ACCESS ECONOMICS

The Global Economic Cost of Visual Impairment

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Report by Access Economics Pty Limited for

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Commercial-in-Confidence

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Glossary

ABS	Australian Bureau of Statistics
AIHW	Australian Institute of Health and Welfare
AFR	Africa region
AMD	age-related macular degeneration
AMR	Americas region
BCV	best-corrected vision
CIA	Central intelligence Agency
DALY	disability adjusted life year
EMR	Eastern Mediterranean region
EUR	Europe region
GBD	global burden of disease
GDP	gross domestic product
MCPF	marginal cost of public funds
OECD	Organisation for Economic Co-operation and Development
PPP	purchasing power parity
PV	presenting vision
SEAR	South East Asia region
UK	United Kingdom
UN	United Nations
US	United States
VA	visual acuity
VI	visual impairment
WHO	World Health Organization
WPR	Western Pacific region
YLD	years of life lost due to disability
YLL	years of life lost due to premature death

Executive Summary

Access Economics was commissioned by AMD Alliance International to estimate the economic impact of visual impairment (VI) in the global all-ages population, including the direct and indirect costs of VI, and the burden of VI on health. In this study, VI includes all people with a visual acuity (VA) less than 6/12.

This report comprises the following estimates:

- prevalence of mild VI (6/18 ≤ VA < 6/12), moderate VI (6/60 ≤ VA < 6/18), and blindness (VA < 6/60) by World Health Organization (WHO) subregion and major cause in 2010;
- the direct health care system costs of VI in each WHO subregion based on previous country studies and relative price adjustments, expressed in 2008 US dollars;
- the indirect costs of VI in each WHO subregion disaggregated by productivity losses, informal care costs, and the deadweight welfare loss (DWL) or tax inefficiency associated with public funding of health care, expressed in 2008 US dollars;
- the burden of disease, measured in disability adjusted life years (DALYs), of VI in each WHO subregion, disaggregated by years of life lost due to premature death (YLL) and healthy years of life lost due to disability (YLD); and
- projections of the above outcomes to the year 2020.

Regional prevalence data were derived from two comprehensive reviews of VI survey data (Resnikoff et al, 2004; 2008). These prevalence rates for WHO-defined categories of VI were adjusted to fit the definitions in this study using data from population based studies that evaluated prevalence according to both sets of definitions. These prevalence rates were applied to United Nations (UN) population projections (UN, 2009) to project the numbers of people with VI to 2020. Although Resnikoff et al (2004) and Resnikoff et al (2008) report prevalence for all regions and ages these studies were limited by the number of countries for which surveys were carried out, and the necessary extrapolations of those survey data to different areas and countries. Therefore, the results of this study must be interpreted with an appropriate degree of caution.

Regional health care system costs of VI were estimated using Access Economics' cost of illness studies in five countries with adjustments for differences in Gross Domestic Product. This method follows a published methodology for estimating global direct costs of a disease (Wimo et al, 2006). DWL was calculated using the proportion of health care costs funded by government through taxation, and a 20% marginal cost of public funds.

The DALY burden of VI was calculated using disability weights derived from a Netherlands study applied to the numbers of people with mild VI (weight 0.02), moderate VI (weight 0.17) and blindness (weight 0.43). These weights have previously been applied in international burden of disease studies (AIHW, 1999; 2007; Access Economics, 2004; 2006; 2008a; 2008b; 2009). Annual numbers of deaths due to VI were estimated using general population life tables for all countries, and Australian data on the relative mortality risk (2.15) and etiological fraction (0.73%) in people with a VA less than 6/12.

Productivity losses due to VI were calculated only for developed WHO subregions using the human capital method. These calculations accounted for relative employment rates and GDP per capita (a proxy for productive output value). Developing countries were excluded as large

unemployment and underemployment pools mean productivity losses from VI are very small as labour supply is rapidly replaced.

Informal care costs were derived for all WHO subregions by adjusting previous study results by the relative availability of community care (using WHO index data) and the opportunity cost of informal care time (proxied by GDP per capita to represent wage differentials).

The global results of the study are summarised in Table i. Detailed results by WHO subregion and, where possible, by VI cause and severity, are presented in the report. The results of the study indicate that 733 million people are visually impaired in 2010. The direct health care costs of VI total $2.3 trillion in 2010, with an expected DWL of $238 billion, productivity loss of $168 billion and an estimated informal care burden of $246 billion. In total the global cost of VI is estimated as $3.0 trillion. The burden of disease is projected to increase over time with population growth.

Table i: Summary of global results for the burden of disease study in visual impairment

	2010	2015	2020
Prevalence of VI (million)	733	826	929
Direct cost ($ billion)	2,302	2,529	2,767
DWL ($ billion)	238	259	280
Productivity loss ($ billion)	168	175	178
Informal care ($ billion)	246	273	302
DALYs (million)	118	133	150

Source: Access Economics calculations. All costs expressed in 2008 US dollars.

The regions having the largest prevalence numbers, health care and other financial system costs were South East Asia region D (SEAR-D) and Western Pacific region B1 (WPR-B1), due to their relatively large populations and hence prevalence. Health care costs are substantially higher in Americas region A (AMR-A) due to a significantly larger mean cost per person with VI.

The results of the study show almost half of all VI to be caused by URE (386 million persons in 2010). A summary of the global burden of VI due to causes other than URE is presented in Table ii. This demonstrates that approximately half of the global cost and DALY burden of VI is due to causes other than URE.

Table ii: Summary of global results for the burden of disease study in visual impairment due to all causes excluding uncorrected refractive error

	2010	2015	2020
Prevalence of VI (million)	347	397	452
Direct cost ($ billion)	1,057	1,176	1,303
DWL ($ billion)	112	123	135
Productivity loss ($ billion)	77	80	81
Informal care ($ billion)	120	135	151
DALYs (million)	62	71	81

Source: Access Economics calculations. All costs expressed in 2008 US dollars.

Resnikoff et al (2004) estimated that for the year 2002, 9% of global blindness not caused by URE was caused by age-related macular degeneration (AMD). This proportion varies widely between geographic regions partly due to differing population age structures. Table iii summarises the global burden of VI due to AMD, which was calculated for each region and year as the product of the proportion of VI caused by AMD (proxied by the 2002 blindness data) and the total regional cost or DALY burden for VI.

Table iii: Summary of global results for the burden of disease study in visual impairment due to AMD

	2010	2015	2020
Prevalence of VI (million)	33	36	40
Direct cost ($ billion)	255	275	294
DWL ($ billion)	31	33	35
Productivity loss ($ billion)	34	36	36
Informal care ($ billion)	23	25	27
DALYs (million)	6	6	7

Source: Access Economics calculations. All costs expressed in 2008 US dollars.

This study adopts techniques necessary to extrapolate limited data to world regions, using information on relative health care prices, informal care costs and requirements, the likelihood of replacing lost production, and the value of lost productivity. To apply consistent methods for all world regions, some calculations use proxies for health care prices, opportunity costs, and availability of community care. Where data inputs are subject to uncertainty, conservative assumptions have been made and sensitivity analysis demonstrates the impact of changes in variables.

This study demonstrates the substantial health and economic impacts of VI globally and the potential burden that could be reduced through strategies to tackle VI worldwide.

1 Background

Access Economics was commissioned by AMD Alliance International (AMDAI) to undertake an economic impact analysis of visual impairment (VI) estimating the prevalence, direct and indirect costs, and burden of disease for low vision and blindness in the global population. VI affects populations in all regions of the world although total prevalence and the distributions between blindness and less severe vision loss vary between countries (Resnikoff et al, 2004).

Access Economics has previously conducted several country-specific burden of disease studies for VI in Australia, Canada, Japan, UK and US (Access Economics, 2004; 2006; 2008a; 2008b; 2009). Other studies assessing the global prevalence, direct costs, and productivity costs associated with VI have also been undertaken (Dandona and Dandona, 2006a; Frick and Foster, 2003; Resnikoff et al, 2004; Smith et al, 2009). This is the first study to estimate the total economic impact of VI in all regions of the world, including direct and indirect costs and disease burden.

The methodology in this study builds on the successful costing and burden of disease methodologies developed by Access Economics and applied internationally for VI. Where appropriate, other methods necessary to extrapolate data to a global analysis have been adopted from peer-reviewed studies.

This report is structured as follows.

- Chapter 2 estimates the prevalence of VI in the global population by age, gender, severity, World Health Organization (WHO) subregion and major cause in 2010, and provides future projections to the year 2020.
- Chapter 3 presents the direct health care system costs of VI in each WHO subregion and the world, to the year 2020.
- Chapter 4 calculates the indirect costs of VI in each WHO subregion and the world, to the year 2020, disaggregated by indirect cost categories including productivity losses, informal care costs, and the deadweight losses associated with healthcare expenditure.
- Chapter 5 estimates the burden of disease of VI in each WHO subregion and the world, to the year 2020, measured in disability adjusted life years (DALYs), and disaggregated by healthy years of life lost due to disability (YLD) and years of life lost due to premature death (YLL).
- Chapter 6 details the sensitivity analyses used to quantify the degree of uncertainty in the results.
- Chapter 7 provides a summary of results and qualifications to the analysis.

Due to the scope of this study and the number of possible data stratifications, summary results are provided in this report with more extensive results detailed in the accompanying Excel model. To compare the burden of disease between regions, all monetary values in this report are in US dollars (USD) and 2008 prices (the most recent year for which global Consumer Price Index data are available) unless otherwise stated.

1.1 Definitions of visual impairment

VI is broadly defined as a limitation in one or more functions of the eye or visual system, most commonly impairment of visual acuity (sharpness or clarity of vision), visual fields (the ability to detect objects to either side or above or below the direction in which the person is looking), contrast sensitivity and colour vision.

Normal vision is recorded as a visual acuity (VA) score of 20/20 in Imperial measures (6/6 in metric), which means that a person can see at 20 feet (6 metres) what a person with normal vision can see at 20 feet. Degrees of low vision and blindness are measured similarly, where the first number in the measure is the furthermost distance at which the person can clearly see an object and the second number is the distance at which a person with normal vision could see the same object. For example, 20/40 vision means that the person can clearly see at 20 feet (but not more) an object that a person with normal vision could see at 40 feet (but not more).

Low vision and blindness can differ from one eye to the other. As a result, prevalence rates can be reported for either the better or the worse eye in terms of the extent of sight loss. Although sight loss may be asymmetrical, often it is only when sight loss becomes bilateral that it is identified and treated. When reporting prevalence rates, better eye measures provide conservative estimates of sight loss while worse eye measures may tend to overstate sight loss and costs. In this study, the conservative approach has been adopted to report VI prevalence for the better eye.

VI is defined in this study as low vision and blindness. Low vision is further disaggregated into mild and moderate VI. The definitions of visual acuity for mild VI, moderate VI, and blindness are consistent with previous Access Economics reports and are commonly used in North America, Australia, and most of Europe.

- Blindness is defined as best-corrected VA less than 6/60 in the better-seeing eye.
- Moderate VI is defined as best-corrected VA less than 6/18 but better than or equal to 6/60 in the better-seeing eye.
- Mild VI is defined as best-corrected VA less than 6/12 but better than or equal to 6/18 in the better-seeing eye.
- VI is defined as mild VI, moderate VI, or blindness in the better-seeing eye.

These definitions differ from those used by the WHO, which defines low vision as best-corrected VA < 6/18 and blindness as best-corrected VA <3/60. The WHO definitions align with *International statistical classification of diseases, injuries and causes of death* 10th revision (ICD-10-AM) classifications. In assessing the global burden of VI, it is important to include people with a VA between 6/12 and 6/18 since their quality of life will also be impacted by low vision. Access Economics has previously demonstrated increased health care costs and mortality for people with mild VI (for example see Access Economics, 2009). Furthermore, mild VI is associated with a disability burden, albeit relatively low (AIHW, 1999). Dandona and Dandona (2006b) have recommended adding the mild VI category used in this study to the ICD definitions. They argue that in more developed countries this level of vision is considered necessary for daily tasks and is already used to define VI, while the increasing complexity of daily tasks in less developed countries will require better vision over time.

In this study, data using the WHO definitions of low vision and blindness have been adjusted, where possible, to fit the Access Economics definitions. These prevalence adjustments are described in Section 2.2.3 of the report.

Best-corrected VI (the definition of VI used in this study and by the WHO) means the VA with the best glasses or contact lens prescription for that person. On the other hand, presenting vision refers to VA that is unaided, or with spectacles, if worn. The major difference between the two measurements occurs with uncorrected (or under-corrected) refractive error (URE) as best-corrected measurements can overlook a large proportion of the population with this condition. This can pose a problem to estimating total prevalence, given that URE is a major cause of VI and is a common occurrence in many parts of the world (WHO, 2009). For this reason, some argue that it is more appropriate to define VI using presenting VA as it enables VI due to URE to be accounted for (Dandona and Dandona, 2006b).

Prevalence rates in this study have been adjusted to account for VI due to URE. This is important since people with URE contribute a substantial proportion of the worldwide burden of VI. These prevalence adjustments are described in Section 2.2.2 of the report.

1.2 Conditions leading to visual impairment

A range of conditions can lead to VI. Within this study, burden of disease estimates are presented for all causes including URE, all causes excluding URE, and age-related macular degeneration (AMD) only. The causes are those investigated in a pivotal study on the global prevalence of VI (Resnikoff et al, 2004). This study is described in Section 2 and the contribution of each cause to the total prevalence of VI is reported in Section 2.3. These causes include:

- cataract;
- glaucoma;
- age-related macular degeneration (AMD);
- corneal opacities;
- diabetic retinopathy;
- childhood blindness;
- trachoma;
- onchocerciasis; and
- others.

Resnikoff et al (2004) reports the regional prevalence rates of VI using WHO definitions and best-corrected vision rather than presenting vision. Therefore, prevalence estimates derived from this pivotal study do not distinguish URE as a cause of VI. However, as detailed above, URE is a key cause of VI, in particular mild VI as included in this study, and may contribute up to half of all VI cases (Resnikoff et al, 2008), so prevalence data have been adjusted accordingly.

2 Prevalence of visual impairment

The burden of disease methodology in this study is based on a prevalence approach to cost measurement, as the data sources lend themselves to such an approach. Prevalence approaches measure the number of people with a given condition (in this case mild VI, moderate VI, or blindness) in a base period (in this case calendar year 2010) and the costs of treating them, as well as other financial and non-financial costs (productivity losses, carer burden, loss of quality of life) in that year, due to the condition. When the aim of a study is to estimate the economic burden of a disease during a specified period of time (e.g. one year) a prevalence approach is recommended. If the aim is to illustrate the economic consequences of various interventions, an incidence approach is preferable (Wimo et al, 2006).

One advantage of a prevalence approach is that where results are reported for a series of years, trends in the disease burden can be examined. This method also avoids the uncertainty surrounding estimates of future treatment costs associated with an incidence approach. It is recognised however, that some of the total prevalence of VI in each year may include the same individuals. However, to calculate the burden of disease using a prevalence based approach all that is required are prevalence rates and average annual costs per person with VI.

In this study, the prevalent numbers of people with mild VI, moderate VI, and blindness were calculated by multiplying population data by prevalence rates according to VI severity, age group and world region (Resnikoff et al, 2004). An overview of the method used to project population prevalence to the year 2020 is provided below.

Although all results are reported by world region, country-specific data (including population numbers) were used in the calculations, where possible, to more accurately calculate regional results.

2.1 Population data

For all countries with a population greater than 100,000 people in 2009, population sizes were obtained from the United Nations (UN) World Population Prospects database (UN, 2009). This database provides population figures for every five years projected to the year 2050 by five-year age group and gender. For this study, 'medium variant' data were obtained for the years 2010, 2015 and 2020.

For countries with a population below 100,000 people in 2009, and countries with limited UN recognition (Gaza Strip, Kosovo, Taiwan, West Bank), population size by five-year age group were not reported in the UN database[1]. Age-group specific data are critical to accurately calculate regional results. For example, prevalence rates for VI differ substantially between people aged less than 15 years, 15-49 years, and 50 years and older (Resnikoff et al, 2004).

[1] The total population sizes for countries with a population below 100,000 people in 2009 are detailed in a report on the World Population Prospects dataset (http://www.un.org/esa/population/publications/wpp2008/wpp2008_text_tables.pdf). As discussed in this report, these populations summed to less than 0.5% of the world population in 2009.

In the absence of population size data by age group, countries having less than 100,000 people in 2009 or with limited UN recognition were excluded from the analysis. These countries totalled over 30 million people in 2009. The global population for that same year is estimated to be 6.79 billion (CIA, 2009). Therefore, the burden of disease study reflects 99.6% of the world population and any adjustments for country exclusions would have a negligible impact (increase) on global results.

Population data for Gaza Strip, Kosovo, Taiwan and West Bank were obtained from the Central Intelligence Agency (CIA) World Factbook (CIA, 2009).

All results in this study are presented by WHO subregion. The WHO defines 17 subregions by geographic region (Africa - AFR, Americas - AMR, South-East Asia – SEAR, Europe - EUR, Eastern Mediterranean - EMR, and Western Pacific - WPR) and child/adult mortality stratum (A to E). In this study, region WPR-A is separated into regions WPR-A1 and WPR-A2, with Japan allocated to the latter subregion. This decision is based on Access Economics having already undertaken independent burden of disease studies for VI in Australia and Japan and having derived markedly different results for both countries.

The 18 WHO subregions evaluated in this study and their constituent countries are presented in Appendix A:. Countries not included in the list of WHO member states, but for which sufficient population size and other data were available, were assigned a WHO subregion based on their assignment in the World Bank global burden of disease project (Lopez et al, 2006). Countries not included in the study by Lopez et al (2006) were assigned a WHO subregion based on their proximity to assigned countries. The assignments of Hong Kong and Taiwan were based on a global prevalence of angina study by Hemingway et al (2008).

Total population sizes including males and females of all ages in countries included in the analysis are presented in Table 2.1 by WHO subregion for the years 2010, 2015 and 2020. Population is forecast to grow in all WHO subregions except EUR-C and WPR-A2, consistent with other forecasts of population decline in Japan and some former Soviet states.

Table 2.1: Total population by WHO subregion and year (000s)

WHO subregion	2010	2015	2020
AFR-D	395,888	443,707	492,533
AFR-E	449,317	505,064	563,522
AMR-A	362,737	379,040	394,444
AMR-B	493,395	516,818	537,571
AMR-D	83,687	90,094	96,388
EMR-B	165,332	177,504	189,495
EMR-D	440,406	489,598	538,782
EUR-A	432,323	439,178	443,932
EUR-B1	171,521	174,812	177,665
EUR-B2	57,618	61,160	64,615
EUR-C	231,508	227,793	223,868
SEAR-B	322,240	336,685	348,995
SEAR-D	1,484,254	1,580,505	1,669,520
WPR-A1	31,058	32,599	34,039

WHO subregion	2010	2015	2020
WPR-A2	127,000	125,792	123,661
WPR-B1	1,412,967	1,455,982	1,491,926
WPR-B2	110,521	117,037	123,372
WPR-B3	131,148	142,344	153,226
World	6,902,920	7,295,712	7,667,554

Source: Access Economics calculations.

2.2 Prevalence by age group, gender, and subregion

This section describes the sources of prevalence data for low vision and blindness, and the adjustments to convert the published estimates to fit the VI definitions in this study.

2.2.1 Prevalence sources

VI prevalence rates were derived from a review by Reskinoff et al (2004), being the most recent and comprehensive study identified on the global prevalence of VI (the published estimates pertain to the year 2002). This study updates a publication of global and regional prevalence for the year 1990 (Thylefors et al, 1995). Since the 1995 publication, population-based studies on the prevalence of VI have been carried out in nearly all WHO regions using a standardised WHO methodology in most cases (Resnikoff et al, 2004). Resnikoff et al (2004) synthesise all available published and unpublished population-based survey data to 2002 that fit the WHO criteria, to derive regional prevalence rates for blindness (VA < 3/60) and low vision (3/60 ≤ VA < 6/18).

The Resnikoff et al (2004) study was used in the WHO global burden of disease analyses (Lopez et al, 2006). Advantages of the study include prevalence rates being reported for best-corrected VA by WHO subregion and age group (< 15 years old, 15 to 49 years old, 50 years old and over) consistent with the aims of this project.

Reskinoff et al (2004) used the following survey inclusion criteria:

- clear, unequivocal definitions of VI, including the use of WHO and non-WHO definitions if classifiable within the ICD-10 ranges of vision loss;
- cross-sectional design with a description of the sample design and plan, sample size, response rate, and assessment of non-sampling errors; and
- a description of the ophthalmic examinations and VA testing.

Reskinoff et al (2004) identified surveys from a global update of VI data to 2002 (Pascolini et al, 2004), and a search for unpublished survey data. For countries where data were scarce, information was sourced from ministries of health, national prevention of blindness programs, academic institutions, regional WHO offices and consultants. In total, survey results from 55 countries were selected. These 55 countries covered all WHO subregions except EUR-C, where prevalence rates were assumed equivalent to region EUR-B1 (Resnikoff et al, 2004). Where national estimates were derived from surveys covering several areas, the authors accounted for the population size in each area and the national population structure.

