated economic and social costs of IPV are based on the health burden (DALYs) estimated by the 2013 Global Burden of Disease for intimate partner violence for each country, gender and age group.

The VISES model estimates the economic and social costs of IPV by multiplying the DALYs (D_i) for each country *i* by country specific measures of per capita social or economic costs of each DALY. For economic costs, the relevant metric is the country specific GDP per worker for each country (GDP/LF_i), while for social costs, it is half the average GPP/cap (*avGDP/cap*) for all *i* countries following Stenberg et al. (2014) and other models developed for this study. The product of DALYs times the relevant per capita measure is multiplied by the relevant population. For social cost, this is the population of women aged 15–19 ($P_{i,15\text{-}19}$), and for economic cost, it is this population times the labour force participation rate for women aged 15–64 (L_i). The economic costs are restricted to those likely to be employed over their lifetimes; hence the use of the 15–64 age participation rate. The economic cost for women aged 15–19 in the form of reduced working time, W_i for country $_I$ is:

$$W_i = D_i * P_{i,15-19} * L_i * GDP/LF_i \ (2)$$

And the social cost S_i for country *i*:

$$S_i = D_i * P_{i,15-19}.* 0.5 * avGDP/cap \quad (3)$$

The total economic and social cost of IPV for women aged 15–19 is:

$$T_i = D_i * (P_{i,15-19} * L_i * GDP/LF_i + P_{i,15-19}.* 0.5 * avGDP/cap \ ) \ (4)$$

$$T_i = D_i * P_{i,15-19}. (L_i * GDP/LF_i + 0.5 * avGDP/cap \ ) \ (5)$$

For convenience, the expression, $L_i * GDP/LF_i + 0.5 * avGDP/cap$ is replaced by an income factor, y_i to give:

$$T_i = D_i * P_{i,15-19} * y_i \ (6)$$

8.4 Benefits and Costs of the Interventions Programs

8.4.1 Benefits

The benefits of IPV intervention programs (*B*) are the value of economic and social costs averted. These estimated benefits depend on the assumed effectiveness (*E*) and participation or coverage rate (*C*) of the intervention programs. The benefits for country *i* are:

$$B_i = T_i * E * C \quad (7)$$

Intervention programs are designed to address the complex factors effecting violence against women. The ecological model describes factors beginning with the individual, and extending to relationships with the community and broader society (Dahlberg and Krug 2002; Dahlberg 2007; Heise 1998). Interventions may be at each of these levels. For this project, interventions focussed on the individual and community were considered.

The most promising interventions are group training programs and community mobilisation programs targeted at women and girls aged 14–20 (Ellsberg et al. 2015). Group training is aimed at improving life skills and includes education programs in cultural norms, mentoring on sexual health and is generally aimed at improving the empowerment of young women and girls. The community programs systematically involve a broad range of stakeholders within the community including community activists, local governmental and cultural leaders (Ellsberg et al. 2015; Abramsky et al. 2014).

Some of these programs are ongoing and participation can be multiyear. However, more typically, girls enter the program for a limited period, 78 hours in the case of the program evaluated by Sarnquist et al. (2014). Evaluations of the effectiveness of such programs have been conducted up to two years after completion (Jewkes et al. 2008, O'Farrell et al. 1999; Bybee and Sullivan 2002; Pronyk et al. 2008). These studies demonstrate the likelihood of an ongoing effectiveness of such programs on IPV. In the case of Jewkes et al. (2008), the measured effectiveness on IPV was higher after the second year than the first. On the basis of this evidence, it could be expected that the programs would have a duration of at least three years. We test the impact of such a possibility in the model using a decay function with the following form to estimate total effectiveness (*TE*), in which α_2, α_3, are the discounted proportions of the first year impact continuing in years 2 and 3:

$$TE = E \quad + \alpha_2 . E \quad + \alpha_3 . E \quad (8)$$

$$TE = E(1 + \alpha_2 + \alpha_3) \quad (9)$$

This modifies the benefit equation to:

$$B_i = T_i * TE * C \quad (10)$$

8.4.2 Costs

The intervention program cost I_i for each country *i* is the product of the cost per participant (IP_i) in the intervention program and the number of participants (N_i).

$$I_i = N_i . * IP_i \quad (11)$$

The number of participants is assumed to be the number of 15–19 women in country *i* times a participation rate (*C*).

$$I_i = IP_i * P_{i,15-19} . * C \quad (12)$$

8.4.3 Benefit-cost ratio

The benefit-cost ratio (BCR) is the total benefits for each country (B_i), total economic and social costs of IPV (T_i) times the total effectiveness (*TE*) times the coverage rate (*C*) (see equation 10) divided by the total costs (I_i) (see equation 12):

$$BCR_i = B_i / I_i \quad (13)$$

This reduces to:

$$BCR_i = TE * D_i * y_i / IP_i \quad (14)$$

This means that the BCR for country *i* is a function of the program's effectiveness (*TE*), cost per participant (IP_i), the country DALY rate (D_i) and the income factor y_i.

8.5 Model Parameter Values: Costs, Coverage and Effectiveness of IPV Intervention Programs

In addition to the country DALY rate (D_i) and the income factor (y_i), the economic and social outcomes of the IPV programs depend on three parameters. The cost of delivery, its effectiveness and the duration of the impact. There is a large amount of literature which provides qualitative support for the efficacy of IPV programs in a wide variety of countries and settings, including South Asia (Fulu et al. 2014; Khanker et al. 2003; Verma et al. 2008; Bradley et al. 2011; Heise 2011; Raab 2011) and Africa (Ellsberg et al. 2015; Jewkes et al. 2010; ICRW 2009; Pulerwitz et al. 2010; Kim et al. 2001; Wagman et al. 2015; Wallace 2006). However, the number of studies either in the peer reviewed or grey literature which provided detailed quantitative analysis is limited (see for example Abramsky et al. 2016; Wagman et al. 2015; Jewkes et al. 2008; Sarnquist et al. 2014; Bandiera et al. 2012; Sewall-Menton and Bruce 2012). In the grey literature, ICRW (2009) is an important data source.

The costs of the programs and their effectiveness varies significantly between sites. The inclusion of administration costs (or pro rata for initiatives with multiple programs) also makes a significant difference to program costs. Modelling based is on two programs. It is acknowledged that benefit-cost ratios based on only two programs is not sufficiently representative. Accordingly, modelling is conducted for a range of program costs and effectiveness outcomes to place the two programs, for which reasonable data are available, in broader context.

One program is based on a Kenyan group training program for girls evaluated by Sarnquist et al. (2014) and the other using the results of another group training program BRAC, for girls in Uganda, for which detailed data are available (Bandeira et al. 2012). Sarnquist et al. (2014) provided details of the program inputs (78 hours per participant) for a 'Life Skills' program and its outcomes, but not costs per hour. Program costs per hour ($0.29) were taken from another similar 'Safe Places' program in Kenya (Sewall-Menton and Bruce 2012). Total program costs were assumed to be $22.62 per annum per participant. The program was effective in reducing sexual assault by 38% (Sarnquist et al. 2014).

For BRAC, Bandiera et al. (2012) provided both detailed costs and outcome data to enable analysis to be undertaken for its Life Skills component. The cost of this program, in particular, was highly sensitive to the allocation of administrative overhead. Cost estimates for BRAC were made both including and excluding administration costs. The estimated annual costs of the BRACs program per participant was $29.29 exclusive and $73.23 inclusive of administration costs for the Life Skills component. The effectiveness of the BRAC program was a reduction in unwilling sex of 83% (Bandiera et al. 2012).

