**Thirty year projected magnitude (to 2050) of near and distance vision impairment and the economic impact if existing solutions are implemented globally**

Running head: Projections of the reduced global prevalence of VI

**Authors:**

Dr Andrew Bastawrous MRCOphth PhD1

Dr Antti-Ville Suni PhD2

1. International Centre for Eye Health, Clinical Research Department, London School of Hygiene & Tropical Medicine, United Kingdom, email: andrew.bastawrous@lshtm.ac.uk
2. Corresponding author. Fordham University London Centre, W8 5HQ, London, United Kingdom, email: asuni@fordham.edu, tel. +44 20 7937 5023

Number of text pages: 11

This submission has not been published anywhere previously and it is not simultaneously being considered for any other publication.

## Abstract

Purpose. Recent global, regional and country-level prevalence estimates for blindness and vision impairment will be important when designing future public health policies. The aim of this paper is to contribute to this discussion by estimating the productivity impact of known effective interventions to treat all preventable cases of vision impairment at the global, regional and country-level up to 2050. We also provide estimates of potential reduction in the number of people with vision impairment, as well as averted vision impaired years up to 2050.

Methods. We combined recent estimates of the prevalence of blindness, distance and near vision impairment with the World Bank’s World Development Indicators (WDI) and estimated the global, regional and country-level productivity gains up to 2030, 2040 and 2050 from known effective interventions, primarily cataract surgery and treated uncorrected refractive errors. The magnitude of productivity gains relative to baseline depended on population size, estimated current and future prevalence of vision impairment, level of economic development, long-term wage growth and long-term real interest rates.

Results. Globally, we estimate that the number of people affected by blindness could be reduced from the estimated 114.6 million by 2050 to 58.3 million. This would be associated with over one billion blind life-years averted and US$ 984 billion in global productivity gains. These numbers are dwarfed by the impact of interventions to reduce the prevalence of Moderate and Severe Vision Impairment (MSVI) [Presenting Acuity <20/60 to 20/400 in the better seeing eye]. We estimate that the number of people affected by MSVI could be reduced by 435.8 million people to 147.9 million by 2050. This reduction would translate to over 9 billion MSVI -life-years avoided and US$ 17 trillion in productivity gains by 2050. While other causes of VI would not be possible to eliminate completely based on current known effective treatments, low-cost interventions to eliminate VI from uncorrected presbyopia would avert 1.2 billion presbyopia life-years and achieve US$ 1.05 trillion in productivity gains by 2050. In total, the global productivity gains for all three categories are estimated to be US$ 19 trillion by 2050. East Asia makes up the greatest share of productivity gains due to the high number of people affected by VI and the region’s continuing economic growth.

Conclusion.

Implementation of currently known and effective treatments of avoidable blindness, MSVI and presbyopia would be expected to contribute significant productivity gains to the global economy at a fraction of the estimated costs to deliver them.

## Keywords: productivity, vision impairment, blindness, presbyopia

## Introduction

The importance of alleviating avoidable vision impairment has been acknowledged by the World Health Organization, which adopted a Global Action Plan to reduce avoidable vision impairment by 25% from 2010 to 2019. 1 Nevertheless, the magnitude of vision impairment is estimated to increase significantly due to population growth and aging.1 The United Nations estimates that the global population will reach 9.8 billion by 2050.2 17.6% of this population is projected to have distance vision impairment (moderate, severe or blind) or near vision loss, up from 14.5% in 2020, according to the estimates of Global Burden of Disease and Fricke et al (2018).1,3 An estimated 1,079 million people had vision impairment in 2015. Of these, an estimated 36 million people were blind [Presenting Acuity < 20/400 in the better seeing eye]. The number of blind people is expected to grow to 38.5 million people by 2020 and 114.6 million by 2050. At the same time, Moderate and Severe Vision Impairment (MSVI) [Presenting Acuity <20/60 to 20/400 in the better seeing eye] affected an estimated 216.6 million people in 2015. This is expected to increase from 237.1 million in 2020 to 587.6 million by 2050. Finally, an estimated 826 million people were affected by vision impairment from uncorrected presbyopia in 2015.3 This is expected to increase to between 996 million and 1,022 million people by 2050 (Holden et al (2008) and personal correspondence respectively). Holden et al estimated that of the 996 million people that will have uncorrected presbyopia, 789 million will be functionally affected.