Population-based studies for VI have largely been restricted to people aged 50 years and older and a limited number of countries. Given the limited source data, Resnikoff et al (2004) used a modelling approach to extrapolate the available data to all WHO subregions and age groups. The assumptions made by Resnikoff et al (2004) are detailed below.

- Prevalence rates for blindness in people aged 15-49 years were estimated by mortality stratum based on interpolations derived from data on blindness in children and people aged over 50 years.
- For country areas where no data were available, prevalence was extrapolated from areas with similar availability of eye and health care and epidemiology of eye diseases and services, where data were available.
- In other instances, data from one area are representative of the entire country.
- For countries where recent epidemiological data were not available, the prevalence of blindness was extrapolated from countries within the same subregion or from neighbouring subregions that share similar epidemiological, socioeconomic, ecological and eye care service characteristics.
- Extrapolations between countries for blindness are valid for low vision.
- The mean ratio of low vision to blindness for 15 subregions was applied to subregions EUR-C and WPR-B1 where ratios could not be calculated due to a lack of data.

In using the prevalence data for this project, three disadvantages of the Resnikoff et al (2004) study were addressed.

First, prevalence rates for low vision were not reported by age-group "owing to the paucity of data on age-specific prevalence of low vision" (Resnikoff et al, 2004). This study assumes the age-group distribution for the prevalence of mild or moderate VI to be the same as for blindness. This assumption is considered plausible given older people tend to represent a greater proportion of both low vision and blindness.

Second, Resnikoff et al (2004) did not include VI due to URE, since definitions of VI were based on best-corrected vision. To account for the significant burden of disease from VI due to URE additional data were included in the model. The estimation of VI due to URE is detailed in Section 2.2.2.

Third, the prevalence rates were adjusted to account for the different definitions of VI used in this study (e.g. blindness defined as VA less than 6/60 rather than 3/60) as described in Section 2.2.3.

The unadjusted prevalence rates of low vision and blindness reported by Resnikoff et al (2004) are presented in Table 2.2. Subregion rates fall within the ranges reported by Thylefors et al (1995) but are considered more accurate estimates of current prevalence rates. The adjustments are in subsequent sections.

Table 2.2: Prevalence of low vision and blindness by WHO subregion, using WHO visual acuity definitions (%)

WHO subregion	Blindness (VA < 3/60)				Low vision (3/60 ≤ VA < 6/18)			
	All ages	<15 years	15-49 years	50+ years	All ages	<15 years	15-49 years	50+ years
AFR-D	1.00	0.12	0.20	9.00	3.00	0.37	0.60	27.00
AFR-E	1.00	0.12	0.20	9.00	3.00	0.37	0.60	27.00
AMR-A	0.20	0.03	0.10	0.40	1.20	0.18	0.60	2.40
AMR-B	0.30	0.06	0.15	1.30	1.70	0.35	0.85	7.37
AMR-D	0.50	0.06	0.20	2.60	2.00	0.25	0.80	10.40
EMR-B	0.80	0.08	0.15	5.60	2.50	0.25	0.47	17.50
EMR-D	0.97	0.08	0.20	7.00	2.90	0.24	0.60	20.93
EUR-A	0.20	0.03	0.10	0.50	1.30	0.20	0.65	3.25
EUR-B1	0.40	0.05	0.15	1.20	1.50	0.19	0.56	4.50
EUR-B2	0.30	0.05	0.15	1.30	1.10	0.19	0.55	4.77
EUR-C	0.40	0.05	0.15	1.20	1.80	0.23	0.68	5.40
SEAR-B	1.00	0.08	0.15	6.30	2.40	0.20	0.36	15.12
SEAR-D	0.60	0.08	0.20	3.40	2.00	0.27	0.67	11.33
WPR-A1	0.30	0.03	0.10	0.60	1.20	0.12	0.40	2.40
WPR-A2	0.30	0.03	0.10	0.60	1.20	0.12	0.40	2.40
WPR-B1	0.60	0.05	0.15	2.30	1.90	0.16	0.48	7.28
WPR-B2	0.80	0.08	0.15	5.60	1.90	0.20	0.36	13.30
WPR-B3	0.30	0.08	0.15	2.20	1.20	0.33	0.60	8.80

Note: Age-group distribution for blindness is assumed for low vision due to data limitations.

Source: Resnikoff et al, 2004; Access Economics calculations.

2.2.2 Prevalence adjustments for uncorrected refractive error

The unadjusted prevalence rates above are based on best-corrected measures of VA, which exclude uncorrected (or undercorrected) refractive error as a cause of VI. This exclusion will underestimate the total burden of disease due to VI (Dandona and Dandona, 2006), and this underestimation may be substantial in certain regions. Dandona and Dandona (2006) estimated that including URE as a cause of VI increases the estimated number of people with VI by up to 61%. Moreover, Resnikoff et al (2008) calculate the number of people with VA less than 6/18 to almost double when accounting for VI due to URE, with URE being the second cause of blindness after cataract and the main cause of low vision. The burden of VI due to URE is likely to be substantial and should be included in global burden of disease studies (Smith et al, 2009).

The prevalence rates derived from Resnikoff et al (2004) were adjusted upwards to account for VI due to URE. These adjustment factors were obtained from a follow-on review of 68 surveys by the same investigators (Resnikoff et al, 2008). This review used similar methods to the previous study in identifying, selecting, and extrapolating survey data. For each included

study, the authors estimated the prevalence of URE as the difference between the prevalence of VI using either presenting or best-corrected VA. An earlier review of nine population studies for VI due to refractive error was considered to be outdated by this study (Dandona and Dandona, 2006).

Prevalence rates of low vision and blindness due to URE were reported by WHO subregion for three age groups: <15 years, 15-49 years and 50 years (Resnikoff et al, 2008). These regions and age groups concord with the earlier study by Resnikoff et al (2004). For each subregion, the prevalence rates in people aged 15-49 years were estimated using the average prevalence for age groups 16-39 years and 40-49 years, weighted by age-specific population size. Resnikoff et al (2008) only found blindness due to URE in people aged 50 years and older.

Resnikoff et al (2008) report separate higher prevalence rates for China and India. In this study, prevalence rates for subregions SEAR-D and WPR-B1 are an average of prevalence rates for India (or China) and all other countries in subregion SEAR-D (or WPR-B1) weighted by population size in 2010. For EMR-B and EMR-D a simple average of the prevalence rates reported for urban and rural populations was used to estimate the prevalence of blindness due to URE in people aged 50 years and older. The prevalence of VI due to URE in India is claimed by some experts to be an overestimate, which would overestimate the global prevalence of VI, although this issue is yet to be resolved (Dandona and Dandona, 2008).

Prevalence rates for low vision and blindness due to URE were added to the prevalence rates for best-corrected VA presented in Table 2.2. The adjusted prevalence rates of WHO-defined low vision and blindness are reported in Table 2.3.

Table 2.3 Prevalence of low vision and blindness by WHO subregion, including visual impairment due to uncorrected refractive error (%)

WHO subregion	Blindness (VA < 3/60)			Low vision (3/60 ≤ VA < 6/18)		
	<15 years	15-49 years	50+ years	<15 years	15-49 years	50+ years
AFR-D	0.12	0.20	10.64	0.61	0.99	36.22
AFR-E	0.12	0.20	10.64	0.61	0.98	36.22
AMR-A	0.03	0.10	0.40	1.18	1.78	6.00
AMR-B	0.06	0.15	1.60	0.90	1.55	13.53
AMR-D	0.06	0.20	3.35	0.95	1.71	17.51
EMR-B	0.08	0.15	6.28	0.80	1.15	23.71
EMR-D	0.08	0.20	7.68	0.79	1.26	27.04
EUR-A	0.03	0.10	0.50	1.20	1.84	6.85
EUR-B1	0.05	0.15	1.20	1.19	1.71	7.30
EUR-B2	0.05	0.15	1.30	1.19	1.68	7.57
EUR-C	0.05	0.15	1.20	1.23	1.84	8.20
SEAR-B	0.08	0.15	6.56	0.99	1.34	20.15
SEAR-D	0.08	0.20	5.27	0.90	1.85	34.53
WPR-A1	0.03	0.10	0.60	0.32	0.60	4.39
WPR-A2	0.03	0.10	0.60	0.32	0.60	4.39

WHO subregion	Blindness (VA < 3/60)			Low vision (3/60 ≤ VA < 6/18)		
WPR-B1	0.05	0.15	2.57	2.76	3.44	17.26
WPR-B2	0.08	0.15	5.80	0.99	1.32	18.25
WPR-B3	0.08	0.15	2.40	1.12	1.54	14.07

Source: Resnikoff et al, 2004; Resnikoff et al, 2008; Access Economics calculations.

2.2.3 Prevalence adjustments for differences in visual acuity definitions

Definitions of VI differ between the prevalence data source (Resnikoff et al, 2004), which uses WHO definitions, and this study which defines the lower bound VA for low vision (and upper bound VA for blindness) as 6/60 rather than 3/60, and includes mild VI (6/18 ≤ VA < 6/12).

Expert opinion suggests there is no agreed standard conversion for adjusting prevalence rates based on WHO definitions to the definitions used in this study (EpiVision, pers. Comm., 4 December 2009). Therefore, a review was undertaken of population-based studies reporting prevalence using both sets of definitions. These studies were identified through a literature search using search terms based on VA scores. Similarly, Resnikoff et al (2004) has reported that "with regard to correction factors to determine prevalences according to ICD-10 from different definitions of visual impairment (e.g. US definitions), there (are) a sufficient number of studies reporting data with both definitions to enable a table of conversion to be calculated". Unfortunately, Resnikoff et al (2004) does not present the correction factors used in that study.

Identified studies were reviewed with regard to the following questions:

- What proportion of people with a VA less than 6/18 but no lower than 3/60, have a VA no lower than 6/60 (i.e. the moderate VI proportion of low vision)?
- In any population, given the proportion of people with a VA less than 6/18, what is the likely proportion of people with a VA less than 6/12 but no lower than 6/18 (i.e. the prevalence of mild VI)?

Table 2.4 presents studies identified with data relevant to answer the first question above. Where necessary, prevalence rates were derived from data reported in the publication. A simple average moderate VI proportion of 71% was calculated using only studies of best-corrected VA. The simple average moderate VI proportion using studies of presenting VA was similar, being 70%.

Table 2.4: Studies used to estimate the prevalence of moderate VI (6/60 ≤ VA < 6/18) from the prevalence of WHO-defined low vision (3/60 ≤ VA < 6/18)

Study	Country	Age group (years)	VA measure	Prevalence (%) of 6/60 ≤ VA < 6/18 (A)	Prevalence (%) of 3/60 ≤ VA < 6/18 (B)	A ÷ B
Amansakhatov et al, 2002	Turkmenistan	50+	PV	15.9	20.3	0.78

Study	Country	Age group (years)	VA measure	Prevalence (%) of 6/60 ≤ VA < 6/18 (A)	Prevalence (%) of 3/60 ≤ VA < 6/18 (B)	A ÷ B
Beltranena et al, 2007	Guatemala	50+	PV	11.5	18.1	0.64
Dineen et al, 2003	Bangladesh	30+	BCV	3.6	4.9	0.74
Duerksen et al, 2003	Paraguay	50+	BCV	8.7	13.9	0.63
Haider et al, 2003	Pakistan	50+	PV	16.5	26.0	0.63
Huang et al, 2009	China	50+	BCV	2.9	3.1	0.94
Jadoon et al, 2006	Pakistan	30+	BCV	5.6	9.0	0.62
Khandekar et al, 2007	Oman	40+	PV	34.1	45.1	0.76
Nano et al, 2006	Argentina	50+	PV	4.6	7.1	0.65
Nirmalan et al, 2002	India	50+	BCV	8.5	13.1	0.65
ICEH, 2009	Nigeria	40+	BCV	5.3	9.5	0.56
Ramke et al, 2007	East Timor	40+	PV	17.7	25.1	0.70
Access Economics, 2009	UK	75+	PV	8.3	10.3	0.81
Salomao et al, 2008	Brazil	50+	PV	2.0	3.0	0.67
Thulasiraj et al, 2003	India	40+	BCV	12.2	14.4	0.85
VanNewkirk et al, 2001	Australia	40+	BCV	1.2	1.7	0.70
Venkata et al, 2005	India	50+	BCV	9.3	13.6	0.68

Abbreviations: BCV = best-corrected vision; PV = presenting vision.

Source: Studies referenced in table.

The review did not reveal any obvious relationship between the moderate VI proportion of WHO-defined low vision and the type of country. Any relationship between the moderate VI proportion and age is more difficult to determine given that older age groups have been included in all studies. In the absence of data, there was assumed to be no relationship with age. However, the model does account for different prevalence rates of WHO-defined low vision between age groups before applying the proportion with moderate VI.

Based on the above findings, a moderate VI proportion of 71% was applied to the prevalence rates of WHO-defined low vision in all subregions. The range of this proportion between studies (56% to 94%) was used in the sensitivity analysis (Section 6).

Table 2.5 presents studies identified with data relevant to answer the second question on page 10 regarding mild visual impairment.

Table 2.5: Studies used to estimate the prevalence of mild VI (6/18 ≤ VA < 6/12)

Study	Country	Age group (years)	VA measure	Prevalence (%) of 6/18 ≤ VA < 6/12 (A)	Prevalence (%) of 6/60 ≤ VA < 6/18 (B)	Prevalence (%) of VA < 6/18 (C)	A ÷ B	A ÷ C
Dineen et al, 2003	Bangladesh	30+	BCV	2.8	3.6	6.0	0.78	0.47
Higaldo et al, 2009	Spain	65+	BCV	14.6	Not reported	6.3	-	2.32
Jadoon et al, 2006	Pakistan	30+	BCV	7.9	5.6	11.7	1.41	0.68
ICEH, 2009	Nigeria	40+	BCV	4.5	5.3	12.9	0.85	0.35
Access Economics, 2009	UK	75+	PV	7.5	10.3	12.4	0.73	0.60
VanNewkirk et al, 2001	Australia	40+	BCV	1.9	1.2	1.9	1.54	0.99
Access Economics, 2006	US	50+	BCV	1.3	0.6	1.4	2.17	0.96

Abbreviations: BCV = best-corrected vision; PV =, presenting vision.

Source: Studies referenced in table.

An average ratio of 1.35 for mild VI to moderate VI was derived from studies of best-corrected VA. This ratio was applied to all WHO subregions in the study. The range of ratios between studies (0.73 to 2.17) was wide, and was included in a sensitivity analysis (Section 6). Dandona and Dandona (2006b) have also noted a lack of published data for mild VI prevalence, and cite the wide differences in prevalence between Bangladesh and Australia as an example of the problem of upwardly adjusting the prevalence of VI to account for mild VI. The differences are due to different age structures, different epidemiology and ethnicity, and different health systems in different countries.

2.2.4 Adjusted prevalence rates used in the model

Prevalence rates used in the model are reported in Table 2.6. These were derived from Resnikoff et al (2004) as described in Section 2.2.1 and adjusted for differences in VA definitions and URE, as detailed in Section 2.2.2 and Section 2.2.3, respectively.

It is recognised that 12 countries have switched WHO subregion since 2002. Those countries are assumed to be more closely associated with the epidemiological characteristics of their

new region rather than their previous region. Any impact of this assumption is thought to be limited given that only three of the 12 countries switched mortality strata (Cuba from AMR-B to AMR-A, Myanmar and South Korea from WPR-B to SEAR-D), and only five of the 12 countries moved from subregions where prevalence was partly based on surveys carried out in those countries (Malaysia, Myanmar, Pakistan, Philippines, Sudan). The approach is also consistent with the assumptions stated by Resnikoff et al (2004) and by Access Economics elsewhere in this report, being that prevalence for all countries can be extrapolated using average prevalence rates within that country's subregion.

Table 2.6: Prevalence rates for visual impairment in the burden of disease study (%)

WHO subregi-on	Blindness (VA < 6/60)			Moderate low vision (6/60 ≤ VA < 6/18)			Mild low vision (6/18 ≤ VA < 6/12)		
	<15 years	15-49 years	50+ years	<15 years	15-49 years	50+ years	<15 years	15-49 years	50+ years
AFR-D	0.30	0.49	21.27	0.43	0.70	25.59	0.58	0.94	34.55
AFR-E	0.30	0.49	21.27	0.43	0.69	25.59	0.58	0.93	34.55
AMR-A	0.38	0.62	2.16	0.83	1.26	4.24	1.13	1.69	5.72
AMR-B	0.33	0.60	5.57	0.64	1.10	9.56	0.86	1.48	12.90
AMR-D	0.34	0.70	8.49	0.67	1.21	12.37	0.90	1.63	16.70
EMR-B	0.31	0.49	13.23	0.57	0.81	16.75	0.76	1.09	22.61
EMR-D	0.31	0.57	15.61	0.56	0.89	19.11	0.75	1.21	25.80
EUR-A	0.38	0.64	2.51	0.84	1.30	4.84	1.14	1.76	6.53
EUR-B1	0.40	0.65	3.34	0.84	1.21	5.16	1.14	1.63	6.96
EUR-B2	0.40	0.64	3.52	0.84	1.18	5.35	1.13	1.60	7.22
EUR-C	0.41	0.69	3.61	0.87	1.30	5.79	1.17	1.75	7.82
SEAR-B	0.37	0.54	12.47	0.70	0.94	14.24	0.94	1.27	19.23
SEAR-D	0.34	0.74	15.40	0.63	1.31	24.40	0.86	1.76	32.94
WPR-A1	0.12	0.28	1.89	0.23	0.42	3.10	0.31	0.57	4.19
WPR-A2	0.12	0.28	1.89	0.23	0.42	3.10	0.31	0.57	4.19
WPR-B1	0.86	1.16	7.63	1.95	2.43	12.20	2.63	3.28	16.46
WPR-B2	0.37	0.54	11.15	0.70	0.93	12.89	0.94	1.26	17.40
WPR-B3	0.41	0.60	6.53	0.79	1.09	9.94	1.07	1.47	13.42

Source: Access Economics calculations.

2.3 Prevalence by cause of visual impairment

This study presents VI prevalence numbers, DALYs and health care system costs by cause of VI. Specifically, in Sections 3-5 of this report, the cost and DALY burdens of disease in each WHO subregion are presented for:

- All causes including URE;
- All causes excluding URE; and
- AMD only.

The proportions of blindness by cause were ascertained by Resnikoff et al (2004) for the year 2002 from the cause attributions reported in the surveys used to derive prevalence rates. However, due to scarcity of data, the causes of low vision could not be quantified with confidence either at a regional or global level (Resnikoff et al, 2004). In the absence of data, this study assumes the distribution of all mild and moderate VI by cause to be the same as for blindness.

The distribution of VI prevalence by cause, using best-corrected VA only (i.e. excluding VI due to URE), is detailed for the year 2002 in Table 2.7[2]. The data show cataract and glaucoma to be the major causes of VI in developing regions. In developed regions, particularly AMR-A and EUR-A, AMD and diabetic retinopathy contribute greater proportions of all VI. These findings are consistent with the higher prevalence of diabetes and longer life expectancy in more developed countries.

Table 2.7: Distribution of visual impairment based on best-corrected visual acuity by cause (%)

WHO subregion	Cataract	Glaucoma	AMD	Corneal opacities	Diabetic retinopathy	Childhood blindness	Trachoma	Onchocerciasis	Other	Total
AFR-D	50.0	15.0	0.0	8.0	0.0	5.2	6.2	6.0	9.6	100.0
AFR-E	55.0	15.0	0.0	12.0	0.0	5.5	7.4	2.0	3.1	100.0
AMR-A	5.0	18.0	50.0	3.0	17.0	3.1	0.0	0.0	3.9	100.0
AMR-B	40.0	15.0	5.0	5.0	7.0	6.4	0.8	0.0	20.8	100.0
AMR-D	58.5	8.0	4.0	3.0	7.0	5.3	0.5	0.0	13.7	100.0
EMR-B	49.0	10.0	3.0	5.5	3.0	4.1	3.2	0.0	22.2	100.0
EMR-D	49.0	11.0	2.0	5.0	3.0	3.2	5.5	0.0	21.3	100.0
EUR-A	5.0	18.0	50.0	3.0	17.0	2.4	0.0	0.0	4.6	100.0
EUR-B1	28.5	15.0	15.0	8.0	15.0	3.5	0.0	0.0	15.0	100.0
EUR-B2	35.5	16.0	15.0	5.0	15.0	6.9	0.0	0.0	6.6	100.0
EUR-C	24.0	20.0	15.0	5.0	15.0	2.4	0.0	0.0	18.6	100.0
SEAR-B	58.0	14.0	3.0	5.0	3.0	2.6	0.0	0.0	14.4	100.0
SEAR-D	51.0	9.0	5.0	3.0	3.0	4.8	1.7	0.0	22.5	100.0
WPR-A1	5.0	18.0	50.0	3.0	17.0	1.9	0.0	0.0	5.1	100.0
WPR-A2	5.0	18.0	50.0	3.0	17.0	1.9	0.0	0.0	5.1	100.0
WPR-B1	48.5	11.0	15.0	3.0	7.0	2.3	6.4	0.0	6.8	100.0
WPR-B2	65.0	6.0	5.0	7.0	3.0	3.6	3.5	0.0	6.9	100.0
WPR-B3	65.0	6.0	3.0	3.0	5.0	9.5	4.3	0.0	4.2	100.0

Source: Resnikoff et al, 2004.