The estimated cost for each country was adjusted for different likely cost structures by applying the ratio of country specific GDP per capita to that for Kenya and Uganda respectively. Further sensitivity analysis was conducted using the hourly costs of other programs detailed in Sewall-Menton and Bruce (2012) which gave annual costs per participant ranging from $7·80 to $71·76.

Community programs such as SASA (Abramsky et al. 2014), SHARE (Wagman et al. 2015) and TOSTAN (Diop et al. 2004) were reviewed, each of which had a significant impact on IPV (20% to 52% reductions); but there was insufficient detail to provide a reasonable basis for modelling.

A participation or coverage rate (C_i) of 21% derived from the BRAC program was used (Bandeira et al. 2012). The benefit-cost ratios do not vary with the participation rate given that both costs and benefits change proportionately.

These programs, as for most of the programs that have been evaluated in the literature, are for girls, and accordingly the modelling undertaken here is for girls only. The programs evaluated by Bandiera et al. (2012) and Sarnquist et al. (2014) appear to be quite effective focussed only on girls. For the inclusion of boys to be cost effective, the impact, assuming similar costs, would need to more than double. This would need to be tested empirically, but appears to be a challenging target.

8.6 Benefit-cost Ratios of Intervention Programs

The BCR as shown in equation 13 is a function of the intervention costs (IP_i), the effectiveness rates (TE), the DALY rate (D_i), and the income factor y_i. While we have reliable data for the DALY rate and the components of the income factor y_i, the data for costs and interventions is as discussed above more uncertain. Accordingly, the BCRs were estimated for a range of intervention costs (IP_i) and effectiveness rates (TE). The ranges chosen encompass those related to the two programs discussed above, Kenya (Sarnquist et al. 2014) and the BRAC program evaluated by Bandiera et al. (2012). The effectiveness of the Kenyan program was 38%, while that of BRAC was 83%. Estimated costs of the Kenyan program were $7·80, $22·62 and $71·76 per participant, while for BRAC they were $29·29 and $73·23. To adjust these costs to local cost levels, they were varied by country in accordance of the ratio of country per capita GDP to that for Kenya and Uganda respectively.

The results shown in Table A8.1 are provided for 75 countries for intervention costs ranging from $10–$70 per participant and effectiveness rates of 10% to 80%.

Table A8.1 Benefit-cost ratios (BCRs) for a range of intervention costs and effectiveness rates

	Effectiveness					
Costs ($)	**10%**	**20%**	**30%**	**40%**	**60%**	**80%**
10	0·45	0·90	1·36	1·81	2·71	3·62
20	0·23	0·45	0·68	0·90	1·36	1·81
30	0·15	0·30	0·45	0·60	0·90	1·21
40	0·11	0·23	0·34	0·45	0·68	0·90
50	0·09	0·18	0·27	0·36	0·54	0·72
60	0·08	0·15	0·23	0·30	0·45	0·60
70	0·06	0·13	0·19	0·26	0·39	0·52

Legend
- BRAC: BCR over 1
- Kenyan: BCR over 1
- Other combination: BCR over 1
- Kenyan under 1
- BRAC under 1

8.7 Discussion

The results show the sensitivity of the BCRs to the cost per participant and rate of effectiveness. Based on the assumptions used in the model, it is only intervention programs with a combination of relatively low cost and high effectiveness that yield BCRs over one. The outcomes using assumed parameters for the Kenyan and BRAC programs are also shaded (shaded blue for BRAC, and green for Kenyan) to provide benchmarks for the costs and required effectiveness of an expanded range of programs. Only those with lower assumed costs have BCRs over one.

The overall result shows that an effectiveness of at least 30% and cost no more than $30 per participant is necessary for the program to be cost effective with a BCR over one. The duration of the interventions in reducing IPV is also a significant factor. In this modelling, up to 3 years post intervention is assumed, given the limited evidence, but could conceivably be longer. There are a number of other benefits not modelled. This includes a possible spillover effect to from women in the program to other women in the community not in the program.

This analysis emphasises the need for more, well researched evaluations of the effectiveness of IPV interventions, the duration of their impact and unit costs of interventions on a large scale. Given the high numbers of IPV DALYs for India and Bangladesh in particular, additional studies for those countries would be very valuable.

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Appendix 9. Interventions to Reduce Road Traffic Injuries for Adolescents

This appendix describes the model used to estimate the health outcomes of interventions to reduce road traffic injuries among adolescents.

9.1 Introduction

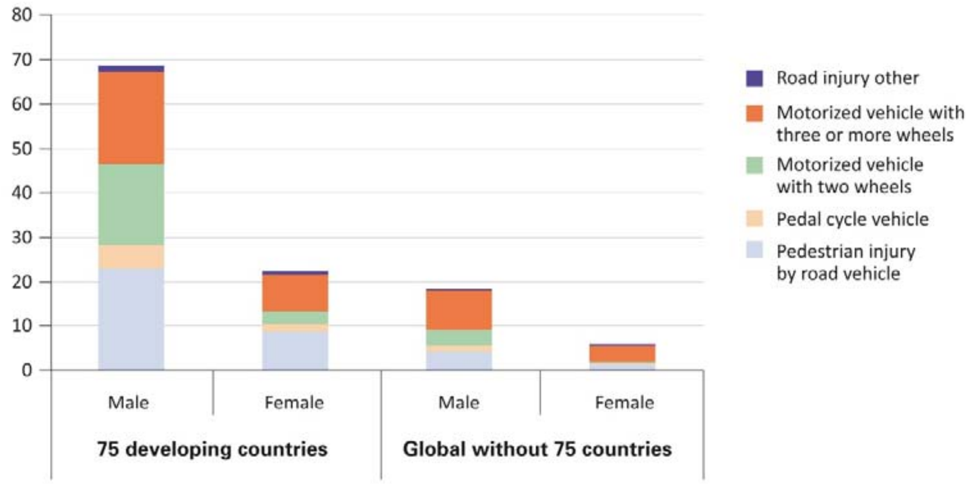
In 2013, nearly 1·4 million road traffic fatalities occurred across the globe (Haagsma et al. 2015). Overall, this corresponds to an average of 17.5 fatalities per 100,000 population (WHO 2015). However, this extremely large figure does not capture the substantial variability in rates and numbers of fatalities between countries and regions. In regional terms, the rate of road traffic deaths is highest in Africa (26·6/100,000), almost three times that for the region with the lowest rate, Europe (9.3/100,000).

Overall, half of the world's road traffic deaths occur among motorcyclists (23%), pedestrians (22%) and cyclists (5%), i.e. "vulnerable road users", with 31% of deaths among car occupants and the remaining 19% among unspecified road users.

Road crashes are a major cause of both injury and mortality for young adults. Young persons from the ages of 14 to 29 are overrepresented in road crash deaths. In developed countries, road crashes account for around a quarter of all deaths in the 15–24 years age group (BITRE 2013). Worldwide, this age group is over-represented in road crashes, with a population based annual fatality rate over 50% higher than for other age groups.

For the countries and age groups examined in this study, the number of 10–19 year old road fatalities far exceeds that in other countries, as shown in Figure A9.1. This reflects the fact that over 75% of the world's adolescents come from the 75 developing countries being studied, but overall the mortality rate from road accidents is a little higher than in other countries and does not show the steep decline evident in the developed world. This is one of the reasons road accidents are an important focus of this study.