At the regional level, by far the greatest number of people with vision impairment are found in South Asia as shown by Table 1. In 2015, there were almost 12 million blind people in South Asia, almost twice the amount of East Asia (6 million people), the second highest number of people who are blind. According to the UN, India’s population will surpass that of China around 2024, which explains the higher potential for reduction of vision impairment by 2050. The number of people with MSVI is somewhat more evenly distributed with over 61 million people with MSVI residing in South Asia and almost 52 million in East Asia. South-East Asia, led by Indonesia, is the third largest region in terms of vision impairment.

The burden of vision impairment is greatest in those over 50 years old with recent estimates approximating that 52.1% of the blind are 70 years old or over. 33.9 % of the blind are estimated to be 50-69 years old and the remaining 13.9% are 49 years old or younger. Of those with MSVI, 38.4% are estimated to be 70 years or older and 41.1% between 50-69 years old. MSVI is slightly more common among younger people than blindness with 20.5% of the population being 49 years or younger.1 There are no similar estimates for presbyopia, but it is estimated that 60.9% of the population is 50 years or older while the rest (39.1%) are between 35-49 years old.1 According to UN estimates, lower fertility rates will lead to older populations in the coming decades. Compared to 2017, the number of people over 60 years old will double by 2050. This is reflected in the estimated growth rates of vision impairment globally.

The World Report on Vision released by WHO on World Sight Day (October 10th, 2019) estimated that “the costs of the coverage gap for unaddressed refractive errors and cataract globally are $14.3 billion US dollars. These are the additional costs that would be required to the current health system using an immediate time horizon…” “…and requires an additional investment to strengthen existing health systems.”

Vision impairment not only affects people’s economic status, but it also decreases their quality of life and increases their risk of death.4 The aim of this paper is to estimate the productivity gains from known and effective interventions to reduce the prevalence of vision impairment primarily from unaddressed refractive errors and cataract.

 We define lost productivity (or productivity gains from alleviation) of vision impairment as lower wages and lower chances of employment among those with VI relative to the population with healthy vision. While productivity is often seen as a separate issue from employment, we have combined these two factors under one estimate to illustrate the direct macroeconomic impact of treating vision impairment. In fact, most existing studies of the productivity impact of vision impairment have focused on the employment gap. In addition to productivity gains, we also estimate global, regional and country-specific reductions in the number of people with distance vision impairment and near vision loss, as well as averted disability years by 2030, 2040 and 2050.

## Methods

Using prevalence data from the Global Burden of Diseases this study estimates the direct productivity impact of treating avoidable vision impairment in 185 countries and 21 Global Burden of Disease regions from 2018 up to 2030, 2040 and 2050. A recent report1 provided country-level estimates of blindness and MSVI for 2015, global estimate of presbyopia in 2015, and global estimates of blindness and MSVI in 2020 and 2050. Since no future country-level estimates were provided, it was assumed that country-level changes reflected global changes up to 2050. Finally, future estimates of uncorrected presbyopia for 2020 and 2050 were taken from a recent (2018) meta-analysis.3 Since country-specific estimates for presbyopia were also missing, the global presbyopia population was divided by countries according to their population and prevalence of MSVI.

Economic data for all countries was taken from the World Bank’s World Development Indicators database. Current wages were estimated as reported Gross National Income (GNI) per capita figures for 2015 (Atlas method, current US$). Real wage growth was calculated as the 10-year compound annual growth rate of Gross Domestic Product (GDP) per employed people at constant prices in local currency since the 10-year time series for GDP was more complete than that for GNI. Real wage growth for 2018-2020 was estimated as equal to the growth rate over the past 10 years. Real wage growth for 2021-2050 was capped to the range of 0-5% per annum. For example, China’s annual growth rate over the last 10 years has been around 8%, but it has already begun to slow down and is generally expected to remain at lower levels over the coming years. At the same time, several countries have experienced negative growth over the last decade, which is not expected to continue long-term. However, there are real concerns that long-term growth rates and real interest rates are likely to be low especially in the US and Europe due to structural economic changes.5

We discounted all future productivity gains (2018-2050) to the end of 2017 using the 10-year median real interest rate of each country as reported by the World Bank. Due to the financial crisis, many countries have experienced negative real interest rates during this period. For more sensible estimates of future productivity gains, we used zero interest rates in place of negative rates. However, we did not limit the maximum real interest because our goal was to estimate the economic costs of vision impairment given a country’s true cost of capital. Zimbabwe had a staggering interest rate of 541% while Madagascar had the second highest rate at 50%. Such high rates naturally render the value of any future productivity gains nil. The median interest rate was a reasonable 5.3% and the GNI-weighted rate was 3.95%.