This study also includes VI due to URE (see Section 2.2.2). The distribution of VI prevalence by cause including URE is detailed for the year 2002 in Table 2.8. In 2002, URE contributed between 20% and 61% of all VI depending on the subregion. Therefore, including VI due to

[2] For subregion WPR-A, the proportion of VI due to other causes is increased from 5.0% as reported by Resnikoff et al (2004) to 5.1% in order for the proportions to sum to 100%.

URE substantially increases the global burden of VI in regions such as SEAR-D. The proportional increases are less marked in African and Eastern Mediterranean regions.

In the model, the age-group specific prevalence rates of VI due to URE reported by Resnikoff et al (2008) were applied to the population data for each year. Due to changing population age structures in each region, the modelled proportion of VI caused by URE varies between 2010 and 2020 and, for all years, differs to the 2002 estimates. For this reason, the regional distributions in Table 2.8 are only illustrative of the year 2002.

Table 2.8: Distribution of visual impairment by cause including uncorrected refractive error (%)

WHO subregion	Cataract	Glaucoma	AMD	Corneal opacities	Diabetic retinopathy	Childhood blindness	Trachoma	Onchocerciasis	Other	Uncorrected refractive error	Total
AFR-D	40.0	12.0	0.0	6.4	0.0	4.2	5.0	4.8	7.7	20.0	100.0
AFR-E	44.0	12.0	0.0	9.6	0.0	4.4	5.9	1.6	2.5	20.0	100.0
AMR-A	2.1	7.6	21.1	1.3	7.2	1.3	0.0	0.0	1.6	57.7	100.0
AMR-B	23.3	8.7	2.9	2.9	4.1	3.7	0.5	0.0	12.1	41.9	100.0
AMR-D	37.1	5.1	2.5	1.9	4.4	3.4	0.3	0.0	8.7	36.5	100.0
EMR-B	36.0	7.3	2.2	4.0	2.2	3.0	2.4	0.0	16.3	26.5	100.0
EMR-D	37.5	8.4	1.5	3.8	2.3	2.4	4.2	0.0	16.3	23.5	100.0
EUR-A	2.1	7.6	21.1	1.3	7.2	1.0	0.0	0.0	1.9	57.7	100.0
EUR-B1	15.5	8.2	8.2	4.4	8.2	1.9	0.0	0.0	8.2	45.6	100.0
EUR-B2	16.6	7.5	7.0	2.3	7.0	3.2	0.0	0.0	3.1	53.2	100.0
EUR-C	13.9	11.6	8.7	2.9	8.7	1.4	0.0	0.0	10.8	42.0	100.0
SEAR-B	39.8	9.6	2.1	3.4	2.1	1.8	0.0	0.0	9.9	31.5	100.0
SEAR-D	20.1	3.5	2.0	1.2	1.2	1.9	0.7	0.0	8.9	60.7	100.0
WPR-A1	3.1	11.1	30.9	1.9	10.5	1.2	0.0	0.0	3.1	38.3	100.0
WPR-A2	3.1	11.1	30.9	1.9	10.5	1.2	0.0	0.0	3.1	38.3	100.0
WPR-B1	17.8	4.0	5.5	1.1	2.6	0.8	2.4	0.0	2.5	63.3	100.0
WPR-B2	41.2	3.8	3.2	4.4	1.9	2.3	2.2	0.0	4.4	36.6	100.0
WPR-B3	31.9	2.9	1.5	1.5	2.5	4.7	2.1	0.0	2.1	51.0	100.0

Source: Resnikoff et al, 2004; Resnikoff et al, 2008; Access Economics calculations.

The cost and DALY burdens of VI due to all causes excluding URE were calculated by excluding the prevalence rates of VI due to URE from the model calculations. The burdens due to AMD were calculated by multiplying the burdens for all causes excluding URE by the proportions of VI due to AMD (Table 2.7, column 4). These calculations were performed at a regional level and were summed to give global totals. This approach was adopted due to the proportion of VI due to AMD only being reported for all ages/genders at the regional level (Resnikoff et al 2004).

2.4 Global prevalence numbers for visual impairment

The prevalence of VI was calculated by multiplying the estimated prevalence rates (Table 2.6) by the population in each WHO subregion five-year age group for 2010, 2015, 2020. In the absence of time-series data the prevalence of VI and the distribution of VI by cause (excluding URE) are assumed constant to 2020. However, due to forecast population growth, the number of visually impaired people is projected to increase over time. This approach is in line with previous global burden of disease studies for VI (Frick and Foster, 2003; Smith et al 2009)

The model disaggregates prevalence numbers by age group, gender, WHO subregion, and year. Given the vast amount of information, Table 2.9, Table 2.10, Table 2.11, and Table 2.12 summarise prevalence numbers by WHO subregion, year and VI severity only.

- With VI due to URE included in the model, the worldwide number of visually impaired people (VA < 6/12) is projected to increase from 733 million in 2010 to 929 million in 2020 (Table 2.12). The number of blind people (VA < 6/60) in the world is projected to increase from 156 million in 2010 to 200 million in 2020 (Table 2.11).
- When VI due to URE is not considered (VI is based on best-corrected VA only), the number of visually impaired people is projected to increase from 347 million in 2010 to 452 million in 2020. The number of blind people is projected to increase from 91 million in 2010 to 119 million in 2020.

These prevalence numbers are consistent with the findings of previous studies. The WHO estimated there to be 161 million people worldwide with VI in 2002 when defined using a best-corrected VA less than 6/18 (Resnikoff et al, 2004). The model used in this study estimates 200 million people worldwide with VI in 2010, consistent with population growth between 2002 and 2010 (the prevalence of blindness is forecast to increase by approximately 30 million people every five years).

Dandona and Dandona (2006a) calculated the WHO estimate for 2002 would increase to 259 million when accounting for VI due to URE. However, this estimate was superseded by Resnikoff et al (2008) in a more extensive review of population-based studies, where the prevalence in 2002 was increased to 314 million (an increase of 95%). Using the model developed for this study, the number of people with a VA less than 6/18 is estimated to be 400 million. Again, the difference between the 2002 and 2010 estimates is consistent with population growth, with the prevalence of moderate VI or blindness increasing by approximately 50,000 people every five years. Furthermore, when accounting for URE, the model shows a 100% increase in the prevalence of moderate VI or blindness (from 200 million to 400 million people worldwide). This increase is marginally higher than the estimate by Resnikoff et al (2008), which is likely due to changing population age structures and relative population growth between regions.

- The overall prevalence of VI in this study is higher than previously published figures, since it includes people with a VA less than 6/12 but greater than or equal to 6/18 (mild VI). The prevalence of mild VI is forecast to increase from 331 million people in 2010 to 419 million people in 2020 when accounting for VI due to URE (Table 2.9), or from 147 million people in 2010 to 191 million people in 2020 when not accounting for VI due to URE. This suggests that mild VI accounts for 42-45% of all VI depending on whether best-corrected or presenting VA measures are used, and supports recent suggestions to

modify the WHO criteria for the substantial worldwide impact of mild VI (Dandona and Dandona, 2006b).

Table 2.9: Prevalence of mild visual impairment (6/18 ≤ VA <6/12) (000s)

WHO subregion	2010	2015	2020
AFR-D	16,795	19,459	22,569
AFR-E	18,746	21,285	24,154
AMR-A	10,369	11,192	11,894
AMR-B	17,412	19,791	22,222
AMR-D	3,029	3,452	3,919
EMR-B	6,465	7,681	9,182
EMR-D	17,983	20,985	24,461
EUR-A	14,797	15,532	16,198
EUR-B1	5,082	5,333	5,597
EUR-B2	1,344	1,512	1,661
EUR-C	8,470	8,561	8,495
SEAR-B	15,070	17,317	19,726
SEAR-D	94,846	108,872	124,241
WPR-A1	522	583	636
WPR-A2	2,673	2,740	2,805
WPR-B1	89,510	98,881	109,868
WPR-B2	4,288	5,097	5,965
WPR-B3	4,020	4,663	5,344
World	331,420	372,937	418,937

Source: Access Economics calculations.

Table 2.10: Prevalence of moderate visual impairment (6/60 ≤ VA <6/18) (000s)

WHO subregion	2010	2015	2020
AFR-D	12,441	14,414	16,718
AFR-E	13,886	15,766	17,892
AMR-A	7,680	8,291	8,810
AMR-B	12,897	14,660	16,460
AMR-D	2,243	2,557	2,903
EMR-B	4,789	5,689	6,802
EMR-D	13,321	15,544	18,119
EUR-A	10,961	11,505	11,998
EUR-B1	3,765	3,950	4,146
EUR-B2	995	1,120	1,230
EUR-C	6,274	6,341	6,293
SEAR-B	11,163	12,827	14,611
SEAR-D	70,255	80,644	92,029

WHO subregion	2010	2015	2020
WPR-A1	387	432	471
WPR-A2	1,980	2,030	2,078
WPR-B1	66,302	73,244	81,383
WPR-B2	3,176	3,775	4,418
WPR-B3	2,977	3,454	3,958
World	245,493	276,245	310,319

Source: Access Economics calculations.

Table 2.11: Prevalence of blindness (VA < 6/60) (000s)

WHO subregion	2010	2015	2020
AFR-D	10,073	11,680	13,562
AFR-E	11,246	12,771	14,498
AMR-A	3,846	4,156	4,420
AMR-B	7,366	8,392	9,440
AMR-D	1,450	1,660	1,892
EMR-B	3,574	4,275	5,146
EMR-D	10,295	12,051	14,097
EUR-A	5,573	5,858	6,116
EUR-B1	2,270	2,390	2,519
EUR-B2	586	666	736
EUR-C	3,716	3,765	3,740
SEAR-B	9,075	10,524	12,085
SEAR-D	43,437	49,948	57,096
WPR-A1	238	265	289
WPR-A2	1,213	1,243	1,272
WPR-B1	37,613	42,018	47,249
WPR-B2	2,511	3,023	3,576
WPR-B3	1,831	2,136	2,460
World	155,911	176,821	200,192

Source: Access Economics calculations.

Table 2.12: Prevalence of all visual impairment (VA < 6/12) (000s)

WHO subregion	2010	2015	2020
AFR-D	39,308	45,552	52,849
AFR-E	43,878	49,822	56,544
AMR-A	21,895	23,639	25,123
AMR-B	37,675	42,843	48,122
AMR-D	6,722	7,669	8,715
EMR-B	14,828	17,645	21,130

WHO subregion	2010	2015	2020
EMR-D	41,599	48,581	56,678
EUR-A	31,331	32,895	34,312
EUR-B1	11,117	11,674	12,262
EUR-B2	2,925	3,298	3,627
EUR-C	18,461	18,668	18,528
SEAR-B	35,307	40,668	46,423
SEAR-D	208,538	239,464	273,366
WPR-A1	1,147	1,279	1,395
WPR-A2	5,865	6,012	6,154
WPR-B1	193,424	214,143	238,500
WPR-B2	9,976	11,895	13,959
WPR-B3	8,828	10,253	11,762
World	732,824	826,003	929,448

Source: Access Economics calculations.

The estimated prevalence of all VI by cause for 2010 is presented in Table 2.13. As discussed in Section 2.3, these numbers highlight the large contribution to VI from cataract and glaucoma and, in developed countries, the substantial impact of population ageing (with associated AMD) and diabetes (with associated retinopathy). However, in most subregions, URE is the biggest contributor to total VI, particularly in WPR-B1 and SEAR-D.

Table 2.13: Prevalence of all VI by cause (000s)

WHO subregion	Cataract	Glaucoma	AMD	Corneal opacities	Diabetic retinopathy	Childhood blindness	Trachoma	Onchocerciasis	Other	Uncorrected refractive error	Total
AFR-D	14,552	4,365	0	2,328	0	1,513	1,804	1,746	2,794	10,205	39,307
AFR-E	17,882	4,877	0	3,902	0	1,788	2,406	650	1,008	11,365	43,878
AMR-A	418	1,505	4,181	251	1,422	259	0	0	326	13,532	21,894
AMR-B	8,326	3,122	1,041	1,041	1,457	1,332	167	0	4,329	16,861	37,676
AMR-D	2,195	300	150	113	263	199	19	0	514	2,969	6,722
EMR-B	4,993	1,019	306	560	306	418	326	0	2,262	4,639	14,829
EMR-D	14,729	3,306	601	1,503	902	962	1,653	0	6,403	11,540	41,599
EUR-A	700	2,521	7,002	420	2,381	336	0	0	644	17,326	31,330
EUR-B1	1,677	883	883	471	883	206	0	0	883	5,233	11,119
EUR-B2	499	225	211	70	211	97	0	0	93	1,518	2,924
EUR-C	2,611	2,176	1,632	544	1,632	261	0	0	2,024	7,581	18,461
SEAR-B	14,114	3,407	730	1,217	730	633	0	0	3,504	10,973	35,308
SEAR-D	37,915	6,691	3,717	2,230	2,230	3,568	1,264	0	16,727	134,194	208,536
WPR-A1	34	122	339	20	115	13	0	0	34	470	1147
WPR-A2	172	620	1,722	103	585	65	1	0	175	2,422	5,865

WHO subregion	Cataract	Glaucoma	AMD	Corneal opacities	Diabetic retinopathy	Childhood blindness	Trachoma	Onchocerciasis	Other	Uncorrected refractive error	Total
WPR-B1	31,977	7,252	9,890	1,978	4,615	1,516	4,220	0	4,483	127,493	193,424
WPR-B2	4,235	391	326	456	195	235	228	0	450	3,461	9,977
WPR-B3	3,190	294	147	147	245	466	211	0	206	3,920	8,826
World	160,219	43,076	32,878	17,354	18,172	13,867	12,299	2,396	46,859	385,702	732,822

Source: Access Economics calculations.

Note: Figures in the total column differ slightly to the 2010 figures in Table 2.12 due to rounding.

3 Health care system expenditure

A societal perspective is adopted for this study. The societal perspective includes all direct and indirect costs incurred by society due to VI, irrespective of the payer. These include costs incurred by people who are not themselves visually impaired but still impacted, for example health care payers, carers, and taxpayers.

In this section of the report, the worldwide direct health care costs of VI are presented. These include all costs to the health care system that are associated with partial sight and blindness, including:

- hospital inpatient expenditure;
- non-admitted expenditure (outpatient costs and community services);
- pharmaceutical prescribing within a primary and secondary care environment;
- general ophthalmic services (eye examinations and corrective vision aids);
- expenditure associated with injurious falls attributable to partial sight and blindness;
- research and development;
- aged care and community care; and
- capital and administration expenditure.

For any given year, total health care expenditure is the product of VI prevalence and the mean total health care cost per person with VI. A worldwide perspective presents several methodological difficulties. Country-specific costs of VI will differ according to local resource use, unit costs of health care products and services, and costing methods. Resource use will be dependent on population demographics and care patterns in that country. The health care cost per person is likely to differ between countries due to a number of factors including clinical practice, availability of ophthalmic health care products and services, and relative prices for those products and services. Methodological differences between studies include the selection of cost categories and, partly related to this, the availability and completeness of resource use and cost data.

Although several studies on global productivity losses associated with VI have been published (see Section 4.1), no previous studies on the global or regional direct costs of low vision were identified. A global perspective therefore requires costs to be imputed for countries where data are unavailable which, in turn, requires a costing method that can be applied consistently across countries and regions. The method used in this project follows a global cost of dementia study (Wimo et al, 2006). The approach assumes the ratio of annual direct health care costs to gross domestic product (GDP) per capita to be similar between countries, including those where cost data are or are not available. This approach is based on macro-economic research showing a strong correlation between health care expenditure per capita and GDP per capita (Wimo et al, 2006) and as such is applicable to many clinical areas including VI.

Differences between country unit costs (e.g. hospital care, pharmaceuticals) are assumed to be reflected by differences in the GDP per capita. Furthermore, differences in GDP per capita are

assumed to also reflect differences in health care resource use, so countries with a higher GDP per capita utilise more costly resources, such as long-term care.

Following this method, direct health care system costs are imputed using GDP per capita and the average ratio of annual direct costs to GDP per capita for countries where data are available.

3.1 Published direct costs

Data were sought on the total health care system costs in countries around the world. Studies of specific health care system costs (e.g. inpatient or pharmaceutical expenditure only) were of limited use given the need to estimate total health care costs for all countries using a consistent 'basket' of health care services.

Access Economics previously estimated the total health care system costs of VI for Australia, Canada, Japan, UK, and US (Access Economics, 2004; 2006; 2008a; 2008b; 2009). Other published studies report total direct costs for Australia, UK, and US (Frick et al, 2007 and 2010; Grainger and Hutchinson, 2003; Meads and Hyde, 2003; Rein et al, 2006; Taylor et al, 2006; Wright et al, 2000). No data on total health care costs in other countries were identified.

The previous Access Economics studies were preferred to the other published studies for two key reasons. First, they use a consistent costing framework to minimise costing bias between countries and regions. Second, those studies estimate costs using the same VI definitions as the current study. Other studies generally focus on blindness, or exclude mild VI.

Total health care system costs in Australia, Canada, Japan, UK, and US were estimated using health care expenditure records. Therefore, costs could only be derived for VI broadly defined by ICD-10 codes (e.g. problems of the eye or adnexa) or categories specific to the database (e.g. expenditures of 'visual disorders' or 'vision care'). Costs could not be derived specifically for each VI severity in this study. An average health care system cost is thus applied in the model to all people with a VA less than 6/12.

Although this approach does not account for the distribution of mild VI, moderate VI, and blindness, the underlying cost data used to impute costs in other countries are weighted towards Canada, UK, and US (having the largest populations). These countries are in subregions where the proportion of VI due to blindness is lowest. Therefore, the costing approach is expected to estimate conservative health care costs in other countries.

Reported health care system costs of VI are presented in Table 3.1. All cost categories in the table were included in each country report. However, some costs are included under other headings depending on the estimation method. For example, in the UK study (Access Economics, 2009), emergency care costs are included in the inpatient and outpatient data, and the community care costs are included with residential care costs. Therefore, emergency hospital and community care costs are included in the mean total health care system cost.

For this study, total health care system costs per person were converted from 2008 British pounds to 2008 US dollars using the 2008 Purchasing Power Parity of 0.54 British pounds per US dollar (OECD, 2010).

Table 3.1: International total health care system costs of visual impairment

	UK	Australia	US	Japan	Canada
Health system expenditure per person with sight loss per year (2008 £)					
Inpatient	336	899	3,342	764	1,121
Outpatient	288	324	1,070	2,651	-
Emergency	-	-	323	-	-
Pharmaceuticals	90	370	2,099	587	422
Optometry	274	328	228	-	2,609
Residential care	173	178	201	165	333
Eye care research	8	64	155	336	28
Community care	-	-	3,299	2,975	519
Other health	47	1,061	2,837	268	1,952
Visual aids	191	656	71	1	228
Total health care system costs (2008 £)	**1,405**	**3,880**	**13,623**	**7,747**	**7,212**
Total health care system costs (2008 US$)	**2,602**	**7,186**	**25,228**	**14,346**	**13,356**

Source: Access Economics, 2004; 2006; 2008a; 2008b; 2009.

As observed from Table 3.1, the annual health care system cost per person with sight loss differs markedly between the five countries and is substantially lower for the UK. Reasons for this would include differences in ophthalmology practice and the unit costs of health care services. However, each country report used somewhat different cost of illness methods according to the format and availability of health care and financial data for that country. The lower UK cost is therefore likely to be due in part to the specific methodology and data used in the UK study.

Regarding the impact of these cost differences on the current global study, a key reason for combining data from the five countries is to reduce inter-country variability and more accurately estimate a relationship between direct cost and GDP that can be applied to all regions. The UK cost (which is notably lower than the other four countries) receives only a 21% weighting when calculating the average ratio of direct cost to GDP per capita (see Table 3.2).

3.2 Imputed direct costs

Total health care system costs per person with VI were derived from five countries where data were available (Table 3.1) with other countries' costs imputed using the method proposed by Wimo et al (2006).

As described above, health care expenditure per person as a proportion of GDP per capita is assumed similar between countries. GDP per capita were obtained from the International Monetary Fund (IMF) World Economic Outlook (IMF, 2009)[3]. The most recent GDP per capita

[3] To estimate GDP per capita in the Channel Islands, GDP per capita in 2005 (the most recent year of data) for Jersey and Guernsey were weighted by the relative population sizes for both Islands (CIA 2009)

pertained to 2008 for almost all countries, fitting with the price year used in this study. Where only reported for an earlier year, GDP per capita was inflated to a 2008 estimate using the most recent annual GDP growth (CIA, 2009).

The average health care system cost, GDP per capita, and ratio of these two variables, were calculated over the five countries. These averages were weighted by the prevalence numbers used to calculate per person costs in each country (Access Economics, 2009). The weighted average ratio of health care system cost per person to GDP per capita was 0.372.