Figure A9.1 Road deaths (10–19 year olds), 75 developing countries and other countries, 2013.



Source: IHME (2013).

9.2 Base Case for Estimation of Fatalities

To estimate the level of fatalities after implementation of interventions, it is necessary to establish a base case level of fatalities. McManus (2007) suggested road fatalities per capita follow a Kuznets curve (an inverted-U shaped pattern) with rising income per capita. For the purposes of this study, there are difficulties in determining the scale of any Kuznets effect in a particular country which include: lack of accurate vehicle registration data including number and type, impact of safer vehicles, the GDP/population assumption, level of community demand for improved safety, level of aspiration and leadership, total travel and change in mode splits. Given these difficulties, the Kuznet's curve is not suitable for the establishment of a baseline.

To establish a base case for road fatality projections, McManus (2007) assumes a constant fatality/100,000 rate from the last year of data (2013). This is consistent with the fatality rate for the 75 developing countries being examined with the fatality rate plateauing in the vast majority in the last 5 years of available data. A base case for fatalities which will apply in each year from 2013 to 2030 and extended to 2050 for the two age groups of interest by country (by male and female) was developed by using the GBD 2013 data, and then adjusting this level for the future years by the estimated change in population for the relevant age cohorts, using ILO population projections. Serious injury estimation is discussed later in this paper.

9.3 Proposed Interventions and their Effectiveness

An assessment was carried out to identify potential road safety interventions more likely to be implementable in 75 developing countries to 2030, which would lower the level of fatalities if implemented.

The following factors for all categories of road fatalities were modelled: speed compliance, alcohol enforcement and improved infrastructure. Additional factors were included specifically for motor cycle riders or occupants of motor vehicles. For motor cycle riders, helmet wearing rates were included, whereas seat belt usage rates were included for motor vehicle occupants. An additional factor for 15–19 year olds only was the introduction of a Graduated Licensing Scheme (GLS).

Each of the factors had an assumed maximum effectiveness in reducing road deaths, these were the following and summarised in Table A9.1.

Table A9.1 Summary of interventions

Intervention	Base case	Intervention improvement	Intervention effect
Helmet usage	40% unless data available	36%	64% of base case
Alcohol enforcement	0	25%	75% of base case
Infrastructure improvement	0	15%	75% of base case
Speed compliance	0	14%	86% of base case
Graduated Licensing Scheme	0	20%	80% of base case
Seat belt usage	60% unless data available	420%	80% of base case

The base rate for some of the factors varied according to individual countries. For example, some countries are Islamic and therefore a reduced effectiveness of alcohol enforcement is assumed. In addition, some data is available from the World Health Organisation regarding helmet wearing and seat belt usages, for example Burkina Faso is reported to have a helmet wearing rate of 9·2%. These figures are used as the base case for the countries with available data, otherwise a base rate of 40% and 60% respectively is assumed for helmet wearing and seat belt usage.

The model assumed an inverse exponential increase from the base rate for all of the above factors from 2016 to 2030, where each factor is assumed to have reached its maximum effectiveness.

The factors are independent of one another and hence their effects are multiplicative. For example, for motor cycle riders in the 15–19 age bracket, the effectiveness of interventions in reducing fatalities by 2030 is calculated according to the following multiplicative factors:

Increase in helmet usage × Alcohol enforcement improvement × Infrastructure safety improvement × Speed compliance improvement × Graduated Licensing Scheme × Vehicle safety promotion outcomes

$= (1-0.6*0.36) \times 0.85 \times 0.8 \times 0.83 \times 0.8 \text{ x } 0.9$

$= 0.318$

This figure shows that if all interventions were implemented, then the road fatalities level for motorcyclists would be 31·8% of the base case, a reduction of 68·2%.

Specific interventions with their estimated beneficial effects for rider and driver fatalities (with some estimated benefit for pedestrian and cyclist fatalities) are as follows.

9.4 Intervention Literature Search Strategy

The search strategy for the literature review sought journal articles through a mainstream index, and grey literature of published and unpublished studies on road traffic injuries both at a country specific and regional level.

The literature search for journal articles was as follows:

- Web of Science All Databases was identified as one of the most suitable database to search (it includes the Web of Science Core Collection, Current Contents Connect, and MEDLINE). A keyword search was run initially with the term "road traffic injur*" generating 796 results. This search was further refined by the terms "intervention or interventions" (resulting in 201 articles), then only journal articles were selected resulting in 161 articles), followed by the terms "cost or costs" leaving 22 journal articles, of which 15 were selected as relevant.
- References cited in this final set of articles were also investigated for further articles.

For the grey literature, international organisations and country-level institutions and organizations websites were searched to obtain un-published reports and official crash statistics. Any report or publication providing a breakdown of road traffic injuries by road user group at the sub-national, national or regional level was considered in the review. From this approach a total of 61 documents were identified.

All documents found were examined to find the reported efficacy of the following interventions: seat belt use, alcohol restrictions, motorcycle helmet use, speed enforcement, graduated licensing schemes and safer infrastructure. In addition, the literature was assessed to determine the cost of these interventions in the different settings as opposed to hospital costs of treating injuries sustained in road traffic accidents. Studies examining the efficacy of interventions and the range of these interventions were more numerous with the summary figures shown in Table A9.2. Fewer studies examined the costs associated with applying these interventions and these are shown in Table A9.3, with a summary in Table A9.4.

Many studies examined the costs of treating road traffic injuries in hospital and ongoing costs of disabilities or the provision of public transport costs in order to reduce road traffic injuries. These were not included in the analysis as the costs pertinent to this study are those concerning implementing the measures modelled.

Table A9.2 Range of efficacy of interventions

Intervention	Figure used in study	Effectiveness summary range	Effectiveness	Source
Helmets	36%	Fatalities 20%–48%	36%	Chisholm & Naci 2008
			20%	Bishai & Hyder 2006
			42%	Liu et al. 2009
			29%	Olson et al. 2016
			36%	Chisholm & Naci 2012
		Injuries 18%–72%	18–29%	Chisholm & Naci 2008
			41%	Bishai & Hyder 2006
			69%	Liu et al. 2009
			54%	Olson et al. 2015
			18%–29%	Chisholm & Naci 2012
Graduated licensing scheme	20%	Fatalities 31%–57%	57%	Williams et al. 2012
			31%	Healy et al. 2012
		Crash rates 4%–43%	28% (4–43%)	Hartling et al. 2004
			31% (26%–41%)	Dellinger et al. 2007
			20%–40%	Shope 2007
Seat belts	20%	Fatalities 7%–65%	65%	Peden et al. 2005
			7–9%	Dellinger et al. 2007
			11%	Chisholm & Naci 2008
			11%	Chisholm & Naci 2012
			11%	Elvik & Vaa 2004
		Injuries 18%–83%	40%	Peden 2005
			18%	Chisholm & Naci 2008
			77%	Milder et al. 2013
			18%	Chisholm & Naci 2012
			18%	Elvik & Vaa 2004
Alcohol	25%	Fatalities 3%–48%	10%	Bishai et a. 2008
			25%	Chisholm & Naci 2008
			22% (IQR 14%–35%)	Elder et al. 2002
			20% (18%–22%)	WHO 2006a
			25%	Chisholm & Naci 2012
		Injuries 3%–48%	3%	Bishai et al. 2008
			15%	Chisholm & Naci 2008
			35–48%	Ditsuwan et al. 2013
			15%	Chisholm & Naci. 2012
Speed enforcement	14%	Fatalities 6%–56%	56%	Ameritunga et al. 2006
			17%	Bishai et al. 2008
			25%	Bishai & Hyder 2006
			14%	Chisholm Naci 2008
			30–40%	Wilson et al. 2010
			14%	Chisholm et al. 2012
			14%	Elvik & Vaa 2004
		Injuries6%–50%	9%	Bishai et al. 2008
			6%	Chisholm & Naci 2008
			8%–50%	Wilson et al. 2006
			6%	Elvik & Vaa 2004
Infrastructure	15%	Injury accidents 7%–20%	7% (urban) – 20% (rural)	Elvik & Vaa 2004