The study focused on direct productivity benefits of treating vision impairment. These benefits include higher wages and higher chances of employment of those without vision impairment. The employment gap between those with blindness or MSVI and those with healthy vision was assumed to be 50% globally. The employment gap is likely to vary significantly by country, but 50% was a reasonable assumption in the absence of reliable country-level estimates for more than a handful of countries.6,7 Due to lack of reliable estimates, we made no assumptions of the employment gap of presbyopia.

There are even fewer existing estimates for the wage gap between those with vision impairment and those without impairment. We assumed a global wage gap of 29.7% for those with MSVI and 36.5% for those who are blind as previously observed in the US.8 Again, since there were no reliable estimates of the wage effect for presbyopia, we used the disability weight of 0.011 as reported by the Global Burden of Disease in 2013.9 The disability weight was therefore the only cost factor for presbyopia as no employment gap was assumed.

We assumed a global working age of 15-64 years. There are no exact estimates of the break-down of blindness, MSVI or presbyopia by age. Therefore, based on the broader estimates discussed earlier, we estimated that 40% of the blind population were of working age. For MSVI and presbyopia, these ratios were estimated to be 50% and 55%, respectively. These ratios were held constant up to 2050.

We used two approaches or criteria to estimate potential interventions to reduce avoidable MSVI and blindness. The first approach was to use the country with the lowest prevalence blindness or MSVI as a benchmark for the potential lowest level of vision impairment. The second approach was to assume that 75% of the population with MSVI or blindness could be prevented as defined by “avoidable” causes of vision loss, primarily cataract and uncorrected refractive error. In each case, we chose the approach that implied a less ambitious intervention. In the case of blindness, for most countries, this translated to aspiring to reach the prevalence level of Brunei (0.06%). In the case of MSVI, there was much more variation in terms of the two goals. The United Arab Emirates has the lowest prevalence of 0.73%. For most countries, this level turned out to be too ambitious considering our second criteria. 75% reduction in prevalence turned out to be the more achievable goal for many countries. In the case of uncorrected presbyopia, we assumed that there was a low-cost treatment for 100% of the population. Therefore, we assumed that 100% of presbyopia cases could be prevented.

To calculate the productivity gains of averted blindness and MSVI (PRBM), we used the following equation:

$PRBM = \sum\_{i=1}^{n}\frac{[\left(φ × \left(1 + μ\right)^{i} × \left(ε- γ\right)× δ × \left(1 + σ\right)^{i} + φ × \left(1 + μ\right)^{i} × γ × δ × \left(1 + σ\right)^{i} × θ\right) × ρ ] }{(1+ τ)^{i}}$

To calculate the productivity gains of averted presbyopia (PRBR), we used the following equation:

$PRBR= \sum\_{i=1}^{n}\frac{\left(φ × \left(1 + μ\right)^{i} × ε × δ × \left(1 + σ\right)^{i} × θ × ρ\right) }{(1+ τ)^{i}}$

Where:

 $φ=avoided cases of vision impairment in year 2015 $

 $μ=compound annual growth rate of vision impairment$

 $ε=employment rate$

 $γ=employment rate among those with vision impairment$

 $δ=GNI per capita (current US\$)$

 $σ=real wage growth $

 $θ=wage effect of vision impairment$

 $ρ=share of working age population among visually impaired$

 $τ=real interest rate$

The calculation of productivity gains from averted MSVI/blindness differs from that of presbyopia in that the employment gap is considered only in the former case.

## Results

Our study suggests that the productivity effects of vision impairment may be much higher than previously estimated. We estimate that the total global productivity gains from treating avoidable blindness, MSVI and presbyopia is around US$ 19 trillion over a period of 2018-2050. To put this number into perspective, we estimate that the discounted productivity gains during the year 2020 will be US$ 372 billion, which is equivalent to US$ 338 per person with vision impairment (1.1 billion people). This would constitute 0.45% of an estimated US$ 83.28 trillion global GNI. In 2050, the discounted productivity gains will be an estimated US$ 920.5 billion, forming 0.52% of global GNI of US$ 177 trillion. The reason why the discounted productivity gains only get larger is that the annual growth rate of vision impairment cancels out the discount factor, leaving only real wage growth to influence the magnitude of future productivity gains.

MSVI forms the largest share of all productivity gains by 2050, making up US$ 17 trillion. Productivity gains from averted blindness are estimated at US$ 984 billion. Productivity gains from averted uncorrected presbyopia vary between US$ 907 billion and US$ 1.05 trillion, depending on the estimate of uncorrected presbyopia population in 2050 (789 million in 2050 as estimated by Holden et al 2008 versus 1022 million in Fricke et al 2018).