Table 3.2: Data used to impute health care system costs in all countries

Key country	Prevalence of VI (000s)	Direct cost per person with VI (2008 US$) (A)	GDP per capita in 2008 (2008 US$) (B)	A ÷ B
UK	1,770	2,602	36,700	0.071
Australia	480	7,186	38,200	0.188
US	3,560	25,228	47,500	0.531
Japan	1,640	14,346	34,100	0.421
Canada	820	13,356	39,200	0.341
Average weighted by prevalence		16,003	41,168	0.372

Source: Access Economics, 2009; IMF, 2009; Access Economics calculations.

For Australia, Canada, Japan, UK and US actual reported health care system costs were applied in the model. For other countries, GDP per capita was multiplied by 0.372 to impute the annual health care system cost per person with VI. A summary of imputed health care system costs per person is presented by subregion in Table 3.3.[4]

Table 3.3: Imputed health care system costs per person with visual impairment

WHO subregion	Health care system cost per person (2008 US$)
AFR-D	1,115
AFR-E	963
AMR-A	23,421
AMR-B	4,365
AMR-D	2,321
EMR-B	5,422
EMR-D	1,236
EUR-A	11,359
EUR-B1	4,913
EUR-B2	1,583
EUR-C	5,182

[4] Average costs are weighted by the total population in each country, since prevalence is assumed equivalent for all countries in a subregion. For accuracy, the model calculates all regional costs as the sum of country-specific costs.

WHO subregion	Health care system cost per person (2008 US$)
SEAR-B	1,877
SEAR-D	1,206
WPR-A1	9,621
WPR-A2	14,346
WPR-B1	2,262
WPR-B2	997
WPR-B3	2,284

Source: Access Economics calculations.

3.3 Summary of health care system expenditure

Total health care system expenditure on VI is the product of the number of people with VI (Table 2.12) and the health care cost per person with VI (Table 3.3). Total expenditures by WHO subregion are presented in Table 3.4.

> Total health care expenditure associated with VI is forecast to increase from $2.30 trillion in 2010 to $2.77 trillion in 2020.

Total expenditures in the subregions of AMR-A, EUR-A and WPR-B1 are particularly high. The average health care cost per person in AMR-A is almost twice as high as any other region, driven by the relatively high cost of VI per person as estimated in the US burden of disease study (Access Economics, 2006; 2009).

Table 3.4: Total health care system expenditure for visual impairment due to all causes (2008 US$)

WHO subregion	Health care system cost per person with VI ($)	Health care costs in 2010 ($ billion)	Health care costs in 2015 ($ billion)	Health care costs in 2020 ($ billion)
AFR-D	1,115	43.8	50.8	58.9
AFR-E	963	42.3	48.0	54.4
AMR-A	23,421	512.8	553.6	588.4
AMR-B	4,365	164.4	187.0	210.0
AMR-D	2,321	15.6	17.8	20.2
EMR-B	5,422	80.4	95.7	114.6
EMR-D	1,236	51.4	60.1	70.1
EUR-A	11,359	355.9	373.7	389.8
EUR-B1	4,913	54.6	57.4	60.2
EUR-B2	1,583	4.6	5.2	5.7
EUR-C	5,182	95.7	96.7	96.0
SEAR-B	1,877	66.3	76.3	87.1
SEAR-D	1,206	251.5	288.8	329.7

WHO subregion	Health care system cost per person with VI ($)	Health care costs in 2010 ($ billion)	Health care costs in 2015 ($ billion)	Health care costs in 2020 ($ billion)
WPR-A1	9,621	11.0	12.3	13.4
WPR-A2	14,346	84.1	86.2	88.3
WPR-B1	2,262	437.5	484.4	539.5
WPR-B2	997	9.9	11.9	13.9
WPR-B3	2,284	20.2	23.4	26.9
World		2,302.2	2,529.3	2,767.3

Source: Access Economics calculations.

Table 3.5 presents the total expenditures by WHO subregion for VI due to all causes excluding URE, and Table 3.6 presents the total expenditures by WHO subregion for VI due to AMD. The direct health care system expenditures for these causes of VI were separated out using the methods described in Section 2.3.

Table 3.5: Total health care system expenditure for visual impairment due to all causes excluding URE (2008 US$)

WHO subregion	Health care system cost per person with VI ($)	Health care costs in 2010 ($ billion)	Health care costs in 2015 ($ billion)	Health care costs in 2020 ($ billion)
AFR-D	1,115	32.5	37.7	43.8
AFR-E	963	31.4	35.7	40.5
AMR-A	23,421	195.8	212.6	226.9
AMR-B	4,365	90.9	103.6	116.6
AMR-D	2,321	8.7	10.1	11.5
EMR-B	5,422	54.9	66.1	80.1
EMR-D	1,236	37.4	43.9	51.5
EUR-A	11,359	159.2	168.3	176.6
EUR-B1	4,913	29.1	30.9	32.8
EUR-B2	1,583	2.3	2.6	3.0
EUR-C	5,182	56.4	57.5	57.2
SEAR-B	1,877	45.9	53.8	62.2
SEAR-D	1,206	89.6	102.8	117.3
WPR-A1	9,621	6.5	7.3	7.9
WPR-A2	14,346	49.4	50.6	51.7
WPR-B1	2,262	149.5	171.7	198.7
WPR-B2	997	6.5	7.9	9.5
WPR-B3	2,284	11.3	13.3	15.5
World		1,057.4	1,176.4	1,303.4

Source: Access Economics calculations.

Table 3.6: Total health care system expenditure for visual impairment due to AMD (2008 US$)

WHO subregion	Health care system cost per person with VI ($)	Health care costs in 2010 ($ billion)	Health care costs in 2015 ($ billion)	Health care costs in 2020 ($ billion)
AFR-D	1,115	0.0	0.0	0.0
AFR-E	963	0.0	0.0	0.0
AMR-A	23,421	97.9	106.3	113.4
AMR-B	4,365	4.5	5.2	5.8
AMR-D	2,321	0.3	0.4	0.5
EMR-B	5,422	1.6	2.0	2.4
EMR-D	1,236	0.7	0.9	1.0
EUR-A	11,359	79.6	84.1	88.3
EUR-B1	4,913	4.4	4.6	4.9
EUR-B2	1,583	0.3	0.4	0.4
EUR-C	5,182	8.5	8.6	8.6
SEAR-B	1,877	1.4	1.6	1.9
SEAR-D	1,206	4.5	5.1	5.9
WPR-A1	9,621	3.3	3.6	3.9
WPR-A2	14,346	24.7	25.3	25.9
WPR-B1	2,262	22.4	25.8	29.8
WPR-B2	997	0.3	0.4	0.5
WPR-B3	2,284	0.3	0.4	0.5
World		254.8	274.8	293.7

Source: Access Economics calculations.

4 Indirect costs

This chapter investigates the indirect costs of VI. These costs do not relate to the direct health care system costs, but are indirectly associated with sight loss rather than with treatment. Indirect costs examined within this chapter include:

- productivity losses from reduced labour market participation through lower employment, greater absenteeism, and premature mortality associated with low vision and blindness;
- costs to informal carers from providing care to someone with low vision and blindness; and
- deadweight loss associated with raising additional tax revenue to publicly fund health care services and direct payments to people with low vision and blindness.

When evaluating indirect costs, it is important to make the distinction between real costs and transfer payments. A real cost is incurred when economic resources are used in the production of goods and services, such as land, labour and capital. Using resources in one area of the economy reduces the opportunity to produce goods and services in other areas of the economy. Transfer payments are payments from one economic agent to another that are made without receiving any good or service in return. Examples of transfer payments include taxes, subsidies, and pensions. In the context of this study, transfer payments could include living allowances and other direct payments provided to visually impaired people by government. Transfer payments could also include taxation paid by society to government to be used for funding health care for the visually impaired.

As transfer payments do not represent a real economic cost they have not been presented as an economic cost within this report. However, the proportion of health care costs funded by government (i.e. via taxation) has been calculated in order to estimate the associated deadweight loss to the economy.

4.1 Productivity losses

Sight loss can impact on economic productivity through three primary channels. These include:

- reduced productivity per worker due to the impacts of sight loss on the ability to undertake work;
- a temporary reduction in the size of the labour force (total number of hours worked) due to absenteeism associated with partial sight and blindness; and
- a permanent reduction in the size of the labour force due to premature retirement and premature mortality within working age due to partial sight and blindness.

Total labour productivity is typically lower for people with partial sight and blindness. However, a loss in productivity of an individual due to sight loss will only equate to a loss in productivity to the economy under fairly strict conditions. These are:

- the economy is at full employment so any reduction in hours worked due to sight loss, or any permanent reduction in labour force participation through early retirement or death, cannot be replaced by employing or increasing hours of other workers; and
- the income of an individual is proportional to the total value added to production.

The first condition will fluctuate over time as the economy moves into, and out of, full employment. A reduction in labour when labour is scarce will have a greater impact on productivity compared to an economy with an abundant labour supply. In this situation, a temporary or permanent reduction in working hours due to partial sight and blindness cannot be replaced by another worker. Consequently, a loss in productivity due to VI is expected to represent a real cost to an economy operating at a low level of unemployment.

The second condition will occur if there is a perfect labour market such that the marginal benefit from an additional hour of work (the value added) is equal to the marginal cost (the wage). In reality, labour markets are imperfect for a number of reasons, for example asymmetric information in the market, and labour market restrictions imposed by government regulation and natural barriers. In addition, synergy created between labour, capital and land means a reduction in working hours may also impact the productivity of other factors of production. Consequently the value of productivity from labour will be larger than the wage provided to an individual so using lost income from partial sight and blindness as a proxy for lost productivity will tend to underestimate the true cost. It is likely that in the absence of sight loss, people with VI would participate in the labor force and obtain employment at the same rate and average weekly earnings as others. The implicit assumption is that the numbers of such people would not be of sufficient magnitude to substantially influence the overall clearing of global labour markets, and average wages remain the same.

Productivity losses can be measured using the human capital approach or the frictional approach. The former assumes the worker is not replaced, which means the total productive value (or income) from the loss in employment is counted as an indirect cost. This approach is the most consistent with the first condition above.

The frictional approach assumes the production loss is only incurred while looking for a replacement worker (the friction period) and there is a cost in filling a vacancy and training new personnel.

In this study, the human capital approach is used to estimate the productivity loss associated with VI for industrialised WHO regions. It is assumed that countries within the 'developed' WHO subregions AMR-A, EUR-A, EUR-B1, EUR-B2, EUR-C, WPR-A1, and WPR-A2 are operating at sufficiently low unemployment to incur a permanent loss in productivity. For these subregions, productivity losses due to disability and premature death from VI are estimated separately.

For high and low mortality in developing WHO subregions, it is assumed that a relatively large pool of unemployed people and a low skilled labour force enable workers to be easily replaced at low cost. Hence, productivity costs for developing subregions will be negligible and have not been included in this study. This approach is more conservative than previous studies of global productivity loss due to VI (Frick and Foster, 2003; Smith and Smith, 1996; Smith et al, 2009). However, as described below, those studies necessarily had to make unsupported assumptions regarding lost productivity in countries where there are scarce employment data for the visually impaired.

4.1.1 Productivity losses due to disability

The productivity loss due to disability is dependent on a number of factors:

- the likelihood of someone with that disability being employed;
- the likelihood of someone with that disability needing time off work; and
- the value of lost production.

In this study, it is assumed that someone with VI is just as likely to have been employed in the absence of their condition. That is, being susceptible to developing VI does not mean a lower chance of employment. However, on becoming visually impaired there is a likelihood of needing time off work due to that disability.

For each country in the model, the likelihood of employment was estimated as the country's employment-to-population ratio (UN, 2010). This ratio is only reported by the UN for people aged 15-24 years or 25 years and older in each country. The ratio for people aged 15 years and older was applied to that age group in each country.

Calculation of productivity losses for each country is restricted to people aged 15-64 years. This was necessary since the age groups in this study include 15-19 years and data for people aged 18-19 years could not be disaggregated from this group. This approach is consistent with the age group for which the employment-to-population ratio is reported.

The upper age limit for the employment-to-population ratio varies between countries but is not explicit and is imposed infrequently (UN, 2010). Applying this ratio to people aged 15-64 years may slightly underestimate productivity losses in countries where the ratio is calculated on a wider age group (employment may be considerably lower for people aged less than 15 years and higher than 64 years). The employment-to-population ratio was set to zero for countries where not reported. The Channel Islands was the only country in a developed subregion with no reported ratio (population 149,000 in 2010). Therefore, underestimation of productivity losses due to missing ratios will be negligible.

The likelihood of someone with VI needing time off work was proxied by the relative reduction in employment with VI (the 'employment gap'). These estimates were derived from previous country studies of productivity losses due to VI (Access Economics, 2004; 2006; 2008a; 2008b; 2009) as summarised in Table 4.1. Given the disparities in the definition of VI between these five country studies, productivity losses are only calculated for people with moderate VI or blindness.

Table 4.1: International employment gaps due to visual impairment

Country and population	Employment in people with VI (A)	Employment in people without VI (B)	Employment gap (1 – [A ÷ B])	VI definition
Australia				
40-65 years	34.5%	62.0%	44.4%	VA < 6/12
Canada				

Country and population	Employment in people with VI (A)	Employment in people without VI (B)	Employment gap (1 – [A ÷ B])	VI definition
Working age	32.0%	60.4%	47.0%	"Seeing disability" as defined in the Participation and Activity Limitations Survey
Japan				
Working age	50.4%	68.8%	26.7%	Minimum classification of visual disability is "visual acuity of one eye is 0.02 or less and visual acuity of the other eye is 0.6 or less, and the sum of visual acuity of both eyes is 0.2 or more" (JEED 2008)
United Kingdom				
Working age			22.5%	"Seeing difficulty"
United States				
25-44 years	78.9%	81.3%	3.0%	Self-assessed low vision and legal blindness
45-61 years	61.6%	73.2%	15.8%	

Source: Access Economics, 2004; 2006; 2008a; 2008b; 2009.

In the absence of additional data, the employment gap for each developed subregion was extrapolated from country data. Employment gaps for Australia and Japan were applied to subregions WPR-A1 and WPR-A2, respectively. US data are less reliable, being derived from surveys measuring self-reported 'bad, blurred, defective, limited, poor, double, problem with, trouble with' eyesight (Access Economics, 2006). Therefore, the employment gap for AMR-A was derived from a Canada study (Access Economics, 2008b) where VI was defined as for the Australia and Japan studies.

This approach differs from other published methods. Frick and Foster (2003) and Smith et al (2009) used the disability weight for each severity of VI (see Section 5.1) to proxy the proportion of productive time lost due to VI. For example, blindness was assumed to impose a 60% productivity loss based on the disability weight being 0.6 (Lopez et al, 2006). Smith and Smith (1996) applied a productivity loss equivalent to annual Gross National Product per capita to all blind people. This method implies that blind people do not contribute to GNP and there is zero employment among the blind. These methods are arbitrary and less well supported than the approach in this study.

Additional employment data for the visually impaired was identified from a South Korea survey (Lee and Park, 2008). In 2004, employment among the visually impaired (defined by South

Korean government disability criteria) was 33%. Unfortunately, this study was uncontrolled and the employment gap could not be estimated. However, OECD data for 2004 showing an employment-to-population ratio of 69% imply the relative reduction in employment may be around 52%[5]. This suggests the approach in this study may be conservative, unless different employment patterns in South Korea cause VI to have greater impact on the labour force.

In the absence of comprehensive international wage data, GDP per capita was used to proxy the annual production loss for people unemployed due to VI. GDP per capita represents the average value of output per year for an employed person. Someone unemployed due to VI is assumed unemployed for the entire year, consistent with the assignment of other impacts of prevalent VI over a full year.

Total productivity losses due to VI were calculated for each subregion as the product of:

- the number of people aged 15-64 years with moderate VI or blindness;
- GDP per capita in 2008 or the most recent year of data;
- the employment-to-population ratio; and
- the relative reduction in employment for people with VI (employment gap).

Productivity losses due to disability from VI are presented in Table 4.2. The total productivity loss for the seven developed subregions increases from $167 billion in 2010 to $176 billion in 2020.

In comparison, Smith et al (2009) estimated the global productivity loss due to URE alone to be $268 billion in 2007. A lower productivity loss is estimated for this study even when accounting for VI (VA < 6/18) due to all causes. This is primarily due to productivity losses only being calculated for seven regions in this study. These regions do not include SEAR-D and WPR-B1, where the burden of VI due to URE is substantially higher (Smith et al, 2009). Other methodological differences also contribute to the lower estimate. For example, Smith et al (2009) assumed a 60% productivity loss for blind people, where this study uses a (lower) relative reduction in employment based on actual data.

Table 4.2: Productivity losses due to absenteeism from visual impairment due to all causes

WHO subregion	Weighted GDP per capita	Employ-ment to population ratio (%)	Relative reduction in employ-ment with VI (%)	Productivity loss in 2010 ($ billion)	Productivity loss in 2015 ($ billion)	Productivity loss in 2020 ($ billion)
AMR-A	45,557	59.3	47.0	96.8	102.1	104.3
EUR-A	34,662	51.1	22.5	40.0	41.1	42.2
EUR-B1	13,208	45.9	22.5	5.6	5.8	5.9
EUR-B2	4,256	56.5	22.5	0.6	0.7	0.8
EUR-C	13,933	55.4	22.5	11.6	11.6	11.0
WPR-A1	39,055	60.3	44.4	4.2	4.5	4.7

[5] The figure may be greater, since the general population includes the visually impaired

WHO subregion	Weighted GDP per capita	Employ-ment to population ratio (%)	Relative reduction in employ-ment with VI (%)	Productivity loss in 2010 ($ billion)	Productivity loss in 2015 ($ billion)	Productivity loss in 2020 ($ billion)
WPR-A2	34,100	54.2	26.7	8.4	7.7	7.6
World				167.2	173.6	176.4

Source: Access Economics calculations.

Productivity losses relating to absenteeism due to VI are presented in Table 4.3 for all causes excluding URE. The global productivity loss ranges from $76 billion in 2010 to $81 billion in 2020.

Table 4.3: Productivity losses due to absenteeism from visual impairment due to all causes excluding URE

WHO subregion	Weighted GDP per capita	Employ-ment to population ratio (%)	Relative reduction in employ-ment with VI (%)	Productivity loss in 2010 ($ billion)	Productivity loss in 2015 ($ billion)	Productivity loss in 2020 ($ billion)
AMR-A	45,557	59.3	47.0	39.7	42.0	42.9
EUR-A	34,662	51.1	22.5	18.4	19.1	19.7
EUR-B1	13,208	45.9	22.5	3.1	3.2	3.3
EUR-B2	4,256	56.5	22.5	0.3	0.4	0.4
EUR-C	13,933	55.4	22.5	6.9	7.0	6.6
WPR-A1	39,055	60.3	44.4	2.6	2.8	2.9
WPR-A2	34,100	54.2	26.7	5.3	4.9	4.8
World				76.3	79.4	80.6

Source: Access Economics calculations.

Productivity losses relating to absenteeism are presented in Table 4.4 for VI due to AMD. The global productivity loss ranges from $34 billion in 2010 to $36 billion in 2020. As reported in Table 2.7, AMD is a major cause of VI in developed regions, contributing towards half of all VI cases in regions AMR-A, EUR-A, and WPR-A1. This is reflected in Table 4.4 as productivity losses due to AMD constitute half of all productivity losses due to causes other than URE in those regions (Table 4.3).

Table 4.4: Productivity losses due to absenteeism from visual impairment due to AMD

WHO subregion	Weighted GDP per capita	Employ-ment to population ratio (%)	Relative reduction in employ-ment with VI (%)	Productivity loss in 2010 ($ billion)	Productivity loss in 2015 ($ billion)	Productivity loss in 2020 ($ billion)
AMR-A	45,557	59.3	47.0	19.83	20.98	21.43

WHO subregion	Weighted GDP per capita	Employ-ment to population ratio (%)	Relative reduction in employ-ment with VI (%)	Productivity loss in 2010 ($ billion)	Productivity loss in 2015 ($ billion)	Productivity loss in 2020 ($ billion)
EUR-A	34,662	51.1	22.5	9.21	9.54	9.84
EUR-B1	13,208	45.9	22.5	0.05	0.06	0.06
EUR-B2	4,256	56.5	22.5	0.05	0.06	0.06
EUR-C	13,933	55.4	22.5	1.04	1.06	1.00
WPR-A1	39,055	60.3	44.4	1.32	1.42	1.47
WPR-A2	34,100	54.2	26.7	2.64	2.43	2.38
World				34.13	35.54	36.24

Source: Access Economics calculations.

4.1.2 Productivity losses due to premature mortality

There is evidence of higher mortality for people with VI due to falls, fractures, depression, and accidents (e.g. driving). However, only a proportion of these deaths are due to VI rather than associated comorbidities. A future stream of productivity losses is incurred due to deaths from VI within a year. The number of deaths each year due to VI is estimated using the following data:

- the number of visually impaired people in that year;
- the probability of death in the general population;
- the relative risk of death in the visually impaired; and
- the etiological fraction (proportion of additional deaths attributed to VI rather than any comorbidity).

As described below, the relative mortality risk was evaluated from studies in people with VA less than 6/12. Therefore, all people with VI in the model are subject to an increased risk of death. For the calculation of productivity losses this means that while mild VI is not assumed to impact employment (see Section 4.1.1) a loss is incurred from death due to VI.