Table A9.3 Range of costs of interventions

Intervention	Cost range	Components	Source
Helmets	Int$0·13 – Int$0·49 (per capita 2016 Int$)[1] $0·011 – $0·304 (per capita 2016 US$) 0·001% – 0·007% of GDP (2005)	Summary range	
	Int$0·14 – Int$0·49 per capita (2016 Int$) 0·001% – 0·007% of GDP (2005)	AfrE Int$52m AmrA Int$118m SearD Int$146m WprB Int$603m (2005 Int$ per annum)	Chisholm & Naci 2008
	Int$0.13 – Int$0·17 per capita (2016 Int$)	AfrE Int$0·13 SearD Int$0·10 (2005 Int$ per capita per annum)	Chisholm & Naci 2012
	$0·011 – $0·304 (2016 US$ per capita)	Cost per capita (2016 US$) EAP $0·016 ECA $0·264 LAC $0·304 MENA $0·155 SA $0·011 SSA $0·033 Unweighted average $0·131	Bishai & Hyder 2006
Graduated licensing scheme	AUS$20·8 mil (2012) 0·06% of GSP		Healy et al. 2012
Seat belts	Int$0·09 – $1·45 (per capita 2016 Int$) 0·003% – 0·011% of GDP (2005) US$0·263 (per capita 2016 US$) 0·0079% of GDP	Summary range	
	Int$0·09 – $1·45 (per capita 2016 Int$) 0·003% – 0·011% of GDP (2005)	AfrE Int$92m AmrA Int$384m SearD Int$99m WprB Int$533m (2005 Int$ per annum)	Chisholm & Naci 2008
	Int$0·09 – $0·30 per capita (2016 Int$)	AfrE Int$0·23) SearD Int$0·07 (2005 Int$ per capita per annum	Chisholm & Naci 2012
Alcohol	Int$0·15 – $2·24 (per capita 2016 Int$) US$0·251 (per capita 2016 US$) 0·004% – 0·012% of GDP (2005)	Summary range	
	Int$0·15 – $0·33 (per capita 2016 Int$)	AfrE Int$0·26) SearD Int$0·12 (2005 Int$ per capita per annum)	Chisholm & Naci 2012
	Int$0·15 – $2·24 (per capita 2016 Int$) 0·004% – 0·012% of GDP (2005)	AfrE Int$103m AmrA Int$592m SearD Int$162m WprB Int$824m (2005 Int$ per annum)	Chisholm & Naci 2008
	US$0.251 (per capita 2016 US$) 0·0079% of GDP	$16,327,805 (2016 US$)	Ditsuwan et al. 2013
Speed enforcement	Int$0·17 – $2·37 (per capita 2016 Int$) $0·0032 – $0·304 (per capita 2016 US$) 0·00091% – 0·013% of GDP (2005)	Summary range	
	Int$0·17 – $0·36 per capita (2016 Int$)	AfrE Int$0·28) SearD Int$0·13 (2005 Int$ per capita per annum)	Chisholm & Naci 2012
	$0·011 – $0·304	Cost per capita (2016 US$)	Bishai & Hyder 2006

Intervention	Cost range	Components	Source
	(per capita 2016 US$)	EAP $0·016 ECA $0·264 LAC $0·304 MENA $0·155 SA $0·011 SSA $0·033 Unweighted average $0·131	
	Int$0·17 – $2·37 per capita (2016 Int$) 0·005% – 0·013% of GDP (2005)	AfrE Int$112m AmrA Int$625m SearD Int$185m WprB Int$967m (2005 Int$ per annum)	Chisholm & Naci 2008
	US$0·0032 (per capita 2016 US$) 0·00091% of GDP	US$89,280 (2016 US$)	Bishai et al. 2008
Infrastructure	No data		

Notes: [1] 2005 Int$ were converted to 2016 Int$ using a global average of available inflation figures between 2005 and 2016 of 1.283.
EAP: East Asia & Pacific.
ECA: Europe & Central Asia.
LAC: Latin America & Caribbean.
MENA: Middle East & North Africa.
SA: South Asia.
SSA: Sub-Saharan Africa.
AfrE: Botswana, Burundi, Central African Republic, Congo, Côte d'Ivoire, Democratic Republic of the Congo (the), Eritrea, Ethiopia, Kenya, Lesotho, Malawi, Mozambique, Namibia, Rwanda, South Africa, Swaziland, Uganda, United Republic of Tanzania (the), Zambia, Zimbabwe.
AmrA: Canada, United States of America (the), Cuba.
SearD: Bangladesh, Bhutan, Democratic People's Republic of Korea, India, Maldives, Myanmar, Nepal.
WprB: Cambodia, People's Republic of China, Lao People's Democratic Republic, Malaysia, Mongolia, Philippines, Republic Of Korea, Viet Nam Cook Islands, Fiji, Kiribati, Marshall Islands, Micronesia (Federated States Of), Nauru, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu.

Table A9.4 Summary of intervention costs, % of GDP

Intervention	% of GDP
Helmets	0·001% – 0·007%
Seat belts	0·003% – 0·011%
Speed cameras	0·005% – 0·013%
Breath testing	0·004% – 0·012%
Total cost (sum of individual components)	0·013% – 0·043%
Total cost (savings through coordinated implementation)	0·007% – 0·024%

As shown in Table A9.2, the efficacy of the interventions varies widely in the literature and the figure used in this study falls in the middle or lower part of the ranges for the various interventions.

The study by Chisholm and Naci (2012) is used as the basis for the effectiveness figures in this study, unless there is a lack of evidence (e.g. graduated licensing scheme and infrastructure). However, the coverage rates used by Chisholm and Naci (2012) and other studies are much lower than this study. For example, while Chisholm and Naci (2008, 2012) state coverage of all interventions is assumed to be 80%, they then specify that only 10% of all vehicles will be pulled over per year which will result in a 25% reduction in fatalities. Bishai et al. (2008) state that the intervention would issue citations to 1 in 3 vehicles per year, but provide no information on the coverage of their intervention. Conversely, Bishai et al. (2008) do not specify a coverage rate, but refer to the "intensive" traffic enforcement on all major roads leading in and out of the capital city in the study country. Ditsuwan et al. (2013) assume a coverage rate of 4·6% for traffic enforcement and 100% media coverage.

9.4.1 Helmet wearing for motorcycle riders and passengers of all ages

The benefit of a 100% wearing rate being achieved by 2030 would be a 36% reduction in fatalities, if starting at a zero wearing rate in a country (Liu et al. 2008; WHO 2006a, 2006b). If the existing wearing rate is known (an estimated current wearing level of say 40% has been adopted) in each country, we calculate the potential benefits available using that wearing rate as the starting point.