At the regional level, the greatest productivity gains would take place in East Asia, almost solely because of China’s current and future economic influence. North America comes in a distant second place and Western Europe in third place. It is notable that the largest region in terms of vision impairment, namely South Asia, falls far behind in terms of productivity gains due to its low levels of development.

## Discussion

This study is the first to quantify the global economic impact of treating blindness, MSVI and presbyopia while taking into account population growth and aging up to 2050. Previous studies have focused on fewer causes of vision impairment10 shorter time period,10 more limited geography,6,8,11,12 or a combination of these factors.13-15 While many of these and other studies look at a broader social impact of vision impairment, the study focuses on the productivity gains from treating preventable cases of blindness, MSVI, and presbyopia. To estimate realistic country-level differences in economic impact, this study takes into account differences in future real-wage growth rates and real interest rates. Most existing studies assume universal levels of wage growth and discount rates which leads to under- or overestimating country-specific economic impacts.

This study has illustrated how significant the productivity gains are that result from interventions to reduce the prevalence of vision impairment. At the same time, it is clear that, in absolute terms, the productivity gains are larger in more affluent countries regardless of the high numbers of persons with vision impairment in regions such South Asia and Africa. As a share of GNI, productivity gains are largest in areas with the highest number of vision impaired people, particularly in East Asia (0.64% in 2020). They are lowest in Central Asia (0.09% in 2020).

There are costs associated with vision impairment, which this study did not account for. Several existing studies also assign an economic value to Disability Adjusted Life Years (DALYs), which serves as a proxy for the impact of vision impairment on the quality of life.6 The study also ignored the economic impact of vision impairment-related deaths. While it was assumed that estimates of future prevalence take into account potentially shorter lifespans of those with vision impairment, lost life years arguably have intrinsic and economic value. Moreover, the study did not take into account the economic savings due to avoided healthcare costs of vision impairment. While these costs may be relatively significant, they have been documented well by other studies.16 Similarly, we ignored the deadweight loss related to raising taxes to pay for these additional healthcare costs. Since no future country-level estimates were provided, it was assumed that country-level changes reflected global changes up to 2050 however in reality demographic shifts will vary throughout the globe. Finally, the study did not account for informal care costs of those with VI. These costs are difficult to quantify reliably, but they are likely to be relatively insignificant for MSVI.16 It is estimated that blind people in India require 10% of the productive time of one member of a family.11 Although these economic costs are likely to be small compared to direct productivity gains, further studies should attempt to quantify these costs up to 2050.

Estimates have been made on the cost to eliminate avoidable vision impairment. In those with avoidable blindness (accounting for 75% of all blindness globally) the cost has been estimated at $40 Billion globally per year or $5.80 per person over a ten-year period.17 The cost of establishing and operating the educational and refractive care facilities required to deal with vision impairment resulting from URE (the majority of MSVI) was estimated at an upper-limit total cost of $28 Billion.18 These costs are a fraction of the economic gain from providing access to affordable vision services providing not just huge economic and productivity gains, but also major social, educational and health gains. At a time in history where the majority of the world living with sight loss does not need to due to existing, cost-effective solutions, the delivery of the solutions must be prioritised.

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Table 1. Regional blind and MSVI baseline and projected with potential productivity gains