Probabilities of death in the general population were derived from 2006 life tables for WHO member states (WHO, 2006). These life tables report the probability of dying in a year by age and gender (variable nQx). For countries without life tables, proxy tables were based on the geographically closest country in the same WHO subregion having equivalent or very similar life expectancy.

In estimating the increased risk of mortality with VI, it is important to control for age and gender (Anstey et al, 2001; Globe et al, 2005). Klein et al (1995) reported that people with specific vision conditions had an increased mortality risk of 1.57 times for the presence of sight loss and of 1.28 times for any cataract. However, when accounting for the presence of cardiovascular disease none of the conditions causing sight loss showed a statistically significant odds ratio for decreased survival.

An improved level of statistical control was achieved in the Melbourne Visual Impairment Project (MVIP) where partial sight and blindness was found to be significantly associated with an increased mortality risk of 2.34 times (McCarty et al, 2001). The result accounted for the confounding presence of age and age-related comorbidities, such as basic cardiac risk factors. Similarly, Wang et al (2001) report an increased mortality risk of 1.7 times with the presence of any sight loss. Their analysis accounted for comorbidities such as a history of cancer, stroke, gout and diabetes, some of which result from basic cardiovascular risk factors such as hyperlipidemia and hypertension.

Following previous international Access Economics studies on the burden of disease for VI, the increased risk of death in the visually impaired was derived from the MVIP and Australian mortality data (Access Economics, 2004; 2006; 2008a; 2008b; 2009). Using MVIP data, the odds ratio of mortality for the visually impaired (VA < 6/12) is estimated to be 2.34 (95% confidence interval: 1.03-5.32) times the average, based on approximately five years' follow-up for urban participants (McCarty et al, 2001) and after standardising for age, male sex, smoking duration, duration of high blood pressure and arthritis. As described in the Japanese burden of disease study this converts to a relative risk of 2.15 (Access Economics, 2008a).

As detailed above, incremental deaths of the visually impaired are not all due to VI but also due to comorbidities. An etiological fraction (proportion of the higher number of deaths due to VI itself) of 0.83% has previously been estimated using Australian Bureau of Statistics (ABS) mortality data. This fraction was applied in previous international burden of disease studies (Access Economics, 2004; 2006; 2008a; 2008b; 2009). The etiological fraction was updated using 2007 ABS data (ABS, 2009). These data show a ratio of 136.5:1 between multiple and underlying causes for 'diseases of the eye and adnexa'. In 2007, there were 546 Australians who had eye disease as one of multiple causes of death, and 4 Australians having eye disease as the underlying cause of death. The etiological fraction thus derived for this study is 0.73% (i.e. where people die who have eye disease as a contributing cause of death, 0.73% of those deaths can be said to be caused by the eye disease). Factors that combine with VI to cause death include conditions such as osteoporosis, events such as falls or motor vehicle accidents, and risk factors such as poor light or roads.

Productivity losses due to premature mortality were restricted to people who die between the ages of 15 and 65 years, consistent with the calculation of productivity losses due to disability (see Section 4.1.1). The productivity loss, or future stream of lost output, is also related to life expectancy. However, in all developed countries, average life expectancy exceeds 65 years (UN, 2009). Therefore, in this study the productivity losses due to death are based only on the expected retirement age and life expectancy.

The size of the annual production loss was valued using the annual GDP per capita as detailed in Section 4.1.1. It is important to discount future streams of costs and benefits when expressing results for a specific year (present value). For cost effectiveness studies, there have been numerous international debates regarding both the discount rate and whether the same rate should be applied to both costs and health benefits (Drummond et al, 2005). For this study, which does not synthesise economic costs and DALYs, the issue of differential discount rates for both costs and benefits is not considered relevant. Given the global scope of this study, and the need to compare results for different regions, it is proposed that the same discount rate be used for all regions. The discount rate was set to 3%, with sensitivity analysis performed for the range 0% to 10% (see Section 6), following the advice of the US Panel on Cost effectiveness (Lipscomb et al, 1996) and Drummond et al (2005).

Finally, productivity losses due to premature mortality are adjusted by the likelihood that someone with VI is employed. This is estimated as the difference between the employment-to-population ratio with and without an adjustment for the relative reduction in employment due to VI.

Productivity losses relating to premature mortality due to VI are presented in Table 4.5, and the global estimate ranges from $1.11 billion in 2010 to $1.14 billion in 2020. These productivity losses account for the future stream of forgone employment due to death, but are substantially lower than productivity losses due to absenteeism given the low attributable mortality risk. Although the risk of death in the visually impaired is 2.63 times that of the general population, only 0.73% of the additional deaths are attributed to VI in the model. Furthermore, general mortality is lower in developed countries, and the greatest additional risk of death due to VI is therefore experienced by those people aged over 65 years to whom productivity losses are not applied.

Table 4.5: Productivity losses due to premature mortality from visual impairment due to all causes

WHO subregion	Weighted GDP per capita	Employment in people with VI (%)	Productivity loss in 2010 ($ million)	Productivity loss in 2015 ($ million)	Productivity loss in 2020 ($ million)
AMR-A	45,557	31.4	324.9	342.8	346.2
EUR-A	34,662	39.6	313.8	329.4	341.1
EUR-B1	13,208	35.5	75.8	77.5	78.7
EUR-B2	4,256	43.7	12.2	14.7	15.9
EUR-C	13,933	42.9	329.7	329.5	307.9
WPR-A1	39,055	33.5	10.3	11.3	11.6
WPR-A2	34,100	39.7	45.1	42.0	42.2
World			1,111.9	1,147.1	1,143.6

Source: Access Economics calculations.

Productivity losses relating to premature mortality due to VI are presented in Table 4.6 for all causes excluding URE. The global productivity loss ranges from $551.7 million in 2010 to $564.1 million in 2020.

Table 4.6: Productivity losses due to premature mortality from visual impairment due to all causes excluding URE

WHO subregion	Weighted GDP per capita	Employment in people with VI (%)	Productivity loss in 2010 ($ million)	Productivity loss in 2015 ($ million)	Productivity loss in 2020 ($ million)
AMR-A	45,557	31.4	128.8	136.3	137.6
EUR-A	34,662	39.6	144.2	152.1	158.3
EUR-B1	13,208	35.5	43.4	44.4	45.0
EUR-B2	4,256	43.7	6.6	8.2	8.9
EUR-C	13,933	42.9	195.8	196.7	182.4
WPR-A1	39,055	33.5	6.2	6.7	6.9
WPR-A2	34,100	39.7	26.7	24.9	25.0

WHO subregion	Weighted GDP per capita	Employment in people with VI (%)	Productivity loss in 2010 ($ million)	Productivity loss in 2015 ($ million)	Productivity loss in 2020 ($ million)
World			551.7	569.3	564.1

Source: Access Economics calculations.

Productivity losses relating to premature mortality due to VI are presented in Table 4.7 for VI caused by AMD. The global productivity loss ranges from $184.3 million in 2010 to $193.9 million in 2020. It should be noted that the mortality risk used in the model is associated only with the severity of VI rather than the cause of VI. As reported in Table 2.7, AMD is a major cause of VI in developed regions, contributing towards half of all VI cases in regions AMR-A, EUR-A, and WPR-A1. This is reflected in Table 4.7, where productivity losses for VI caused by AMD constitute half of all productivity losses for VI due to causes other than URE in those regions (Table 4.6).

Table 4.7: Productivity losses due to premature mortality from visual impairment due to AMD

WHO subregion	Weighted GDP per capita	Employment in people with VI (%)	Productivity loss in 2010 ($ million)	Productivity loss in 2015 ($ million)	Productivity loss in 2020 ($ million)
AMR-A	45,557	31.4	64.4	68.2	68.8
EUR-A	34,662	39.6	72.1	76.1	79.1
EUR-B1	13,208	35.5	1.0	1.2	1.3
EUR-B2	4,256	43.7	1.0	1.2	1.3
EUR-C	13,933	42.9	29.4	29.5	27.4
WPR-A1	39,055	33.5	3.1	3.3	3.5
WPR-A2	34,100	39.7	13.3	12.4	12.5
World			184.3	192.0	193.9

Source: Access Economics calculations.

4.2 Informal care costs

Informal care is the provision of home care to another person without receiving pay (although some informal carers may receive a government allowance). Most commonly informal care is the provision of care by a family member, friend, neighbour or community member.

The level of informal care associated with sight loss depends on whether the person is able to live independently while maintaining an appropriate quality of life. Using UK data, Stevenson et al (2004) showed that the ability for a person with sight loss to care for themselves is adversely influenced by sight loss. In a study of individuals with AMD recruited through a hospital eye clinic in Northern Ireland, Ke et al (2007) found that the level of formal and informal care services utilised by an individual depends on the level of VA in the better eye, the age of the individual, and the level of access to informal care, for example, whether the person lives alone or not. Studies in Australia and the US have also found a positive relationship

between the level of informal care and the prevalence of partial sight and blindness (Wang et al, 1999; Schmier et al, 2006).

In order to estimate the total cost of informal care, the time spent providing care to people with sight loss is required along with a monetary figure representing the value of informal care. It is difficult to separate the level of informal care provided due to partial sight and blindness when the person receiving care has comorbidities that also require informal care. For example, a person may receive informal care for dementia and sight loss at the same time.

This study includes the value of informal care time for people with VI. However, it is recognised that there are further significant costs in addition to the value of lost time. For example, Carmichael and Charles (2003) note that informal carers in the UK also forgo significant earnings because they have less opportunity to undertake higher paid employment and therefore earn less than equally qualified non-carers. This is because informal carers require more flexible working arrangements, which make them less likely to be promoted. These additional costs are strongly associated with local labour market conditions and difficult to estimate from a global perspective.

In estimating a monetary value of informal care, two main methodologies can be used – the replacement cost method and the opportunity cost method[6].

The replacement cost method measures the cost of substituting informal care for formal care services. That is, it values the output of production (van den Berg et al, 2006). Thus, the number of hours providing informal care to people with sight loss is multiplied by the cost of providing care from the formal care sector (which is deemed a close substitute). The cost of formal care will depend on the level of sight loss and any co-morbidities the person may have as greater demands are placed on carers as a person's level of disability increases.

There are several reasons why the replacement cost method may overestimate the value of informal care. The method assumes the person receiving care, or society, is willing to pay for the services typically provided by a family or friend. Due to budget constraints faced by individuals and community service funders this may not be the case. Furthermore, the replacement cost method does not consider any differences in the quality of care and will overestimate the value of informal care if formal care is of a higher quality. Also, the time spent on providing formal care may be different from the time forgone by an informal carer if a formal carer is more efficient. Conversely, if the informal carer receives utility from providing care, then the replacement cost method could potentially underestimate the value of informal care.

The opportunity cost method measures the value in alternative use of time spent caring, which is typically valued by productivity losses (or value of leisure time) associated with caring. This is based on the assumption that time spent providing informal care could be alternatively used within the paid workforce or in leisure activities. The value of informal care using the opportunity cost method can be represented by:

Value of informal care = $t_i w_i$

[6] A third methodology known as the self-valuation method is seldom used due to the inherent bias associated with the value people place on the services they provide.

where t_i is the time provided by individual *i* on providing care and w_i is the net market wage rate of individual *i* (van den Berg et al, 2006). For those who provide informal care but are not in paid work (for example, children or those who have retired) the value of providing informal care is the value of the lost opportunity of undertaking leisure time. This can be approximated by the willingness to pay to undertake leisure, or to avoid work. Therefore, the value of leisure time is often proxied by an average age and sex specific wage rate (Brouwer and Koopmanschap, 2000; Heitmueller, 2007). If the value of non-work is more (or less) than the average wage rate, the opportunity cost method will under (or over) estimate the value of informal care.

The replacement cost method and the opportunity cost method differ conceptually. The former values outputs while the latter values inputs. From a theoretical perspective, the opportunity cost method is the benchmark (van den Berg et al, 2006). For this study, the opportunity cost method is preferred from a practical perspective since international employment data and GDPs per capita (a substitute for annual average salary) are more readily available than international data on formal care costs for the visually impaired. The opportunity cost method for the current global study is described below.

4.2.1 Opportunity cost method of informal care

Estimation of the global costs of informal care due to VI is problematic given the lack of data in many countries on hours of care provided to the visually impaired and wage rates. Smith et al (2009) assumed that every person with VI requires some care from an adult with normal sight, who thus loses productive time to that individual. The authors assumed a 10% productivity loss for the care of each person with blindness and a 5% productivity loss for the care of each person with moderate or severe VI. These productivity losses were based on unsupported assumptions made in an economic study of blindness in India (Shamanna et al, 1998). A similar arbitrary approach was not considered appropriate for this study.

Wimo et al (2007) propose a more complex opportunity cost method based on production losses, assigning a fixed number of hours of care per day to people with dementia in all countries. Wimo et al (2007) calculated informal care costs for each country using the estimated proportion of people with dementia living at home, the proportion of carers of working age, and the average wage rate. A major limitation of this approach is that no inter-country variation is assumed in the number of informal care hours per patient. In reality, the level of informal care provided will partly depend on the availability of formal home and residential care services, as well as cultural factors such as extended family cohesion.

The opportunity cost method developed for this study utilises all available and relevant data in previous burden of disease studies for VI (Access Economics, 2004; 2006; 2008a; 2008b; 2009). However, the global scope of this study and a lack of detailed informal care data for many countries necessitates that plausible assumptions be consistently applied across all countries and WHO subregions.

Studies undertaken for Australia and the UK provide useful data for imputing informal care costs in other countries (Access Economics, 2009). Informal care costs in Australia and the UK were assessed through surveys. In other countries, formal/paid care could not be reliably separated from informal care as required to avoid double-counting direct (paid carer) and indirect (informal care) costs (Access Economics, 2004; 2006; 2008a; 2008b).

As explained above, the annual informal care cost in any country is defined as the value of the total hours spent in caring. Therefore, relative to the informal care costs in Australia and the UK, the informal care costs in other countries were imputed using:

- the number of annual informal carer hours in Australia and the UK;
- relative number of hours spent caring;
- the hourly wage rate in the UK; and
- the relative wage in other countries.

In this study, informal carer time is assumed to only be required by people with moderate VI or blindness. Access Economics (2009) estimated the total informal care cost in the UK to be £2.0 billion based on an average hourly wage of £11 and 1.8 million people with VI. This computes to an average of 102 informal care hours per person with VI in the UK. Keeffe et al (2009) estimated an average of 152 hours caregiver time per person visually impaired in Australia.

The relative number of hours of informal care was assumed to be associated with the availability of formal care services. The most extensively reported indicator of formal care services relevant to people with VI is the 'community and traditional health workers density (per 1000 population)' index (WHO, 2010). This index was used to estimate the number of informal care hours in all countries based on the UK and Australia data. The WHO (2010) reports Australia and the UK densities of 0.2 and 8.43 workers, respectively, per 1,000 population. The Australian index pertains to 2001 and is higher than the 2006 index (0.05). However, the lower index may be due to incomplete data.

It should be noted that both the UK and Australian studies (Access Economics, 2009; Keefe et al, 2009) were to some degree based on relatively elderly samples. The UK informal care requirement was calculated by applying the proportion of formal care activity due to VI in people 65 years and older to informal care hours for all ages. The Australian data were derived from a sample with an average age of 66.5 years. In the absence of further data, the current study assumes the number of carer hours to be similar for all people with VI. The potential overestimation of informal care costs in the total population is expected to be low given other findings in the literature. For example, a US study of people aged 70 years and older found those with VI required an additional 15 hours informal care per week (Shih and Lustig, 2002). This equates to over 500 hours per year, far exceeding the UK and Australia estimates.

Informal care hours for other countries were imputed using a power function derived from the carer hours and index for Australia and the UK. A power function prevents unreasonably high or negative informal care hours being imputed from index values outside the range 0.2-8.43.

Following the estimation of production losses (Section 4.1), relative differences in wages between countries are proxied by relative differences in GDP per capita. For each country, one hour of informal carer time was valued using the UK wage rate ($20.87 in 2008 US$) adjusted by the ratio of GDP per capita in that country relative to the UK ($36,700 in 2008).

The function used to impute informal care costs per year in all countries is presented below:

$$128 \times \text{care index}^{-0.19} \times \$20.87 \times (\text{GDPPC}_{\text{country A}} \div \$36{,}700)$$

Index data were only available for 62 countries for the period 1992-2009. Conservatively, the highest index over that period was used for each country. Therefore, several assumptions were required for the imputation of global informal care costs.

- The index value for a country with missing data equals the average index value for the WHO subregion.
- No index values were available for subregion AMR-A. Index values for the US and Canada were set to the index for EUR-A to estimate a conservative cost. The index value for Cuba was based on region AMR-B to which Cuba was previously assigned.
- An index value was not available for Japan (subregion WPR-A2). Therefore, the index value for subregion WPR-A1 was assigned.
- No index values were available for countries in subregions WPR-B2 and WPR-B3. Therefore, the index value for subregion WPR-B1 was assigned.
- No index values were available for countries in subregions EUR-B1 and EUR-B2. Therefore, the average index value for subregions EUR-A and EUR-C were assigned due to lower index values being observed for higher mortality strata subregions.

4.2.2 Regional and global costs of informal care for visual impairment

Using the above approach, informal care costs for VI by subregion are reported in Table 4.8. Global informal care costs are projected to increase from $246 billion in 2010 to $302 billion in 2020.

Table 4.8: Informal care costs for people with moderate VI or blindness due to all causes

WHO subregion	Community and traditional health workers density (per 1000 population)	Weighted informal care cost per person ($)	Total informal care cost in 2010 ($ billion)	Total informal care cost in 2015 ($ billion)	Total informal care cost in 2020 ($ billion)
AFR-D	0.58	256	5.8	6.7	7.7
AFR-E	0.29	213	5.3	6.1	6.9
AMR-A	8.43	2,679	30.9	33.3	35.4
AMR-B	0.35	964	19.5	22.2	25.0
AMR-D	0.14	552	2.0	2.3	2.6
EMR-B	0.34	1,185	9.9	11.8	14.2
EMR-D	0.33	272	6.4	7.5	8.8
EUR-A	8.43	2,034	33.6	35.3	36.8
EUR-B1	5.71	808	4.9	5.1	5.4
EUR-B2	5.71	260	0.4	0.5	0.5
EUR-C	3.00	909	9.1	9.2	9.1
SEAR-B	0.16	513	10.4	12.0	13.7
SEAR-D	0.12	309	35.1	40.4	46.1
WPR-A1	1.52	3,129	2.0	2.2	2.4
WPR-A2	1.52	2,380	7.6	7.8	8.0

WHO subregion	Community and traditional health workers density (per 1000 population)	Weighted informal care cost per person ($)	Total informal care cost in 2010 ($ billion)	Total informal care cost in 2015 ($ billion)	Total informal care cost in 2020 ($ billion)
WPR-B1	0.08	570	59.2	65.7	73.3
WPR-B2	0.08	251	1.4	1.7	2.0
WPR-B3	0.08	576	2.8	3.2	3.7
World			246.3	272.9	301.6

Source: Access Economics calculations.

It should be recalled that these costs are the value of time spent by informal carers regardless of whether that time would otherwise have been spent in paid work or leisure. The costs of informal care are relatively high in subregions SEAR-D and WPR-B1, which have the largest populations and relatively low community worker densities (associated with relatively high use of informal care in the model). Subregions EUR-A and AMR-A also have relatively high total costs of informal care, due to the relatively high opportunity cost of informal care time as proxied by differences in GDP per capita and the wage rate.

Table 4.9 presents the informal care costs for VI due to all causes excluding URE. The global informal care costs are projected to increase from $120 billion in 2010 to $151 billion in 2020.

Table 4.9: Informal care costs for people with moderate VI or blindness due to all causes excluding URE

WHO subregion	Community and traditional health workers density (per 1000 population)	Weighted informal care cost per person ($)	Total informal care cost in 2010 ($ billion)	Total informal care cost in 2015 ($ billion)	Total informal care cost in 2020 ($ billion)
AFR-D	0.58	256	4.3	5.0	5.8
AFR-E	0.29	213	4.0	4.6	5.2
AMR-A	8.43	2,679	12.3	13.4	14.3
AMR-B	0.35	964	11.1	12.6	14.2
AMR-D	0.14	552	1.2	1.4	1.6
EMR-B	0.34	1,185	7.0	8.4	10.2
EMR-D	0.33	272	4.8	5.6	6.6
EUR-A	8.43	2,034	15.6	16.5	17.3
EUR-B1	5.71	808	2.7	2.9	3.1
EUR-B2	5.71	260	0.2	0.2	0.3
EUR-C	3.00	909	5.6	5.7	5.6
SEAR-B	0.16	513	7.5	8.7	10.1
SEAR-D	0.12	309	13.2	15.2	17.3

WHO subregion	Community and traditional health workers density (per 1000 population)	Weighted informal care cost per person ($)	Total informal care cost in 2010 ($ billion)	Total informal care cost in 2015 ($ billion)	Total informal care cost in 2020 ($ billion)
WPR-A1	1.52	3,129	1.2	1.3	1.5
WPR-A2	1.52	2,380	4.6	4.8	4.9
WPR-B1	0.08	570	21.8	25.1	29.0
WPR-B2	0.08	251	1.0	1.2	1.4
WPR-B3	0.08	576	1.6	1.9	2.2
World			119.8	134.5	150.6

Source: Access Economics calculations.