9.4.2 Alcohol

Bishai et al. (2008) estimate alcohol enforcement to reduce deaths by 17%, whereas Chisholm and Naci (2012) use a figure of 25% which is used in this study. Therefore, an estimated progressive reduction of 25% in all fatalities would be possible over a 15-year period if enforcement, legislation and the general justice system deterrence levels were to be lifted to international practice levels in the 75 countries.

These estimates of effectiveness are adjusted downwards in Muslim countries, to reflect much lower alcohol consumption levels to a 5% reduction in fatalities.

9.4.3 Infrastructure safety

Major crash risks arise from construction of new faster roads with inadequate safety provision, leading to increased fatalities and serious injuries. iRAP modelling for the Sustainable Development Goals project estimates that bringing the highest volume 10% of roads (urban or rural) in all countries to a three star iRAP standard or better (as recommended by the UN Secretary General), would reduce fatalities (and serious injuries) in those countries by more than 15%.

9.4.4 Speed compliance

Cameron and Elvik (2010) established the following estimates for the percentage change in fatalities and injuries, which is derived from a change occurring on a section of the network in mean speed, raised to the specific power in Table A9.5.

Table A9.5 Road type, speed and safety

	Types of road environment				
Power estimates	**Urban arterial**	**Rural highway**	**Residential road**	**Freeway**	**All areas**
Fatalities	3·60	5·90	4·84	5·33	4·26
Seriously injured	2·67	4·96	3·90	4·40	3·32
Slightly injured	0·90	3·19	2·13	2·63	1·55
Injured (unspecified)	0·54	2·83	1·77	2·26	1·19
Fatal accidents	2·06	4·36	3·30	3·79	2·72
Serious accidents	0·49	2·78	1·72	2·22	1·14
Slight accidents	-0·07	2·22	1·16	1·66	0·58
Injury accidents	1·25	3·54	2·48	2·98	1·90

Source: Cameron and Elvic (2010).

For example, if speed compliance with safe system based speed limits were to improve by 3 km per hour (for e.g. from 65 km/hr to 62 km/hr on a 60 km/hr road), i.e., 4·6%, there will be a 15% fatality reduction on urban arterial roads, 20% on residential roads and 24% for rural highways for all road users. The model used a figure of 17% fatality reduction as the estimated benefit.

9.4.5 Seat belt wearing

The GRSP Seat Belt Manual (FAS 2009) sets out the benefits of wearing a seat belt compared to not wearing (for 4-wheel vehicle occupants) as follows: 50% fatality reduction for drivers, 45% reduction for front seat passengers and 25% reduction for rear seat passengers: which is represented by a 40% average reduction in fatalities if there is currently no seat belt wearing at all. If it is assumed that the current wearing rate is 60%, unless baseline data is known, then achieving a 100% wearing rate would provide an estimated 16% average reduction in fatalities for all vehicle occupants, i.e. a reduced fatality factor of 0·84.

9.5 Combined Effect of Interventions

9.5.1 Motorcyclists

As noted above, for motor cycle riders in the 15–19 age bracket, the effectiveness of interventions in reducing fatalities by 2030 is calculated according to the following multiplicative factors:

> Increase in helmet usage × Alcohol enforcement improvement × Infrastructure safety improvement × Speed compliance improvement × Graduated Licensing Scheme × Vehicle safety promotion outcomes
>
> = (1-0·6*0·36) × 0·85 × 0·8 × 0·83 × 0·8 × 0·9
>
> = 0·318, i.e. a reduction of 68·2%.

9.5.2 Vehicle occupants

If the above assumptions for vehicle occupant safety improvement are applied, the reduction in fatalities for all age groups in 4-wheel vehicles or as pedestrians or cyclists would be:

> Improved speed compliance benefits × Improved alcohol compliance benefit × Improved infrastructure safety × Improved seat belt wearing compliance × Vehicle safety promotion outcomes
>
> =0·82 × 0·85 × 0·80 × 0·84 ×x 0·90 = 0·42, i.e. a reduction of 58%.

9.5.3 Pedestrians/cyclists

If the interventions proposed are implemented, the reduction in fatalities for all age groups of pedestrians or cyclists would be:

> Improved speed compliance benefit × Improved alcohol compliance benefit × Improved infrastructure safety benefit
>
> =0·82 × 0·96 × 0·80 = 0·63, i.e. a reduction of 37%.

9.5.4 Young drivers/riders (15 years to 19 years) including effects of a Graduated Licensing Scheme

Graduated licensing systems (GLS) which provide a safer learning environment, robust license testing before solo driving and safer novice driving years, has been found to deliver up to a 30% reduction in first year novice driver and rider deaths and serious injury when compared with a control group, by 2030 (Healy et al. 2012). This is based on the experience in Victoria, Australia following the introduction of a good international practice GLS enhancement in 2007. A significant reduction of 16% in the casualty crash involvement of drivers (aged 18–20 when first licensed) in the first 9 months of the second year of holding a probationary licence was also found (Healy et al. 2012).

It is estimated that a 20% reduction in fatalities of young drivers and riders, from the age of 15 to 19 years, could be achieved by 2030 compared to 2013 levels through a graduated licensing scheme. This would reduce fatalities for this age cohort (male and female) for:

- motorcyclists to 0·318 × (1 – 0·20) = 0·254 or 25·4% of the base case, a reduction of 74·6%; and
- vehicle occupants by 0·42 × (1– 0·20) = 0·336 or 33·6% of the base case, a reduction of 66·4%.

9.6 Model

The impact of the specific interventions recommended in this study (which it is assumed will be implemented along a concave growth curve successfully by 2030 in all countries) constitute the estimated fatality reductions in this model. The starting point for each country for each intervention varies according to the availability of data. Regardless of the starting point, the interventions are assumed to be implemented according to the growth curve with full implementation reached by 2030.

Road crash fatality groupings in the GBD data per country include the following transport modes: pedestrian, cyclist, motor cyclist, motor vehicle and other categories. The data for these groupings was further categorised into age cohorts (10–14 and 15–19) as well as gender. Consequently each country effectively had 20 baselines (age cohort × gender × transport mode) for 75 countries. This produced 1500 specific baselines for each age cohort, gender, transport mode and country.

The following factors for all categories of road fatalities were modelled: speed compliance, alcohol enforcement and improved infrastructure. Additional factors were included specifically for motor cycle riders or occupants of motor vehicles. For motor cycle riders helmet wearing rates were included whereas seat belt usage rates were included for motor vehicle occupants. An additional factor for 15–19 year olds only was the introduction of a GLS.

The effectiveness of each intervention in the model generated reduced fatalities and serious injuries for each year as the implementation rate increased to the maximum in 2030. The lives saved and serious injuries prevented were calculated by subtracting the deaths and serious injuries in the intervention case from the baseline projections.

The model used in this study is based upon the work of Chisholm et al. (2012) where they modelled the road traffic injuries through age and sex specific attribution of the global burden of fatal and non-fatal road traffic injuries, both by road user group and by injury risk factor; identification, estimation, and modelling of intervention effectiveness at the population level. They also examined the costs of the interventions.

However, this study differs in several important ways. Chisholm et al. (2012) modelled the cost effectiveness on a courser scale, specifically certain regions of the world, and this study has a finer scale with results modelled for individual countries with separate baselines accounting for age, gender, transport mode and country. This study also uses the more recent Global Burden of Disease 2013 data (IHME 2015).