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| GBD Region | Blind Population 2015 | Blind population 2050 baseline | Potential reduction in blindness by 2050 | Productivity gains blind by 2050 | MSVI population 2015 | MSVI population 2050 baseline | Potential reduction in MSVI by 2050  | Productivity gains MSVI by 2050 | Presbyopia Population 2015 | Presbyopia population 2050 baseline | Productivity gains presbyopia by 2050 |
| South Asia | 11,764,857 | 37,451,461 | 23,487,453 | 115,279,474,220 | 61,152,287 | 165,896,048 | 124,422,036 | 797,878,335,376 | 234,764,784 | 290,471,682 | 48,907,524,953 |
| East Asia | 6,075,711 | 19,341,015 | 7,283,413 | 400,261,915,578 | 51,771,462 | 140,447,420 | 105,335,565 | 7,164,146,620,406 | 198,751,620 | 245,913,022 | 424,535,427,452 |
| South-East Asia | 3,541,764 | 11,274,614 | 5,737,804 | 60,316,650,511 | 20,762,884 | 56,326,273 | 42,244,705 | 544,737,939,678 | 79,709,104 | 98,623,129 | 34,541,635,017 |
| North Africa and Middle East | 3,501,757 | 11,147,260 | 6,594,163 | 92,098,070,333 | 18,352,999 | 49,788,654 | 37,036,500 | 740,433,991,130 | 70,457,511 | 87,176,242 | 48,876,847,677 |
| Western Europe | 1,175,444 | 3,741,830 | 865,370 | 54,194,075,347 | 9,719,414 | 26,367,163 | 19,699,336 | 1,961,274,818,251 | 37,313,013 | 46,166,948 | 126,879,920,053 |
| North America | 966,902 | 3,077,972 | 652,594 | 97,700,300,209 | 7,443,300 | 20,192,443 | 15,144,332 | 2,840,631,773,222 | 28,574,969 | 35,355,471 | 178,925,307,768 |
| Western Sub-Saharan Africa | 1,771,252 | 5,638,486 | 2,557,729 | 7,273,561,679 | 7,334,459 | 19,897,174 | 14,816,740 | 63,769,839,275 | 28,157,125 | 34,838,477 | 4,150,153,185 |
| Eastern Europe | 860,750 | 2,740,054 | 990,991 | 35,781,495,455 | 6,333,297 | 17,181,188 | 12,885,891 | 625,349,188,759 | 24,313,647 | 30,082,986 | 37,674,558,848 |
| Eastern Sub-Saharan Africa | 1,681,522 | 5,352,846 | 2,725,348 | 19,305,223,296 | 6,295,556 | 17,078,803 | 11,889,216 | 63,112,686,868 | 24,168,759 | 29,903,718 | 3,889,833,853 |
| Asia Pacific | 554,635 | 1,765,587 | 461,778 | 46,973,915,559 | 5,037,466 | 13,665,813 | 10,243,135 | 1,249,045,064,855 | 19,338,928 | 23,927,826 | 78,771,817,766 |
| Central Latin America | 965,107 | 3,072,258 | 1,053,343 | 18,320,965,738 | 4,851,697 | 13,161,853 | 9,831,033 | 241,481,994,452 | 18,625,757 | 23,045,428 | 15,484,574,546 |
| Tropical Latin America | 709,554 | 2,258,746 | 620,809 | 1,244,048,976 | 3,452,969 | 9,367,334 | 7,025,501 | 19,467,487,582 | 13,256,013 | 16,401,508 | 1,672,189,673 |
| Central Europe | 523,809 | 1,667,460 | 697,315 | 11,847,986,173 | 2,785,272 | 7,555,982 | 5,666,986 | 128,499,568,429 | 10,692,711 | 13,229,964 | 8,534,603,631 |
| Central Sub-Saharan Africa | 317,094 | 1,009,417 | 217,430 | 702,429,601 | 2,070,293 | 5,616,363 | 4,030,038 | 9,972,797,541 | 7,947,895 | 9,833,836 | 810,304,932 |
| Andean Latin America | 273,269 | 869,907 | 356,257 | 3,746,924,459 | 1,700,024 | 4,611,883 | 3,458,913 | 45,540,470,745 | 6,526,423 | 8,075,066 | 2,967,136,063 |
| Central Asia | 249,847 | 795,346 | 233,811 | 2,610,426,283 | 1,605,440 | 4,355,294 | 3,172,793 | 61,699,488,637 | 6,163,315 | 7,625,796 | 3,887,835,586 |
| Southern Latin America | 168,277 | 535,683 | 123,443 | 5,365,760,933 | 1,530,267 | 4,151,361 | 3,113,521 | 176,452,541,168 | 5,874,723 | 7,268,725 | 10,800,433,426 |
| Southern Sub-Saharan Africa | 423,950 | 1,349,574 | 656,361 | 4,904,711,733 | 1,242,767 | 3,371,422 | 2,278,248 | 23,405,365,942 | 4,771,006 | 5,903,110 | 1,547,232,572 |
| Caribbean | 218,054 | 694,138 | 368,638 | 1,675,040,991 | 907,037 | 2,460,642 | 1,843,509 | 12,611,291,823 | 3,482,134 | 4,308,403 | 891,546,659 |
| Australasia | 67,032 | 213,386 | 37,727 | 4,332,184,800 | 631,185 | 1,712,301 | 1,284,226 | 184,297,319,580 | 2,423,131 | 2,998,112 | 12,089,956,732 |
| Oceania | 40,794 | 129,862 | 45,444 | 304,719,719 | 179,065 | 485,772 | 364,129 | 3,144,423,971 | 687,432 | 850,552 | 200,490,966 |
| World | 35,851,383 | 114,126,902 | 55,767,221 | 984,239,881,594 | 215,159,141 | 583,691,187 | 435,786,352 | 16,956,953,007,691 | 826,000,000 | 1,022,000,000 | 1,046,039,331,357 |