Table 4.10 presents the informal care costs for VI due to AMD. The global informal care costs are projected to increase from $23 billion in 2010 to $27 billion in 2020. The informal care costs for AMD were separated out using the methods described in Section 2.3. Comparative regional data were not identified to stratify the numbers of informal care hours by cause of VI.

Table 4.10: Informal care costs for people with moderate VI or blindness due to AMD

WHO subregion	Community and traditional health workers density (per 1000 population)	Weighted informal care cost per person ($)	Total informal care cost in 2010 ($ billion)	Total informal care cost in 2015 ($ billion)	Total informal care cost in 2020 ($ billion)
AFR-D	0.58	256	0.00	0.00	0.00
AFR-E	0.29	213	0.00	0.00	0.00
AMR-A	8.43	2,679	6.16	6.69	7.14
AMR-B	0.35	964	0.55	0.63	0.71
AMR-D	0.14	552	0.05	0.05	0.06
EMR-B	0.34	1,185	0.21	0.25	0.31
EMR-D	0.33	272	0.10	0.11	0.13
EUR-A	8.43	2,034	7.80	8.24	8.65
EUR-B1	5.71	808	0.41	0.43	0.46
EUR-B2	5.71	260	0.03	0.04	0.04
EUR-C	3.00	909	0.83	0.85	0.85
SEAR-B	0.16	513	0.22	0.26	0.30
SEAR-D	0.12	309	0.66	0.76	0.87
WPR-A1	1.52	3,129	0.60	0.67	0.73
WPR-A2	1.52	2,380	2.32	2.38	2.43
WPR-B1	0.08	570	3.27	3.76	4.35
WPR-B2	0.08	251	0.05	0.06	0.07

WHO subregion	Community and traditional health workers density (per 1000 population)	Weighted informal care cost per person ($)	Total informal care cost in 2010 ($ billion)	Total informal care cost in 2015 ($ billion)	Total informal care cost in 2020 ($ billion)
WPR-B3	0.08	576	0.05	0.06	0.07
World			23.32	25.25	27.17

Source: Access Economics calculations.

4.3 Deadweight welfare losses

Public funding of health care system costs and community services related to partial sight and blindness means that governments must increase tax revenue to achieve a budget neutral position. Consequently tax rates must be higher that they would have otherwise been. As noted previously, tax and subsidy revenue is not an economic cost but a transfer of payments from one individual to another. It has therefore not been included in this study. However, increasing tax revenue is not frictionless as tax reduces the efficiency with which the economy's resources are used. For example, an increase in income tax rates will increase the relative price of work compared to leisure and therefore create a disincentive to work. Alternatively an increase in taxes on goods and services results in a loss in sales. Consequently there is an associated reduction in consumer and producer surplus, which is the deadweight welfare loss (DWL), or excess burden, of tax.

The size of the DWL will depend on the method used to raise additional taxes and the proportion of health care costs funded by the government, both of which vary between countries. However, this societal cost is not expected to be zero in any country. The usual assumption in program evaluation, and applied in this study, is that additional taxes are raised through income tax rate changes.

DWL is estimated in the model using the following variables:

- the total health care system cost of VI;
- the proportion of health care system costs funded by government (i.e. through taxation); and
- the marginal cost of public funds (MCPF).

Accounting for regional DWL must account for countries' differing levels and systems of public health care financing. The method used in this study accounts for differences in the proportion of health care costs financed by government. However, the MCPF, or efficiency loss per additional dollar of tax raised, is assumed to be equivalent for all countries in the absence of data (see below).

The total health care system costs of VI are presented in Table 3.1. The proportion of health care system costs funded by government (through the national health care budget) is estimated using the WHO indicator of 'general government expenditure on health as a percentage of all health expenditure' (WHO, 2008). No global data were identified regarding

the proportion of total health care expenditure for VI by government and the indicator for general health expenditure was used as a proxy. Therefore, the proportion of total expenditure on VI coming from governments is implicitly assumed to not be significantly different from the proportion for other diseases. For countries where no indicator was available, the proportion was conservatively set to zero thus excluding the DWL for those countries. The populations of these countries (Aruba, Channel Islands, French Guiana, French Polynesia, Guadeloupe, Guam, Martinique, Mayotte, Netherlands Antilles, New Caledonia, Puerto Rico, Reunion, US Virgin Islands, and Western Sahara) total only 7.9 million in 2010, and thus their exclusion would not substantially impact regional DWL estimates.

It is the increase in taxation required to meet government-funded health care costs that causes DWL via distortions in the economy. Seminal studies that have evaluated the MCPF mostly relate to the United States (Browning, 1976; Stuart, 1984; Ballard, 1985; Browning, 1987). Estimates have ranged from zero marginal cost to well over 100%. This wide range has been due to alternative models (partial versus general equilibrium), alternative parameter estimates, and assumptions on the adjustment of employment relative to changes in tax rates (labour supply elasticities). In the VI burden of disease studies for the US and Japan, a MCPF of 1.16 was applied as a conservative best estimate from the US studies (Access Economics, 2006; 2008a). A MCPF of 1.16 is interpreted as every additional $1 raised by government to fund the cost of VI incurring a $0.16 DWL.

A limited number of studies have focused on the MCPF in other regions.

- Kleven and Kreiner (2006) estimated the MCPF for five European countries using micro data on taxes, benefits paid, and labour supply elasticities across different income levels. Nine estimates of the UK MCPF ranged from 0.93 to 1.36, and a simple average of 1.12 was used in the UK burden of disease study (Access Economics, 2009).
- Warlters and Auriol (2005) evaluated the MCPF in developing countries for 38 African nations and found the average MCPF to be 1.17.
- Australian studies of research and investment in the pharmaceutical industry apply a MCPF of between 1.20 and 1.33, with the Productivity Commission favouring a mid-estimate of 1.275 (Productivity Commission, 2003).
- A MCPF of 1.20 was applied in the VI burden of disease study for Canada (Access Economics, 2008b) based on a Canadian study estimating the MCPF as the ratio of average family income to median family income (using 1998 data) (Usher et al, 2002).

Based on the above studies, the global average MCPF applied in this study was 1.20 (i.e. an efficiency loss of $0.20 for every $1 raised by government from taxation). Variation in the MCPF as reported in the literature was included in the sensitivity analysis (Section 6).

The DWL for each WHO subregion presented in Table 4.11 was calculated using the data above and the VI prevalence numbers in Table 2.12. The global DWL is projected to increase from $238 billion in 2010 to $280 billion in 2020. Significantly higher DWLs are reported for subregions AMR-A and EUR-A, where health care costs per person are estimated to be higher, and WPR-B1 where governments fund an average of 41% of the total health care costs for a large regional population.

Table 4.11: Deadweight welfare loss for health care expenditure on VI due to all causes

WHO subregion	Weighted direct cost per person with VI ($)	Weighted % total health expenditure from government	DWL in 2010 ($ billion)	DWL in 2015 ($ billion)	DWL in 2015 ($ billion)
AFR-D	1,115	44	3.9	4.5	5.2
AFR-E	963	45	3.8	4.3	4.9
AMR-A	23,421	50	50.8	54.9	58.3
AMR-B	4,365	50	16.4	18.7	21.0
AMR-D	2,321	52	1.6	1.9	2.1
EMR-B	5,422	55	8.8	10.5	12.6
EMR-D	1,236	30	3.1	3.7	4.3
EUR-A	11,359	78	55.3	58.0	60.5
EUR-B1	4,913	69	7.5	7.9	8.3
EUR-B2	1,583	43	0.4	0.5	0.5
EUR-C	5,182	62	11.9	12.1	12.0
SEAR-B	1,877	54	7.1	8.2	9.4
SEAR-D	1,206	27	13.5	15.4	17.6
WPR-A1	9,621	64	1.4	1.6	1.7
WPR-A2	14,346	81	13.7	14.0	14.4
WPR-B1	2,262	41	36.2	40.1	44.7
WPR-B2	997	31	0.6	0.7	0.9
WPR-B3	2,284	38	1.5	1.8	2.1
World			237.7	258.8	280.4

Source: Access Economics calculations.

The DWL was also calculated for health care system expenditure on VI due to all causes excluding URE, and due to AMD only. The results of these analyses are presented in Table 4.12 and Table 4.13, respectively. For health care expenditure on VI due to all causes excluding URE, the global DWL is projected to increase from $112 billion in 2010 to $135 billion in 2020. For health care expenditure on VI due to AMD, the global DWL is projected to increase from $31 billion in 2010 to $35 billion in 2020.

Table 4.12: Deadweight welfare loss for health care expenditure on VI due to all causes excluding URE

WHO subregion	Weighted direct cost per person with VI ($)	Weighted % total health expenditure from government	DWL in 2010 ($ billion)	DWL in 2015 ($ billion)	DWL in 2015 ($ billion)
AFR-D	1,115	44	2.9	3.3	3.9
AFR-E	963	45	2.8	3.2	3.6

WHO subregion	Weighted direct cost per person with VI ($)	Weighted % total health expenditure from government	DWL in 2010 ($ billion)	DWL in 2015 ($ billion)	DWL in 2015 ($ billion)
AMR-A	23,421	50	19.4	21.1	22.5
AMR-B	4,365	50	9.1	10.4	11.7
AMR-D	2,321	52	0.9	1.0	1.2
EMR-B	5,422	55	6.0	7.3	8.8
EMR-D	1,236	30	2.3	2.7	3.1
EUR-A	11,359	78	24.7	26.1	27.4
EUR-B1	4,913	69	4.0	4.2	4.5
EUR-B2	1,583	43	0.2	0.2	0.3
EUR-C	5,182	62	7.0	7.2	7.1
SEAR-B	1,877	54	5.0	5.8	6.7
SEAR-D	1,206	27	4.8	5.5	6.3
WPR-A1	9,621	64	0.8	0.9	1.0
WPR-A2	14,346	81	8.0	8.2	8.4
WPR-B1	2,262	41	12.4	14.2	16.5
WPR-B2	997	31	0.4	0.5	0.6
WPR-B3	2,284	38	0.9	1.0	1.2
World			111.6	122.9	134.7

Source: Access Economics calculations.

Table 4.13: Deadweight welfare loss for health care expenditure on VI due to AMD

WHO subregion	Weighted direct cost per person with VI ($)	Weighted % total health expenditure from government	DWL in 2010 ($ billion)	DWL in 2015 ($ billion)	DWL in 2015 ($ billion)
AFR-D	1,115	44	0.00	0.00	0.00
AFR-E	963	45	0.00	0.00	0.00
AMR-A	23,421	50	9.71	10.55	11.25
AMR-B	4,365	50	0.45	0.52	0.58
AMR-D	2,321	52	0.04	0.04	0.05
EMR-B	5,422	55	0.18	0.22	0.26
EMR-D	1,236	30	0.05	0.05	0.06
EUR-A	11,359	78	12.37	13.07	13.72
EUR-B1	4,913	69	0.60	0.64	0.68
EUR-B2	1,583	43	0.03	0.03	0.04
EUR-C	5,182	62	1.06	1.08	1.07
SEAR-B	1,877	54	0.15	0.17	0.20
SEAR-D	1,206	27	0.24	0.27	0.31

WHO subregion	Weighted direct cost per person with VI ($)	Weighted % total health expenditure from government	DWL in 2010 ($ billion)	DWL in 2015 ($ billion)	DWL in 2015 ($ billion)
WPR-A1	9,621	64	0.41	0.46	0.50
WPR-A2	14,346	81	4.02	4.11	4.20
WPR-B1	2,262	41	1.86	2.14	2.47
WPR-B2	997	31	0.02	0.02	0.03
WPR-B3	2,284	38	0.03	0.03	0.04
World			31.20	33.41	35.47

Source: Access Economics calculations.

5 Burden of disease

Traditionally, measurement of health outcomes that combine duration and quality of life has been undertaken using the quality adjusted life year (QALY). The QALY was developed based off a multi-attribute utility theory framework under strict conditions (Sassi, 2006), and has since been used as a standard in cost effectiveness analysis (Drummond et al, 2005).

In the early 1990s, the multi-attribute utility framework used for the development of QALYs provided a basis for the development of the disability adjusted life year (DALY) by the WHO. DALYs were developed as the measurement unit to quantify non-fatal health outcomes, labelled the burden of disease and injury, on populations around the world for the Global Burden of Disease Study (Murray and Lopez, 1996). Methods and data sources regarding the development of DALYs are detailed further in Murray and Acharya (1997) and Murray et al (2001).

Rather than measuring the healthy part of life associated with a condition as in a quality-adjusted life year (QALY), the DALY was developed to measure the disability imposed on an individual. Thus a DALY is a negative concept, measuring the loss in a healthy life year. Disability weights used in the calculation of DALYs are measured on a scale of zero to one, where zero represents a year of perfect health and one represents death. Other health states associated with specific conditions were attributed values between zero and one by a reference group convened at the WHO on the basis of a person trade-off method for measuring health state preferences (Murray and Acharya, 1997). For example, a disability weight of 0.02 for mild sight loss is interpreted as losing 2% of a person's quality of life relative to perfect health. This represented a departure from the derivation of QALY weights, which rely on preference-based health related quality of life measures derived from population samples or patients, and thus represent individual rather than social preferences.

Access Economics has adopted a DALY approach in this report consistent with other international reports on the economic burden of sight loss (Access Economics, 2004; 2006; 2008a; 2008b; 2009). Because DALY weights are objective and consistent across countries, they are preferred by Access Economics, as well as more broadly, for example, by the WHO.

Under the DALY framework, the total burden of disease for an individual with a condition is the sum of the mortality and morbidity components associated with that condition over time, including the years of healthy life lost due to disability (YLDs), and the years of healthy life lost due to premature death (YLLs). Incorporating time preference for health (and thus discounting), this can be represented by:

$$DALY_i = \sum_{t=a}^{a+L} \frac{Dw_{i,t}}{(1+r)^{t-a}}$$

where *Dw* is the DALY weight of the condition experienced by individual *i*, *L* is the residual life expectancy of the individual at age *a,* and *t* represents individual years within that life expectancy.

The total burden of disease from a condition on society can be calculated by aggregating DALYs of all individuals with the condition, which can be represented by:

$$DALY_t = \sum_{i=0}^{N_t} DALY_{i,t}$$

where *N* is the prevalence of the condition at time *t*.

5.1 Disability weights for visual impairment

Any weighting exercise for use in burden of disease analysis or economic evaluation should measure preferences for clearly defined and relevant health states. Two key sources of disability weights for visual impairment have been identified: the WHO Global Burden of Disease (GBD) study (Lopez et al, 1996) and a Netherlands study (Stoudhart et al, 1997).

The 1990 GBD study asked participants in weighting exercises to make a composite judgement on the severity distribution of various health conditions and the preference for time spent in each severity level for those conditions (Lopez et al, 2006). This was to a large extent necessitated by the lack of population information on the severity distribution of most conditions at the global and regional level. The WHO Global Burden of Disease and Risk Factors study has used the GBD study weights to estimate the DALY burden from various causes and risk factors in different regions of the world (Lopez et al, 2006).

GBD study weights for VI vary by cause of low vision or blindness, according to the disability weights for treated and untreated VI, and the likelihood of treatment. The GBD definitions of VI match the standard WHO levels of VA:

- Low vision (3/60 ≤ VA < 6/18);
  - 0.282 if untreated;
  - 0.227 if treated;
- Blindness (VA < 3/60);
  - 0.6 if untreated; and
  - 0.488 if treated (cataract and diabetes mellitus retinopathy only).

These VA definitions differ from this study, where blindness is defined as a VA less than 6/60. Furthermore, the GBD study did not estimate disability weights for people with a VA less than 6/12 and equal to or greater than 6/18, defined as mild VI in this study.

Netherlands researchers measured disability weights for 53 diseases of public health importance using a methodology consistent with the GBD study (AIHW, 1999; Stouthard et al, 1997). The Netherlands study used more specific disease stages and severity levels so that judgements were not required on the distribution of stages or severities in the population. In addition, the study defined each disease stage by the associated average levels of disability, handicap, mental wellbeing, pain and cognitive impairment using a modified version of the EuroQol health status instrument (AIHW, 1999). The Netherlands study weights are:

- 0.02 for mild vision loss (some difficulty reading newspaper, no difficulty recognising faces at 4 meters);
- 0.17 for moderate vision loss (great difficulty reading newspaper, some difficulty recognising faces at 4 meters); and
- 0.43 for severe vision loss (unable to read newspaper or recognise faces at 4 meters).

Netherlands study weights have been used in Australian burden of disease studies undertaken by the government (AIHW, 1999; 2007), and by Access Economics in burden of disease studies for five countries (Access Economics, 2004; 2006; 2008a; 2008b; 2009). As with the GBD study weights, the Netherlands study health states do not completely concord with the previous or current Access Economics studies. However, the Netherlands weights were used in this study rather than the GBD weights for three reasons:

- consistency with previous Access Economics studies;
- the Netherlands weights cover three severities of VI, consistent with this study; and
- GBD weights are more likely to overestimate the DALY burden given that low vision and blindness are defined as more severe than in this study (a VA cut-off of 3/60 rather than 6/60). Conversely, the Netherlands definitions may, particularly for mild and moderate VI, include less severe cases of vision loss leading to conservative DALY estimates.

The Netherlands study weights for mild vision loss, moderate vision loss, and blindness were used for mild VI, moderate VI, and blindness, respectively, in this study. Given that neither set of weights exactly match this study, a sensitivity analysis is undertaken in Section 6 of this report, using the GBD study weights for untreated low vision (for moderate VI) and untreated blindness (for blindness), and maintaining a disability weight of 0.02 for mild VI.

5.2 Years of healthy life lost due to disability (YLD)

YLDs from VI in each WHO subregion were calculated by multiplying the number of people with VI by the disability weight associated with the severity of their sight loss. Prevalence estimates for mild VI, moderate VI, and blindness in each WHO subregion were derived in Section 2.4. It is assumed that all people with low vision or blindness experience their condition for the entire year.

The DALY burden from YLL is presented in Table 5.1. The proportions of the total DALY burden due to VI severity are 6% for mild VI, 36% for moderate VI, and 58% for blindness, which reflects the relatively high disability weight for blindness. The DALY burden is significantly greater in regions SEAR-D and WPR-B1 where both the regional general population and the prevalence of moderate VI and blindness are greatest. This is partly due to the impact of URE on total VI prevalence being greatest in these regions.

Table 5.1: DALY burden for YLD due to visual impairment (000s)

WHO subregion	2010				2015				2020			
	Mild VI	Moderate VI	Blind	Total	Mild VI	Moderate VI	Blind	Total	Mild VI	Moderate VI	Blind	Total
AFR-D	336	2,115	4,331	6,852	389	2,450	5,023	7,944	451	2,842	5,832	9,220
AFR-E	375	2,361	4,836	7,633	426	2,680	5,492	8,667	483	3,042	6,234	9,838
AMR-A	207	1,306	1,654	3,242	224	1,409	1,787	3,505	238	1,498	1,900	3,729
AMR-B	348	2,193	3,167	5,846	396	2,492	3,608	6,658	444	2,798	4,059	7,486
AMR-D	61	381	624	1,087	69	435	714	1,243	78	494	814	1,415
EMR-B	129	814	1,537	2,537	154	967	1,838	3,031	184	1,156	2,213	3,642
EMR-D	360	2,265	4,427	7,200	420	2,643	5,182	8,420	489	3,080	6,062	9,837
EUR-A	296	1,863	2,396	4,656	311	1,956	2,519	4,892	324	2,040	2,630	5,107
EUR-B1	102	640	976	1,755	107	672	1,028	1,846	112	705	1,083	1,943
EUR-B2	27	169	252	457	30	190	286	518	33	209	316	571
EUR-C	169	1,067	1,598	2,908	171	1,078	1,619	2,944	170	1,070	1,608	2,921
SEAR-B	301	1,898	3,902	6,258	346	2,181	4,525	7,238	395	2,484	5,197	8,290
SEAR-D	1,897	11,943	18,678	33,176	2,177	13,710	21,478	38,118	2,485	15,645	24,551	43,523
WPR-A1	10	66	102	182	12	73	114	203	13	80	124	222
WPR-A2	53	337	521	934	55	345	534	958	56	353	547	980
WPR-B1	1,790	11,271	16,173	29,812	1,978	12,452	18,068	33,167	2,197	13,835	20,317	37,124
WPR-B2	86	540	1,080	1,748	102	642	1,300	2,097	119	751	1,537	2,474
WPR-B3	80	506	787	1,415	93	587	918	1,648	107	673	1,058	1,895
World	6,628	41,734	67,042	117,699	7,459	46,962	76,033	133,096	8,379	52,754	86,083	150,216

Source: Access Economics calculations.

5.3 Years of life lost due to premature death (YLL)

The DALY burden due to YLL is calculated only for deaths that occur within that year. The calculations for 2010 or 2015 do not therefore double count the disease burden due to deaths in 2020. Similar to productivity losses due to death, YLLs were discounted at an annual rate of 3% to estimate the present value of the DALY burden. Sensitivity analysis was performed on the range 0-5% (Section 6) as recommended by Drummond et al (2005) and Lipscomb (1996). The rationale behind discounting both costs and DALYs, and the selection of the discount rate, was discussed in Section 4.1.2.