Chisholm et al. (2012) incorporated the costs of legislative, administrative, supervisory, and monitoring and equipment costs, as does this study. However, this study also includes costs associated with building of management capacity and improved infrastructure.

Equation 1: Baseline deaths per country per year

$$BD_{ic} = \ pp_{icag}fr_{cagm}$$

Equation 2: Adolescent deaths after interventions per country per year

$$ID_{ic} = pp_{icag}fr_{cagm}hu_{ic}aev_{ic}scw_{ic}sbx_{ic}glsy_{iac}biz_i$$

Equation 3: Adolescent lives saved per country in the study period

$$LS_c \sum_{i=2016}^{2030} BD_{ic} - ID_{ic}$$

Equation 4: Baseline number of serious injuries per country per year

$$BSI_{ic} = pp_{icag}YLDR_{cagm}SPD\frac{DW_m}{DLD}$$

Equation 5: Serious injuries after interventions per country per year

$$SII_{ic} = pp_{icag}YLDR_{cagm}SPD\frac{DW_m}{DLD}hu_{ic}aev_{ic}scw_{ic}sbx_{ic}glsy_{iac}biz_i$$

Equation 6: Serious injuries prevented per country in the study period

$$SIP_c \sum_{i=2016}^{2030} BSI_{ic} - SII_{ic}$$

Equation 7: Total costs of interventions per country

$$CI_c = \sum_{i=2016}^{2030} GDP_{ic}(bm + mc + inf)p_i$$

where:

BD	= adolescent baseline deaths
ID	= adolescent deaths after interventions
pp	= ILO population projection
a	= age cohort
g	= gender
c	= country
m	= transport mode
I	= year
Fr	= 2013 fatality rate per 100,000
r	= implementation rate
h	= % reduction in fatalities due to wearing of helmets when fully implemented
u	= proportion of full implementation of helmet wearing
ae	= % reduction in fatalities due to alcohol enforcement measures when fully implemented
v	= proportion of full implementation of alcohol enforcement
sc	= % reduction in fatalities due to speed compliance measures when fully implemented
w	= proportion of full implementation of speed compliance measures
sb	= % reduction in fatalities due to wearing of seat belts when fully implemented
x	= proportion of full implementation of seat belt wearing
gls	= % reduction in fatalities due to graduated licensing scheme when fully implemented
y	= proportion of full implementation of graduated licensing scheme
bi	= % reduction in fatalities due to better infrastructure when fully implemented
z	= proportion of full implementation of better infrastructure
LS	= adolescent lives saved per country
GDP	= gross domestic product
Bm	= aggregated cost of implementing behavioural measures (helmet wearing, alcohol enforcement, speed compliance, seat belts and graduated licensing scheme) (% of GDP)
mc	= cost of improving management capacity (% of GDP)
inf	= cost of constructing better infrastructure (% of GDP)
p	= proportion of final costs when measures fully implemented
SII	= serious injuries after interventions
YLDR	= years of living with a disability rate per 100,000 (2010)
DW	= disability weighting
DLD	= duration of life with disability
SPD	= serious permanent disability factor
SIP	= serious injuries prevented
BSI	= baseline serious injuries

9.7 Summary Base Case and Interventions Deaths

It is intended that the reduced estimated levels of fatalities due to the reduction factors for the interventions outlined above, would be achieved in 2030. The total base case deaths and the effect of interventions for all 75 developing countries to 2030 are summarised in Table A9.6.

Table A9.6 Number of base case and interventions road fatalities, 75 developing countries, 2016–2030

	Deaths		
Income level	**Base case**	**Interventions case**	**Lives saved**
Low	279081	188881	90200
Lower middle	827859	551296	276563
Upper middle	394670	266856	127814
Total	1501610	1007033	494577

9.7.1 Serious injury numbers relative to fatalities

For this model, it was assumed those with greater than 80% permanent impairment were considered to lead to disabilities with severe and profound limitations. For the model, severe and profound limitations were assumed to preclude the person's ability to work in the future.

To obtain a figure for serious road injuries, a figure was calculated according to the years of living with a disability (YLD). YLD for a particular cause in a particular time period is calculated according to the number of prevalent cases (i.e. the number of people living with the injury in any particular year) multiplied by a weight factor that reflects the severity of the disease on a scale from 0 (perfect health) to 1 (dead):

$$YLD = P \times DW$$

where:

P = number of prevalent cases
DW = disability weight

Prior to 2010, YLD was calculated when the number of incident cases in that period is multiplied by the average duration of the disease and the weight factor. The previous formula for YLD is the following:

$$YLD = I \times DW \times L$$

where:

I = number of incident cases
DW = disability weight
L = average duration of the case until remission or death (years)

As data for YLD is available for all 75 countries for 2010, this figure was used. For the purposes of the model, the preferred metric is incidences which give the number of new cases each year. Information on YLDs and the prevalence of such cases, which enables disability weightings to be calculated (Vos 2015), is shown in Table A9.7.

Table A9.7 Years of living with a disability (YLD), prevalence and disability weighting

	Prevalence	YLD	Disability weight
Pedestrian	37844·1	2271·8	0·0600
Bicycle	13678·6	812·4	0·0594
Motor cycle	32483·6	1649·2	0·0508
Motor car	60733·7	3777·8	0·0622
Other road	1371·5	82·3	0·0600

The disability weights enable prevalences to be calculated from YLDs for all the 75 developing countries. Assuming an average duration of 15 years, it is possible to calculate the incidences of injury for each of the 75 countries. The resulting incident figure gives the number of injuries per category for each year.

There is limited data linking crash injuries to disability outcomes. However, statistical analysis was undertaken by the Bureau of Infrastructure, Transport and Regional Economics (BITRE 2009) to estimate both the number people with injuries resulting in a disability and the degree of severity. BITRE estimated that 4619 (14·8%) of the 31,204 people hospitalised in 2006 due to road crash injuries suffered a disability, of which 1,270 people (4·1% of people hospitalised) had severe or profound limitation (i.e. impairment of 80 to 100%).

Consequently, it was assumed 4·1% of injury incidences led to a final outcome disability with severe or profound limitations which resulted in the person being unable to work. For base case projections, the serious injury rate per 100,000 was assumed to be constant and the number of projected serious injuries dependent upon population projections. The number of serious injuries after interventions were then modelled according to the same method used for deaths, where each intervention would result in a percentage decrease in deaths. For the purposes of costs and benefits, this level of disability was then treated as equivalent to death.

9.7.2 Summary serious disabilities base case and interventions

The total base case serious injuries and the effect of interventions for all 75 countries to 2030 are summarised in Table A9.8.

Table A9.8 Number of serious disabilities in 75 developing countries, 2016–2030

Serious disabilities			
Income level	**Base case**	**Interventions case**	**Serious disabilities averted**
Low	212913	149971	62943
Lower middle	793602	552277	241327
Upper middle	302051	220504	81547
Total	1308566	922751	385815

9.8 Cost of Interventions

Other costs not included in the studies in the literature are those associated with improving management capacity in order to effectively implement the listed interventions, as well as improving the quality of the infrastructure resulting in safer roads.

In order to improve management capacity, Bliss and Breen (2009) recommend demonstration projects where capacity can be developed. The recommended number of projects corresponds to 0.08% of GDP.