The numbers of deaths associated with partial sight and blindness were calculated using the methodology outlined in Section 4.1.2. The estimated total numbers of deaths due to partial sight and blindness are reported in Table 5.2.

Table 5.2: Deaths due to visual impairment by year and WHO subregion (000s)

WHO subregion	2010	2015	2020
AFR-D	47	55	64
AFR-E	59	67	78
AMR-A	12	14	15
AMR-B	25	30	36
AMR-D	5	6	7
EMR-B	11	13	16
EMR-D	40	48	57
EUR-A	20	22	24
EUR-B1	8	9	9
EUR-B2	2	2	3
EUR-C	19	20	21
SEAR-B	31	36	43
SEAR-D	215	253	300
WPR-A1	1	1	1
WPR-A2	4	4	5
WPR-B1	117	139	164
WPR-B2	9	10	12
WPR-B3	6	8	10
World	631	738	865

Source: Access Economics calculations.

The DALY burden from YLL is presented in Table 5.3. The global burden of mortality specifically due to VI is projected to increase from 2.3 million DALYS in 2010 to 3.0 million DALYs in 2020. The DALY burden is significantly greater in regions SEAR-D and WPR-B1. The total numbers of people with VI, to which increased mortality risks are applied, are greatest in these two subregions.

Table 5.3: DALY burden for YLL due to visual impairment (000s)

WHO subregion	2010	2015	2020
AFR-D	70	82	95
AFR-E	62	70	79
AMR-A	75	85	93
AMR-B	138	161	184
AMR-D	22	25	29
EMR-B	57	72	89
EMR-D	149	176	205
EUR-A	100	107	114
EUR-B1	37	40	43
EUR-B2	9	11	13
EUR-C	74	76	73
SEAR-B	157	185	215
SEAR-D	658	753	842
WPR-A1	4	4	5
WPR-A2	23	23	24
WPR-B1	577	670	774
WPR-B2	42	53	66
WPR-B3	41	49	58
World	2,295	2,643	3,001

Source: Access Economics calculations.

5.4 Regional and global burden of disease from visual impairment

Total DALYs for each WHO subregion are the sum of YLD and YLL as presented Table 5.4. The global burden of VI is projected to increase from 118 million DALYS in 2010 to 150 million DALYs in 2020. Only 2% of the total DALY burden in each year is due to premature death, which reflects the significant but low mortality attributable to VI.

Table 5.4: Total DALY burden for VI due to all causes (000s)

WHO subregion	2010	2015	2020
AFR-D	6,852	7,944	9,220
AFR-E	7,633	8,667	9,838
AMR-A	3,242	3,505	3,729
AMR-B	5,846	6,658	7,486
AMR-D	1,087	1,243	1,415
EMR-B	2,537	3,031	3,642
EMR-D	7,200	8,420	9,837
EUR-A	4,656	4,892	5,107
EUR-B1	1,755	1,846	1,943
EUR-B2	457	518	571

WHO subregion	2010	2015	2020
EUR-C	2,908	2,944	2,921
SEAR-B	6,258	7,238	8,290
SEAR-D	33,176	38,118	43,523
WPR-A1	182	203	222
WPR-A2	934	958	980
WPR-B1	29,812	33,167	37,124
WPR-B2	1,748	2,097	2,474
WPR-B3	1,415	1,648	1,895
World	117,699	133,096	150,216

Source: Access Economics calculations.

Table 5.5 presents the total DALY burden for VI due to all causes excluding URE. The global burden is projected to increase from 62 million DALYs in 2010 to 81 million DALYs in 2020.

Table 5.6 presents the total DALY burden for VI due to AMD. Each regional DALY burden was calculated as the product of the DALY burden due to all causes excluding URE (Table 5.5) and the proportion of VI prevalence caused by AMD (Table 2.7). The global DALY burden was calculated as the sum of all regional burdens and is projected to increase from 6 million DALYs in 2010 to 7 million DALYs in 2020.

Table 5.5: Total DALY burden for VI due to all causes excluding URE (000s)

WHO subregion	2010	2015	2020
AFR-D	5,249	6,089	7,072
AFR-E	5,852	6,646	7,545
AMR-A	1,360	1,478	1,579
AMR-B	3,411	3,890	4,380
AMR-D	648	744	852
EMR-B	1,848	2,227	2,700
EMR-D	5,484	6,440	7,559
EUR-A	2,251	2,380	2,499
EUR-B1	1,029	1,094	1,162
EUR-B2	247	288	323
EUR-C	1,850	1,886	1,875
SEAR-B	4,678	5,477	6,341
SEAR-D	13,242	15,193	17,324
WPR-A1	117	130	142
WPR-A2	596	610	624
WPR-B1	11,890	13,663	15,812
WPR-B2	1,255	1,533	1,835
WPR-B3	855	1,008	1,171
World	61,862	70,778	80,794

Source: Access Economics calculations.

Table 5.6: Total DALY burden for VI due to AMD (000s)

WHO subregion	2010	2015	2020
AFR-D	0	0	0
AFR-E	0	0	0
AMR-A	680	739	789
AMR-B	171	195	219
AMR-D	26	30	34
EMR-B	55	67	81
EMR-D	110	129	151
EUR-A	1,126	1,190	1,249
EUR-B1	154	164	174
EUR-B2	37	43	48
EUR-C	277	283	281
SEAR-B	140	164	190
SEAR-D	662	760	866
WPR-A1	58	65	71
WPR-A2	298	305	312
WPR-B1	1,784	2,050	2,372
WPR-B2	63	77	92
WPR-B3	26	30	35
World	5,667	6,290	6,966

Source: Access Economics calculations.

6 Sensitivity analysis

The analysis in the preceding sections represents a best estimate of the regional and global burden of VI based on all available and relevant data. However, as discussed above there is considerable variation in some parameter estimates. Furthermore, in the absence of data for all regions, assumptions have been made that, if modified, would change the results.

This section details the sensitivity analyses performed on key assumptions and model parameters that are subject to the most uncertainty[7]. The results of the sensitivity analyses are presented for VI due to all causes.

6.1 One-way sensitivity analysis

Due to a lack of information regarding the distributions for most parameters, probabilistic sensitivity analysis is only undertaken as a secondary analysis. Primarily, one-way sensitivity analyses demonstrate the sensitivity of results to plausible variations in key model inputs and assumptions.

6.1.1 Prevalence adjustments

As detailed in Sections 2.2.2 and 2.2.3 of this report, population-based studies were used to adjust the prevalence of WHO-defined low vision ($3/60 < VA \leq 6/18$) and estimate the prevalence of moderate VI ($6/60 < VA \leq 6/18$), and to estimate the prevalence of mild VI ($6/18 < VA \leq 6/12$) from moderate VI. Substantial variation between the study estimates is reflected by the range of results based on these data as presented in Table 6.1.

A reduction in the proportion of people with WHO-defined low vision classified as having moderate VI actually reduces the total prevalence of VI, and thus health care costs. This is due to mild VI prevalence being calculated from moderate VI prevalence, and being higher than either moderate VI or blindness prevalence in the base case analysis. However, the DALY burden increases given the increase in the number of blind people, and the higher disability weight for blindness (0.6) compared with mild VI (0.02).

A reduction in the prevalence of mild VI relative to moderate VI has a large impact on total VI prevalence (and hence direct health care costs). However, it has very little impact on the DALY burden and productivity losses given the low disability weight for mild VI and low incremental mortality risk attributable to the visually impaired.

[7] A sensitivity analysis on the valuation method for productivity losses was considered. However, no employment gap data for developed regions were identified to enable the human capital approach to be applied for all regions consistent with the methods for developed regions.

Table 6.1: Sensitivity analysis for the adjustments of WHO-defined VI prevalence

	2010	2015	2020
Base case			
Prevalence of VI (m)	733	826	929
Direct cost ($m)	2,302,164	2,529,307	2,767,264
DWL ($m)	237,739	258,760	280,376
Productivity loss ($m)	168,274	174,792	177,551
Informal care ($m)	246,349	272,934	301,580
DALYs (m)	118	133	150
Moderate VI / WHO low vision = 0.56	-	-	-
Prevalence of VI (m)	663	748	841
Direct cost ($m)	2,078,892	2,284,392	2,499,769
DWL ($m)	214,619	233,631	253,191
Productivity loss ($m)	168,165	174,680	177,439
Informal care ($m)	246,349	272,934	301,580
DALYs (m)	130	146	165
Moderate VI / WHO low vision = 0.94	-	-	-
Prevalence of VI (m)	840	947	1,065
Direct cost ($m)	2,645,770	2,906,222	3,178,930
DWL ($m)	273,322	297,432	322,211
Productivity loss ($m)	168,442	174,965	177,723
Informal care ($m)	246,349	272,934	301,580
DALYs (m)	100	113	127
Mild VI / moderate VI = 0.73	-	-	-
Prevalence of VI (m)	580	654	736
Direct cost ($m)	1,813,503	1,993,277	2,181,813
DWL ($m)	187,136	203,762	220,879
Productivity loss ($m)	168,036	174,547	177,306
Informal care ($m)	246,349	272,934	301,580
DALYs (m)	114	129	146
Mild VI / moderate VI = 2.17	-	-	-
Prevalence of VI (m)	933	1,052	1,183
Direct cost ($m)	2,943,881	3,233,231	3,536,090
DWL ($m)	304,193	330,984	358,508
Productivity loss ($m)	168,587	175,115	177,873
Informal care ($m)	246,349	272,934	301,580
DALYs (m)	122	138	156

Source: Access Economics calculations.

6.1.2 Health care cost of uncorrected refractive error

The direct costs per person with VI estimated in Section 3.2 are based on data for five developed countries, and include costs for all causes of VI including URE. However, the model used in this study is based on the prevalence of VI defined using best-corrected VA with an upwards adjustment for uncorrected refractive error (URE). URE accounts for a significant proportion of all VI.

For the sensitivity analysis, it is considered that people with URE may be visually impaired due to not presenting with vision problems. These individuals may be generally less likely to seek health care relating to their vision problems, incurring low or zero health care costs. Under a scenario where people with VI due to URE are assigned no direct health care cost, the direct health care system costs and DWLs are equivalent to those reported in Table 3.6 and Table 4.13, respectively.

It should be noted that people visually impaired due to other causes include those with corrected refractive error. Therefore, the costs of eyewear and other health care resources used to correct refractive error are included in the analysis.

6.1.3 Ratio of direct health care cost to GDP per capita

Using the approach suggested by Wimo et al (2006), the direct health care cost per person with VI in the base case analysis was estimated using available health care cost and GDP data for five countries. The range of values for the five countries reported in Table 3.2 is used in a sensitivity analysis (Table 6.2).

The direct health care costs (and hence DWL also) vary widely given that the upper estimate derived from the US study is over seven times the lower estimate derived from the UK study.

Table 6.2: Sensitivity analysis varying the ratio of direct health care cost per person with VI to GDP per capita

	2010	2015	2020
Base case			
Prevalence of VI (m)	733	826	929
Direct cost ($m)	2,302,164	2,529,307	2,767,264
DWL ($m)	237,739	258,760	280,376
Productivity loss ($m)	168,274	174,792	177,551
Informal care ($m)	246,349	272,934	301,580
DALYs (m)	118	133	150
Ratio of direct health care cost per person to GDP per capita = 0.071	-	-	-
Prevalence of VI (m)	733	826	929
Direct cost ($m)	933,934	1,012,840	1,088,737
DWL ($m)	99,369	107,055	114,344
Productivity loss ($m)	168,274	174,792	177,551
Informal care ($m)	246,349	272,934	301,580

	2010	2015	2020
DALYs (m)	118	133	150
Ratio of direct health care cost per person to GDP per capita = 0.071	-	-	-
Prevalence of VI (m)	733	826	929
Direct cost ($m)	3,025,678	3,331,209	3,654,863
DWL ($m)	310,909	338,980	368,172
Productivity loss ($m)	168,274	174,792	177,551
Informal care ($m)	246,349	272,934	301,580
DALYs (m)	118	133	150

Source: Access Economics calculations.

6.1.4 Disability weights

Two sets of disability weights for VI were identified: the WHO GBD study weights (Lopez et al, 2006) and a Netherlands study (Stouthard et al, 1997). The Netherlands weights are included in the model since they cover three VI severities and are likely to be conservative by their definitions (see Section 5.1).

However, given that neither set of disability weights exactly match the VI definitions used in this study, a sensitivity analysis uses the GBD weights for untreated low vision (applied to moderate VI) and blindness, maintaining a disability weight of 0.02 for mild VI.

Results are presented in Table 6.3. Use of the GBD study weights increases the global DALY burden by 46% in each year, in line with the relative differences between the moderate VI and blind disability weights in both studies, and the relative proportions of people with each VI severity.

Table 6.3: Sensitivity analysis for visual impairment disability weights

	2010	2015	2020
Base case			
Prevalence of VI (m)	733	826	929
Direct cost ($m)	2,302,164	2,529,307	2,767,264
DWL ($m)	237,739	258,760	280,376
Productivity loss ($m)	168,274	174,792	177,551
Informal care ($m)	246,349	272,934	301,580
DALYs (m)	118	133	150
Mild VI = 0.02, moderate VI = 0.28, blindness = 0.6	-	-	-
Prevalence of VI (m)	733	826	929
Direct cost ($m)	2,302,164	2,529,307	2,767,264
DWL ($m)	237,739	258,760	280,376
Productivity loss ($m)	168,274	174,792	177,551
Informal care ($m)	246,349	272,934	301,580

	2010	2015	2020
DALYs (m)	172	194	219

Source: Access Economics calculations.

6.1.5 Discount rate for productivity losses and DALYs

Discounting is applied to both productivity losses and the DALY burden from premature mortality due to VI. Following expert recommendation a discount rate of 3% is applied to costs (productivity losses) and benefits (DALYs, to be considered as negative health benefits), with sensitivity analysis performed on the range 0% to 10% (Drummond et al, 2005; Lipscomb et al, 1996).

Results are presented in Table 6.4. Variation in the discount rate has a negligible impact on productivity losses and the DALY burden, given the low etiological fraction used in the model (proportion of increased mortality with VI specifically due to VI).

Table 6.4: Sensitivity analysis for the discount rate for productivity losses and DALYs

	2010	2015	2020
Base case			
Prevalence of VI (m)	733	826	929
Direct cost ($m)	2,302,164	2,529,307	2,767,264
DWL ($m)	237,739	258,760	280,376
Productivity loss ($m)	168,274	174,792	177,551
Informal care ($m)	246,349	272,934	301,580
DALYs (m)	118	133	150
No discounting (0%)	-	-	-
Prevalence of VI (m)	733	826	929
Direct cost ($m)	2,302,164	2,529,307	2,767,264
DWL ($m)	237,739	258,760	280,376
Productivity loss ($m)	168,571	175,091	177,845
Informal care ($m)	246,349	272,934	301,580
DALYs (m)	118	134	151
5% discount rate	-	-	-
Prevalence of VI (m)	733	826	929
Direct cost ($m)	2,302,164	2,529,307	2,767,264
DWL ($m)	237,739	258,760	280,376
Productivity loss ($m)	168,138	174,655	177,415
Informal care ($m)	246,349	272,934	301,580
DALYs (m)	117	133	150

Source: Access Economics calculations.

6.1.6 Marginal cost of public funds

Studies estimating the MCPF (inefficiency due to taxation used to fund government health care costs) were outlined in Section 4.3. These studies have largely been limited to a few developed countries, although estimates for African developing nations have been within the ranges from other studies. A review of published studies suggested the likely global average MCPF to be between 1.12 and 1.30, which is the range tested in the sensitivity analysis.

Results are presented in Table 6.5. Any increase or reduction in the MCPF has a proportional impact on the DWL associated with publicly funded health care for people with visual impairment.

Table 6.5: Sensitivity analysis for marginal cost of public funds

	2010	2015	2020
Base case			
Prevalence of VI (m)	733	826	929
Direct cost ($m)	2,302,164	2,529,307	2,767,264
DWL ($m)	237,739	258,760	280,376
Productivity loss ($m)	168,274	174,792	177,551
Informal care ($m)	246,349	272,934	301,580
DALYs (m)	118	133	150
MCPF = 0.12	-	-	-
Prevalence of VI (m)	733	826	929
Direct cost ($m)	2,302,164	2,529,307	2,767,264
DWL ($m)	142,644	155,256	168,225
Productivity loss ($m)	168,274	174,792	177,551
Informal care ($m)	246,349	272,934	301,580
DALYs (m)	118	133	150
MCPF = 0.30	-	-	-
Prevalence of VI (m)	733	826	929
Direct cost ($m)	2,302,164	2,529,307	2,767,264
DWL ($m)	356,609	388,139	420,563
Productivity loss ($m)	168,274	174,792	177,551
Informal care ($m)	246,349	272,934	301,580
DALYs (m)	118	133	150

Source: Access Economics calculations.

6.1.7 Increased mortality due to VI

Although the relative risk of death for people with VI has been estimated at twice that of the general population (McCarty et al, 2001), the proportion of incremental mortality actually attributable to VI is very low, being 0.73% based on data from the ABS (2009). In the sensitivity analysis, the relative risk was set to 1.7 based on findings by Wang et al (2001), which also controlled for comorbidities.

Results are presented in Table 6.6. Assuming that no deaths of people with VI are specifically due to VI has a negligible impact on productivity losses and the DALY burden. As explained above for variations in the discount rate (Section 6.1.5) this is due to the low etiological fraction (0.73%) in the model. When multiplied by this fraction, any plausible relative mortality risk has little impact on the burden of disease.

Table 6.6: Sensitivity analysis for the increased mortality risk due to visual impairment

	2010	2015	2020
Base case			
Prevalence of VI (m)	733	826	929
Direct cost ($m)	2,302,164	2,529,307	2,767,264
DWL ($m)	237,739	258,760	280,376
Productivity loss ($m)	168,274	174,792	177,551
Informal care ($m)	246,349	272,934	301,580
DALYs (m)	118	133	150
No increased mortality risk (relative risk = 1)	-	-	-
Prevalence of VI (m)	733	826	929
Direct cost ($m)	2,302,164	2,529,307	2,767,264
DWL ($m)	237,739	258,760	280,376
Productivity loss ($m)	167,162	173,645	176,407
Informal care ($m)	246,349	272,934	301,580
DALYs (m)	115	130	147
Etiological fraction = 0.37%	-	-	-
Prevalence of VI (m)	733	826	929
Direct cost ($m)	2,302,164	2,529,307	2,767,264
DWL ($m)	237,739	258,760	280,376
Productivity loss ($m)	167,718	174,219	176,979
Informal care ($m)	246,349	272,934	301,580
DALYs (m)	117	132	149
Etiological fraction = 1.10%	-	-	-
Prevalence of VI (m)	733	826	929
Direct cost ($m)	2,302,164	2,529,307	2,767,264
DWL ($m)	237,739	258,760	280,376
Productivity loss ($m)	168,830	175,366	178,123
Informal care ($m)	246,349	272,934	301,580
DALYs (m)	119	134	152

Source: Access Economics calculations.

6.1.8 Employment gap

The employment gap due to VI is defined in this study as the relative reduction in the likelihood of employment for someone with VI versus someone without VI. This parameter is

estimated in Section 4.1.1 for each subregion where the human capital approach is used to estimate productivity losses. These values are derived using employment survey data in Australia, Canada, Japan, UK and US (Access Economics, 2004; 2006; 2008a; 2008b; 2009).

In the absence of data to enable statistical ranges to be calculated, these employment gaps were increased and decreased by a relative rate of 20% (e.g. the 47% employment gap for AMR-A was varied between 38% and 56%).

Results are presented in Table 6.7. Any variation in the employment gap leads to a proportional change in the productivity loss due to VI, when all other parameters are held constant.

Table 6.7: Sensitivity analysis for the employment gap due to visual impairment

	2010	2015	2020
Base case			
Prevalence of VI (m)	733	826	929
Direct cost ($m)	2,302,164	2,529,307	2,767,264
DWL ($m)	237,739	258,760	280,376
Productivity loss ($m)	168,274	174,792	177,551
Informal care ($m)	246,349	272,934	301,580
DALYs (m)	118	133	150
AMR-A = 38%, EUR = 18%, WPR-A1 = 36%, WPR-A2 = 21%	-	-	-
Prevalence of VI (m)	733	826	929
Direct cost ($m)	2,302,164	2,529,307	2,767,264
DWL ($m)	237,739	258,760	280,376
Productivity loss ($m)	134,947	140,173	142,379
Informal care ($m)	246,349	272,934	301,580
DALYs (m)	118	133	150
AMR-A = 56%, EUR = 27%, WPR-A1 = 53%, WPR-A2 = 32%	-	-	-
Prevalence of VI (m)	733	826	929
Direct cost ($m)	2,302,164	2,529,307	2,767,264
DWL ($m)	237,739	258,760	280,376
Productivity loss ($m)	201,601	209,412	212,723
Informal care ($m)	246,349	272,934	301,580
DALYs (m)	118	133	150

Source: Access Economics calculations.

7 Conclusions

Access Economics was commissioned by AMD Alliance International to estimate the global burden of VI, including the direct and indirect costs of low vision and blindness, and the burden on health. VI is defined in this study as either:

- Mild VI, being best-corrected VA less than 6/12 but better than or equal to 6/18 in the better-seeing eye;
- Moderate VI, being best-corrected VA less than 6/18 but better than or equal to 6/60 in the better-seeing eye; or
- Blindness, being best-corrected VA less than 6/60 in the better-seeing eye.

A range of conditions can lead to partial sight and blindness, including:

- age-related macular degeneration (AMD);
- cataract;
- diabetic retinopathy;
- glaucoma;
- uncorrected (or undercorrected) refractive error (URE); and
- other causes of partial sight and blindness.

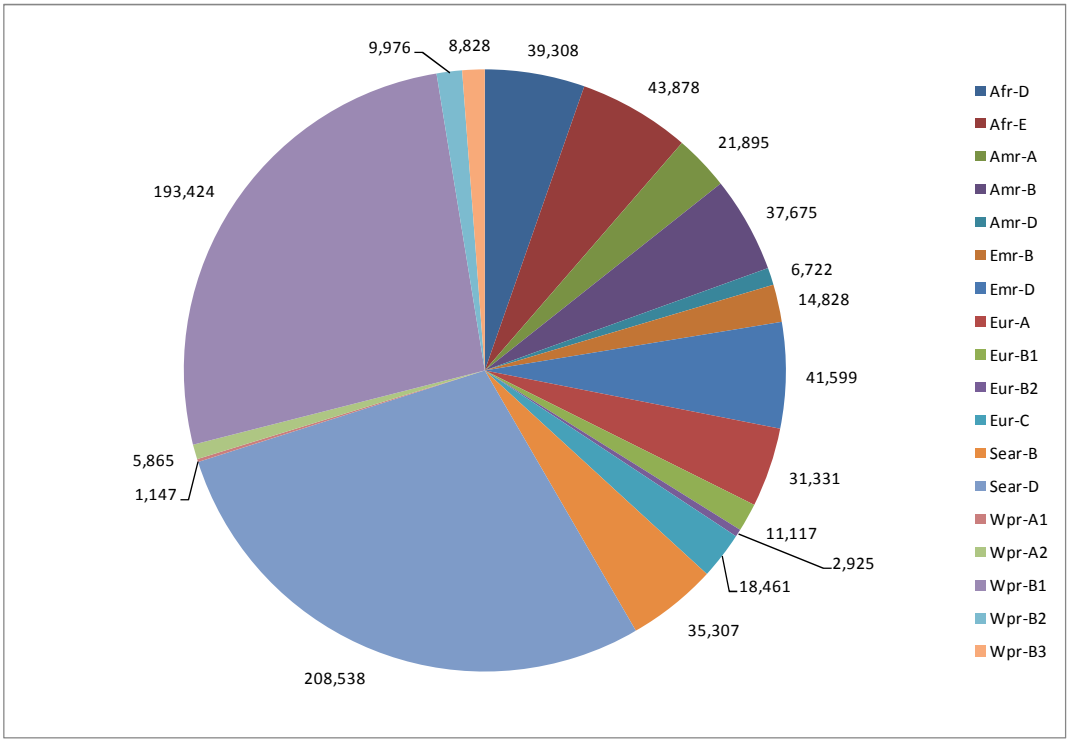
The prevalence of partial sight and blindness in 2010, and projections to 2020, were estimated using published regional prevalence rates (Resnikoff et al 2004, Resnikoff et al 2008) and UN population data. Countries excluded from the study due to a lack of critical data, totalled only 0.4% of the world population, and the results are not substantially affected by their exclusion.

In total, there are estimated to be approximately 733 million people with VI worldwide in 2010 including 386 million with VI due to URE. Adults aged 50 years and older constitute 546 million (74%) of those cases. It is estimated that of all people with partial sight and blindness:

- 331 million (45%) people have mild VI;
- 245 million (34%) people have moderate VI; and
- 156 million (21%) people are blind.

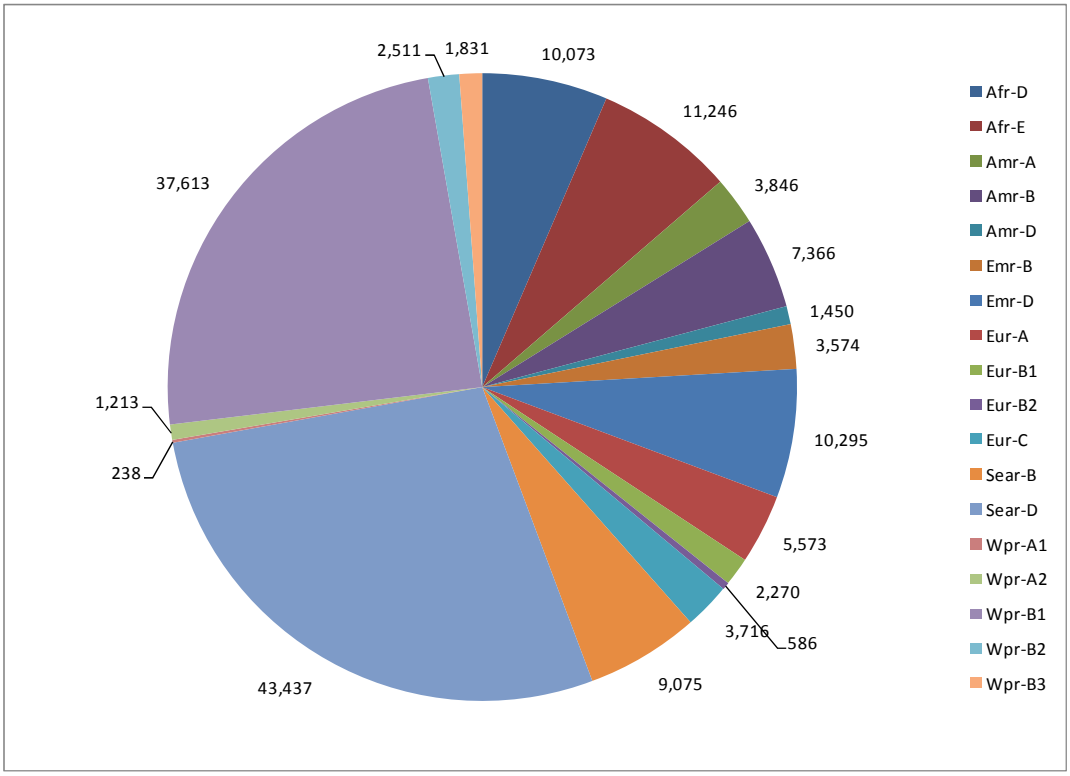
The numbers of people visually impaired and blind in each subregion of the world are presented in Figure 7.1 and Figure 7.2. Subregions SEAR-D and WPR-B1 alone account for half of all VI and blindness due to the large populations and relatively high prevalence rates for VI in those regions.

Figure 7.1: Number of visually impaired by WHO subregion in 2010 (000s)



Source: Access Economics calculations.

Figure 7.2: Number of blind by WHO subregion in 2010 (000s)



Source: Access Economics calculations.

It is projected that by 2020 there will be approximately 929 million people with VI worldwide, which is an increase of 27% from the 2010 estimate. Given the assumptions of constant age-gender prevalence rates over the ten year period, this increase is driven by population growth and ageing.

The numbers of people with VI estimated in this study are in line with the most recent estimates published elsewhere, but represent more recent estimates using all up-to-date information. For example, Resnikoff et al (2008) estimated that worldwide in 2004 there were 153 million people with VI (VA < 6/18) excluding uncorrected refractive error (URE) and 314 million people with VI when including URE. Our estimates for 2010 are 200 million and 401 million people, respectively, the increase accounted for by population growth and some differences in underlying assumptions. However, we also estimate there to be 331 million people with mild VI (6/18 ≤ VA < 6/12) including disease due to URE.

This concordance between our numbers and other published data (which underlie our study) is a validity check on the prevalence numbers produced by the model and, since other results flow from these prevalence figures, a validity check on the projected costs and health burden.

VI imposes a significant cost on public funds, private expenditure, and health. The health care system costs of VI in 2010 total $2.30 trillion worldwide and are expected to vary between $4.6 billion in subregion EUR-B2 and $512.8 billion in subregion AMR-A. Again, these differences are driven by total population size and well as prevalence within each population and different health systems. Given the limitations of the underlying cost data, where costs in

each country were imputed from Australia, Canada, Japan, UK, and US, health care costs have been estimated for all VI rather than by severity or cause.

Worldwide indirect costs of VI estimated in this study include:

- informal care costs contributing $246 billion (38% of all indirect costs) in 2010;
- deadweight welfare loss (inefficiencies resulting from increased tax revenue to fund public health expenditure) totalling $238 billion (36% of all indirect costs) in 2010; and
- productivity losses due to absenteeism or death from VI constituting $168 billion (26% of all indirect costs) in 2010.

The relatively low contribution of productivity losses to total indirect costs reflects both the assumption that workers can be replaced without cost in developing countries, and the size of the employment gap due to VI in developed countries.

Health care system costs and indirect costs were projected to 2020 using the assumptions for 2010 and population forecasts (UN, 2009). In summary, costs are expected to grow by 9-10% between 2010 and 2015, and between 2015 and 2020 (an approximate annual average growth rate of 2%). It is projected that in 2020 direct health care system costs will be $2.77 trillion and indirect costs will be $760 billion in 2008 US dollar prices.

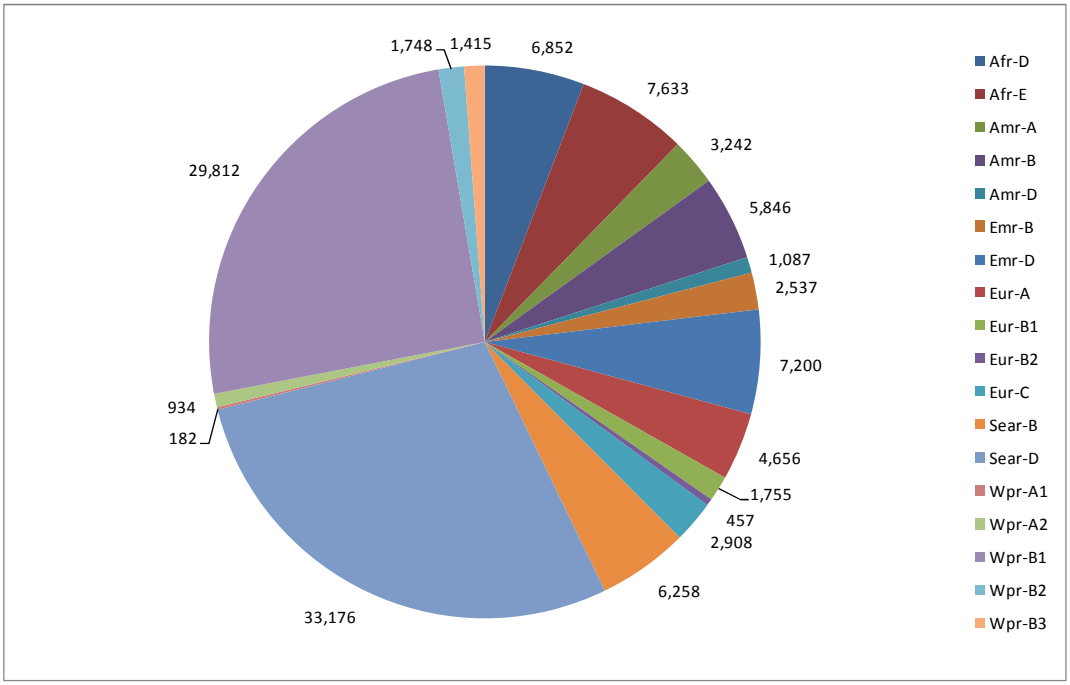
The health burden of VI was calculated using disability adjusted life years (DALYs), with weights of 0.02, 0.17, and 0.43 for mild VI, moderate VI and blindness, respectively.

The global burden of disease in 2010 for all VI (VA < 6/12) is estimated to be 118 million DALYS rising to 150 million DALYs in 2020. For 2010, it is estimated that of all people with VI:

- 7 million DALYS are incurred due to mild VI (6% of all DALYs);
- 42 million DALYS are incurred due to moderate VI (35% of all DALYs);
- 67 million DALYS are incurred due to blindness (57% of all DALYs); and
- 2 million DALYS are incurred due to death attributable to VI (2% of all DALYs).

The region with the greatest burden is SEAR-D as shown in Figure 7.3.

Figure 7.3: DALY burden by WHO subregion in 2010 (000s)



Source: Access Economics calculations.

Globally, URE is the cause of approximately half of all VI. Therefore, as demonstrated in this study, the cost and DALY burdens of VI due to URE are approximately half of the total burdens.

AMD was identified as causing 9% of all global VI in the year 2002 (Resnikoff et al 2004), although the proportion is substantially higher (up to 50%) in developed WHO subregions. The global prevalence of VI due to AMD is projected to increase from 33 million persons in 2010 to 40 million persons in 2020, and is associated with:

- Direct health care system expenditure of $255 billion in 2010, increasing to $294 billion in 2020;
- DWL of $31 billion in 2010, increasing to $35 billion in 2020;
- Productivity losses of $34 billion in 2010, increasing to $26 billion in 2020;
- Informal care costs of $23 billion in 2010, increasing to $27 billion in 2020; and
- A health burden of 6 million DALYs in 2010, increasing to 7 million DALYS in 2020.

Given the global nature of this project, and the limited number of countries and parameters for which data were available, a number of assumptions were necessary by Access Economics and authors of the source studies. The qualifications to the analysis with respect to these assumptions are detailed below.

First, prevalence data were derived from Resnikoff et al (2004) and Resnikoff et al (2008) – two recent and comprehensive reviews of international VI surveys. The authors state the following qualifications to their prevalence estimates:

- heterogeneity of the survey methods for data collection and ophthalmic examinations;

- data extrapolations from specific areas of (potentially diverse) countries to entire countries and regions;
- different estimates of population structure in the surveys;
- conversion factors to determine the prevalence of best-corrected VA in studies using non-WHO definitions;
- extrapolation to current populations of prevalence data from studies over the last 5–10 years;
- assumptions in obtaining blindness prevalence for people aged 15–49 years;
- reporting bias in the determination of causes of VI in surveys designed for specific pathologies; and
- possible non-standardised definitions of eye diseases, criteria for diagnosis, examination methods and comorbidity.

These limitations flow to all analyses in this report, since global and regional health care costs, informal carer hours, employment impacts, and DWL are all extrapolated from a limited number of areas or countries. Similarly, conversion factors used to adjust prevalence rates to our definitions are from pooled analyses of diverse studies with substantial variances around the mean values.

Second, extrapolation from a limited number of countries requires that relationships between economic and health variables are similar between countries. This limitation is greatest for informal care costs, which were derived from Australia and UK data assuming the required number of care hours to be equal for all countries with similar availability of community care.

Third, as pointed out by Wimo et al (2006), the relationship between GDP and social and health care resources may or may not be valid from a worldwide perspective, particularly when underlying cost studies are from advanced economies. Smith et al (2009) argue that estimating productivity losses using employment rates and GDP attributes no losses to people outside the formal labour force or unemployed. These individuals, especially in more agrarian societies, contribute to the production of goods and services in the household or in informal markets. Therefore, the indirect cost of VI may be underestimated for countries with lower employment-to-population ratios.

Fourth, direct health care costs are likely to vary by cause of VI. In the absence of data the mean subregion cost per person with VI was extrapolated using data from five countries. Although health care costs are adjusted by relative GDP (to proxy health care prices, resource availability, and use) regional costs to some extent reflect the distribution of health conditions in those five countries. This limitation is greater given the five countries are all from developed regions, where diabetic retinopathy and AMD, which are potentially more costly to manage, make greater contributions to the prevalence of VI. Further, as explored in sensitivity analysis, people with URE may incur lower health care costs since their VI may be due to either not seeking health care support or not being given corrective eyewear.

Finally, potential regional variation in other variables extrapolated from a limited number of countries may not be captured in the model.

- For example, the likelihood of time off work due to VI may be associated with types of work that differ between more and less developed economies, affecting the productivity cost estimates.
- The risk of death due to VI may vary as certain country and regional environments may be more likely to result in driving accidents, falls, or other sight-related events.

Conservative extrapolations have been used where possible to minimise the risk of overestimating the global and regional burden of disease using a limited evidence base. Regardless, this study demonstrates a substantial cost and health burden placed on every region of the world due to partial sight and blindness. The global costs include health care system expenditure, informal care, productivity losses due to absenteeism and mortality with VI, and tax inefficiencies in raising funds for government payer health care. Although these costs vary between regions, the substantial figures suggest that strategies to improve population sight have substantial potential to reduce both societal costs and health disabilities associated with VI.

Appendix A: Composition of subregions

Table A.1: WHO subregions used in this study

WHO subregion	Child mortality	Adult mortality	Grouping	Member states
Africa				
AFR-D	High	High	High-mortality developing	Algeria, Angola, Benin, Burkina Faso, Cameroon, Cape Verde, Chad, Comoros, Equatorial Guinea, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Madagascar, Mali, Mauritania, Mauritius, Mayotte, Niger, Nigeria, Reunion, Saint Helena*, Sao Tome and Principe, Senegal, Seychelles*, Sierra Leone, Togo
AFR-E	High	Very high	High-mortality developing	Botswana, Burundi, Central African Republic, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Eritrea, Ethiopia, Kenya, Lesotho, Malawi, Mozambique, Namibia, Rwanda, South Africa, Swaziland, Tanzania, Uganda, Zambia, Zimbabwe
Americas				
AMR-A	Very low	Very low	Developed	Canada, United States, Cuba, Saint Pierre and Miquelon*
AMR-B	Low	Low	Low-mortality developing	Anguilla*, Antigua and Barbuda*, Argentina, Aruba, Bahamas, Barbados, Belize, Bermuda*, Brazil, British Virgin Islands*, Cayman Islands*, Chile, Colombia, Costa Rica, Dominica*, Dominican Republic, El Salvador, Falklands*, Grenada, Guadeloupe, Guyana, Honduras, Jamaica, Martinique, Mexico, Montserrat*, Netherlands Antilles, Panama, Paraguay, Puerto Rico, Saint Kitts and Nevis*, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, Turks and Caicos Islands*, Uruguay, US Virgin islands, Venezuela
AMR-D	High	High	High-mortality developing	Bolivia, Ecuador, Guatemala, Haiti, Nicaragua, Peru
Eastern Mediterranean				
EMR-B	Low	Low	Low-mortality developing	Bahrain, Cyprus, Gaza Strip*, Iran, Jordan, Kuwait, Lebanon, Libya, Oman, Qatar, Saudi Arabia, Syria, Tunisia, United Arab Emirates, West Bank*
EMR-D	High	High	High-mortality developing	Afghanistan, Djibouti, Egypt, Iraq, Morocco, Pakistan, Somalia, Sudan, Western Sahara, Yemen

WHO subregion	Child mortality	Adult mortality	Grouping	Member states
Europe				
EUR-A	Very low	Very low	Developed	Andorra*, Austria, Belgium, Channel Islands, Croatia, Czech Republic, Denmark, Faeroe Islands*, Finland, France, Germany, Gibraltar*, Greece, Greenland*, Holy See*, Iceland, Ireland, Isle of Man*, Israel, Italy, Liechtenstein*, Luxembourg, Malta, Monaco*, Netherlands, Norway, Portugal, San Marino*, Slovenia, Spain, Sweden, Switzerland, United Kingdom
EUR-B1	Low	Low	Developed	Albania, Bosnia and Herzegovina, Bulgaria, Georgia, Kosovo*, Montenegro, Poland, Romania, Serbia, Slovakia, Macedonia, Turkey
EUR-B2	Low	Low	Developed	Armenia, Azerbaijan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan
EUR-C	Low	High	Developed	Belarus, Estonia, Hungary, Kazakhstan, Latvia, Lithuania, Moldova, Russia, Ukraine
South-East Asia				
SEAR-B	Low	Low	Low-mortality developing	Indonesia, Sri Lanka, Thailand, Timor-Leste
SEAR-D	High	High	High-mortality developing	Bangladesh, Bhutan, India, Maldives, Myanmar, Nepal, South Korea,
Western Pacific				
WPR-A1	Very low	Very low	Developed	Australia, Brunei, New Zealand, Singapore
WPR-A2	Very low	Very low	Developed	Japan
WPR-B1	Low	Low	Low-mortality developing	China, Hong Kong, Macau, Mongolia, North Korea, Taiwan*
WPR-B2	Low	Low	Low-mortality developing	Cambodia, Laos, Vietnam
WPR-B3	Low	Low	Low-mortality developing	American Samoa*, Cook Islands*, Fiji, French Polynesia, Guam, Kiribati*, Malaysia, Marshall Islands*, Micronesia, Nauru*, New Caledonia, Niue*, Northern Mariana Islands*, Palau*, Papua New Guinea, Philippines, Pitcairn*, Samoa, Solomon Islands, Tokelau*, Tonga, Tuvalu*, Vanuatu, Wallis and Futuna Islands*

Source: World Health Organisation, Access Economics assumptions

*Excluded from analysis due to lack of age-group specific prevalence data (population <100,000 people or limited UN recognition)

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