The most up to date costs associated with improved infrastructure accepted by the international community are those provided by International Road Assessment Program (iRAP) for the Sustainable Development Goals project (iRAP 2014). The cost associated with implementing safer infrastructure in the 75 countries represents 0.055% of GDP. This study was unable to find an equivalent figure in the academic literature.

The costs involved with implementing the proposed interventions consist of the following.

1. <u>The costs for implementation of infrastructure safety interventions</u>

Modelling undertaken by iRAP for the Sustainable Development Goals project (iRAP 2014) has developed estimates of the investment required to target improved infrastructure safety on the 10% of all country road networks where 50% of fatalities are occurring.

It is estimated that this pattern of investment would achieve a 30% reduction of those 50% of fatalities, i.e. a 15% overall reduction in fatalities. For all the 75 countries, the estimated total investment required over 15 years to achieve this 15% reduction in fatalities would be US$170 billion with an average expenditure of US$11.4 billion annually. For the purposes of allocating costs to the various 75 countries, the figure was converted to a percentage of total GDP which represents a figure of 0.055% of GDP per annum.

2. Costs for implementing the proposed behavioural measures

There are few studies in the literature that examine the costs of implementing the various interventions. Studies such as Chisholm and Naci (2008) include the costs of purchasing speed cameras, breathalysing kits, speed cones, etc. However, as discussed previously, Chisholm and Naci (2008 and 2012) effectively assume a 10% coverage rate with a cost varying between 0.007% and 0.024% of GDP depending upon the region where the measures are implemented together. This percentage figure is lower than the sum of the individual intervention costs which vary between 0.013% and 0.043% of GDP (Table A9.6) due to cost savings from coordinated implementation. An alternative figure based on the experience in Victoria, Australia, is 0.12% of GDP based on combined estimates of government and the monopoly injury insurer (Transport Accident Commission – TAC) expenditure for treating and preventing road trauma in 2004. The goal in Victoria was to achieve an effective 100% coverage where every driver is pulled over every year. This is five times the costs and ten times the coverage of the Chisholm and Naci (2008 and 2012) studies and is the costs associated with enforcement of behavioural measures in a high income country. As this study examines low and middle income countries, the high level figure of coordinated implementation (0.024% of GDP) from Chisholm and Naci (2008) and high coverage is modelled. The higher level costs cater for higher level coverage. The 0.024% figure represents the costs for the implementation of the helmet, anti-drink driving, seat belts and speed enforcement interventions. The only data regarding costs associated with implementing a graduated licensing scheme are provided by Healy et al. (2012) and are estimated to be 0.006% of GDP when fully implemented. Consequently, this figure is added to the 0.024% which produces a total for behavioural measures of 0.03% of GDP.

This represented an estimated expenditure per head of population (4.97 million population). There will be an ongoing cost for management and maintenance of governance standards, particularly for enforcement; this is addressed in the years from 2030 to 2050, but this is modelled to reduce to half the maximum figure by 2050.

3. Costs for development of road safety management capacity

There is a dearth of literature on the costs for improving road safety management capacity. However, a report from the World Bank estimates these costs. They recommend that two US$20 million demonstration projects are implemented in each "GDP equivalent entity of $50 billion" over the 2016 to 2021 period to build capacity (Bliss and Breen 2009). In percentage terms, this equates to 0·08% of GDP. This figure is the basis of allocating costs for each of the 75 countries.

In addition to this period of capacity building, authorities will require an allocation of funding for ongoing adequate governance of the necessary adjustment to—and operation of—legislative, enforcement, data (crash, offence, licensing and vehicle registration), infringement management and courts systems. The maintenance of capacity would require further, though reduced funds, for each of years to 2030 of US$6 billon per annum.

Total cost

The total cost assumed in this study to implementing the various interventions, development management capacity and build better infrastructure corresponds to 0·165% of GDP. This figure is adjusted to consider the various portions of the different costs which can be attributed to local costs and those which are likely to require international costs.

For infrastructure investment, it is estimated 70% of the costs could be attributed to the specific country with 30% requiring international expertise, and hence high income country costs. The split for management capacity was estimated to be 80% local, 20% international, and for behavioural interventions 90% local and 10% international. As this study is concerned with the 10–19 age bracket, costs have been apportioned according to what percentage of the overall population that age group makes up. The percentage of 10–19 year olds was calculated for all 75 countries according to ILO estimates and an average of 11% was calculated for all 75 countries for 2013. A more conservative estimate is 15% of the costs as a form of cost contingency.

9.9 Summary Benefit-cost Ratios of Interventions

Over the period 2016, 380,000 adolescent road deaths are averted in the 75 developing countries, with a conservative estimate of 183,000 serious disabilities averted. As is to be expected, this large scale saving of young lives and the avoidance of the personal and community costs associated with serious disability has major economic and social benefits. Our estimate of these benefits, expressed in net present value terms to 2030 and 2050 using a 3% discount rate, are summarised in tables A9.9 and A9.10 below.

Table A9.9 Road deaths interventions benefits and costs, 75 developing countries, US$ millions, NPV to 2030, 3% discount rate

	NPV GDP		NPV social benefits		NPV cost
Income level	**Deaths**	**Disability**	**Deaths**	**Disability**	
Low	3856	2517	5774	2045	2329
Lower middle	35832	25440	18039	7943	16848
Upper middle	40319	23923	9007	2866	27308
Total	80007	51880	32819	12854	46484

Table A9.10 Road deaths interventions benefits and costs, 75 developing countries, US$ millions, NPV to 2050, 3% discount rate

	NPV GDP		NPV social benefits		NPV cost
Income level	**Deaths**	**Disability**	**Deaths**	**Disability**	
Low	10616	6936	15815	5604	5212
Lower middle	86230	59401	44010	18802	32051
Upper middle	83400	50522	19147	6198	43968
Total	180246	116859	78971	30605	81232

The benefit-cost ratios for these investments, again using a 3% discount rate for both costs and benefits, are summarised in tables A9.11 and A9.12.

Table A9.11 Road deaths interventions benefit-cost ratios to 2030, 75 developing countries

	Benefit/cost ratio			
	Economic		Economic plus social	
Income level	**Deaths**	**Deaths plus disability**	**Deaths**	**Deaths plus disability**
Low	1·8	2·9	4·7	6·6
Lower middle	2·1	3·7	3·4	5·5
Upper middle	2·3	4·3	2·7	4·9
Total	2·0	3·5	3·8	5·9

Table A9.12 Road deaths interventions benefit-cost ratios to 2050, 75 developing countries

	Benefit/cost ratio			
	Economic		Economic plus social	
Income Level	**Deaths**	**Deaths plus disability**	**Deaths**	**Deaths plus disability**
Low	2·2	3·5	5·7	8·0
Lower middle	2·6	4·6	4·3	6·9
Upper middle	3·0	5·8	3·6	6·6
Total	2·5	4·3	4·8	7·3

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Appendix 10: Benefit-cost Ratios

Table A10.1 Economic and social benefits, USD billions, net present values, 3% discount rate

	Economic	Social	Total
Adolescent health using OHT			
Low income	101·4	193·6	295·0
Lower middle income	627·1	422·5	1049·6
Upper middle income	153·6	40·6	194·2
Total	882·2	656·7	1538·8
Demographic dividend			
Low income	77·3		77·3
Lower middle income	182.7		182·7
Upper middle income	176		176
Total	436.1		436·1
HPV			
Low income	6·8	24·3	31·1
Lower middle income	19·9	29·9	50·8
Upper middle income*	11·9	7·6	19·5
Total	38·7	61·8	101·4
Road accidents			
Low income	6·4	7·8	14·2
Lower middle income	61·3	26·0	87·3
Upper middle income*	64·2	11·9	76·1
Total	131·9	45·7	177·6
Education			
Low income	2065·9		2065·9
Lower middle income	9164·4		9164·4
Upper middle income*	3533·7		3533·7
Total	14786·9		14786·9
Child marriage, 31 countries			
Low income	105·9	10·2	116·1
Lower middle income	331·8	15·6	347·4
Upper middle income*	14·5	0·0	14·5
Total	452·1	25·9	478·0

Note: * Includes one high income country.

Table A10.2 Benefit-cost ratios, weighted averages, 3%, 5% and 7% discount rates

	3%	5%	7%
Adolescent health using OHT			
Low income	11·7	6·9	4·5
Lower middle income	6·9	4·0	2·6
Upper middle income	2·5	1·5	1·0
Total	5·5	3·3	2·1
HPV			
Low income	23·6	8·5	3·2
Lower middle income	8·7	3·3	1·3
Upper middle income*	6·5	2·6	1·1
Total	10·0	3·8	1·5
Road accidents			
Low income	6·1	3·9	2·8
Lower middle income	5·2	3·3	2·3
Upper middle income*	2·8	1·8	1·3
Total	3·8	2·5	1·7
Education			
Low income	11·7	7·6	5·2
Lower middle income	12·8	8·5	5·9
Upper middle income*	4·1	2·7	1·9
Total	8·4	5·5	3·9
Child marriage			
Low income	7·8	4·8	3·2
Lower middle income	2·4	1·5	1·0
Upper middle income*	9·5	6·4	4·5
Total	2·9	1·8	1·2

Note: * Includes one high income country.

Table A10.3 Benefit-cost ratios, unweighted averages, 3%, 5% and 7% discount rates

	3%	5%	7%
Adolescent health using OHT			
Low income	12·6	7·4	4·9
Lower middle income	9·9	5·8	3·8
Upper middle income	6·4	3·8	2·5
Total	10·2	6·0	3·9
HPV			
Low income	22·5	8·1	3·0
Lower middle income	12·7	4·8	1·9
Upper middle income*	14·0	5·9	2·6
Total	17·0	6·4	2·5
Road accidents			
Low income	6·6	4·3	3·0
Lower middle income	5·5	3·6	2·5
Upper middle income*	4·9	3·2	2·2
Total	5·9	3·8	2·7
Education			
Low income	11·1	7·2	5·0
Lower middle income	12·9	8·7	6·2
Upper middle income*	10.2	6·2	4·5
Total	11·6	7·8	5·5
Child marriage			
Low income	6·9	4·3	2·8
Lower middle income	4·1	2·5	1·6
Upper middle income*	8·9	6·0	4·2
Total	5·7	3·5	2·3

Note: * Includes one high income country.

Figure A10.1 Benefit-cost ratios, by country groupings and intervention type, weighted and unweighted, 3% discount rate.

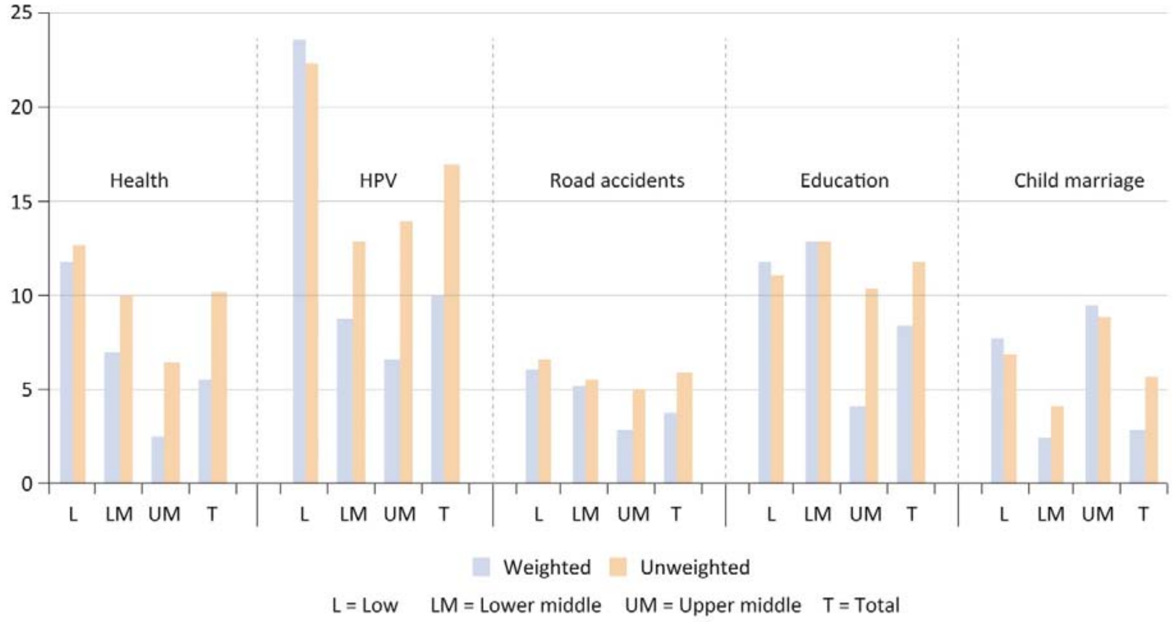

Table A10.4 Sensitivity analysis of benefit-cost ratios, by benefit and cost variations and discount rate, selected cases

	Countries			
	Low income	Lower middle income	Upper middle income	Total
	Ratio of net present value of total benefits to costs (3% discount rates)			
Health interventions				
Base case (3% discount rate)	12·6	9·9	6·4	10·2
High cost/low benefit variation of base case(3% discount rate)	8·4	6·6	4·3	6·8
Base case (5% discount rate)	7·4	5·8	3·8	6·0
Base case (7% discount rate	4·9	3·8	2·5	3·9
HPV				
Base case (3% discount rate)	22·5	12·7	14·0	17·0
High cost/low benefit variation of base case (3% discount rate)	15·0	8·5	9·3	11·3
Base case (5% discount rate)	8·1	4·8	5·9	6·4
Base case (7% discount rate	3·0	1·9	2·6	2·5
Education				
Base case (3% discount rate)	11·1	12·9	9·0	11·6
High cost/low benefit variation of base case (3% discount rate)	7·4	8·6	6·0	7·8
Base case (5% discount rate)	7·2	8·7	6·2	7·8
Base case (7% discount rate	5·0	6·2	4·5	5·5
Road accidents				
Base case (3% discount rate)	6·6	5·5	4·9	5·9
High cost/low benefit variation of base case (3% discount rate)	4·4	3·7	3·3	3·9
Base case (5% discount rate)	4·3	3·6	3·2	3·8
Base case (7% discount rate	3·0	2·5	2·2	2·7
Child marriage				
Base case (3% discount rate)	6·9	4·1	8·9	5·7
High cost/low benefit variation of base case (3% discount rate)	4·6	2·7	5·9	3·8
Base case (5% discount rate)	4·3	2·5	6·0	3·5
Base case (7% discount rate	2·8	1·6	4·2	2·3