IAPB Vision Atlas

Better education in sight.

An estimate of global learning and economic productivity losses from uncorrected refractive error in schools.

IAPB Evidence Series: co-led with the Seva Foundation.

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A report for World Sight Day 2024

Authors: Parami Dhakhwa, Bryce Everett, Brad Wong.

LOVE YOUR EYES

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Better education in sight. An estimate of global learning and economic productivity losses from uncorrected refractive error in schools

Parami Dhakhwa, Seva Foundation
Bryce Everett, Mettalytics
Brad Wong, Seva Foundation

Abstract

Every school day, millions of children around the world go to class with uncorrected refractive error. Children with myopia, astigmatism or hyperopia, who do not have glasses are unable to see blackboards and books, learning much less than their peers. Using a systematic review and meta-analysis of randomized-controlled trials, we estimate that a child with poor vision learns approximately half as much as a child with good or corrected vision. This implies a substantial gain from correcting vision - for example, if a five-year-old is provided with glasses in primary school and continues to wear them until they are 18, they will earn 78% more lifetime income than if they never had their vision corrected. We then estimate the total "equivalent years of schooling" and future global productivity loss associated with uncorrected refractive error for those aged 5-17 enrolled in school. Our estimates suggest that

***one year* of sub-optimal learning** due to poor vision generates
6.3 million equivalent years of schooling loss globally (95% CI: 2.7 to 9.7 million)

and a **future economic productivity loss of $173 billion** (purchasing power parity, PPP in 2022 international dollars) with a **95% confidence interval of $83 billion to $246 billion** (PPP) in present value terms.

While the economic loss is split roughly 50:50 between high income and low-and-middle-income countries (LMICs), **83% of the total equivalent years of schooling loss is concentrated in LMICs**.

1. Introduction

According to the Global Burden of Disease, 17.8 million children aged 5-17 live with uncorrected refractive error.[1] Intuitively, one would expect that children with myopia, hyperopia or astigmatism would have more difficulties learning than their peers with good vision. As illustrated in Figure 1, a child with myopia will have trouble seeing the blackboard. Children with hyperopia will have difficulties focusing on nearby objects such as books, and children with astigmatism may have difficulties focusing on near and far objects. In all cases there will likely be detrimental consequences for their understanding of the curriculum and their ability to learn.

And yet, while it makes intuitive sense that a child with poor vision will learn less, to the best of our knowledge there is no systematic estimate of the expected learning losses associated with poor vision. Moreover, there is no published estimate of the future economic impacts that would result from this learning loss. The aim of this report is to fill this evidence gap.

Figure 1: Comparison of clear vision (left) and blurry vision (right) associated with myopia of -2 dioptres (Source: CooperVision, https://coopervision.com/myopia-simulator).

Utilizing a previous systematic review of learning impacts,[2] we conduct a meta-analysis of randomized-controlled-trials that estimate the learning impacts from the provision of glasses. We use the results from the meta-analysis to estimate the equivalent years of schooling (EYOS) loss associated with uncorrected refractive error, for each age cohort (5-17 years old) and for every country. This provides us with an estimate of the total years of schooling loss from refractive error. To estimate the foregone income resulting from a failure to provide glasses in schools, we apply the years of schooling loss to country-specific returns to education along with other assumptions about school enrolment rates, discount rates and future income. Our approach implies a substantial gain from correcting vision - if a five-year-old is provided with glasses in primary school and continues to wear them until they leave school at age 18, they will earn 78% more lifetime income on average than if they never had their vision corrected. With all forms of visual impairment expected to increase in prevalence over the coming decades,[3] the loss will likely increase in the future if no further action is taken to address uncorrected refractive error in schools.

2. Methods

2.1. Meta-analysis and individual years of schooling loss from uncorrected refractive error

The starting point of the meta-analysis are the results of a previously published systematic review.[2] That review examined the non-health impacts of providing glasses or cataract surgery including learning gains in schools. From the review we focus only on randomized-controlled trials, typically the most rigorous source of evidence. To avoid over-representation of study populations, we remove studies where the same research subjects are already included in a different study.

Our outcome of interest is the reported intent-to-treat (ITT) effect size (plus confidence intervals), measured in standard deviation improvement in test scores of the treatment group, relative to the control group. The summary measure of impacts is based on a random-effects model.

We interpreted the intent-to-treat estimates considering the reported eyeglasses compliance of each study to generate an 'average-treatment effect on the treated' (ATT) measure. The ATT measure is the estimated learning gain from actually wearing glasses rather than being merely offered them. This is a more appropriate metric for use in global costing studies, such as the current one, that seek to measure the total loss associated with a sub-optimal state of the world (in this case, uncorrected refractive error in school children - See Box 1 for further details). The steps for converting the ITT effect to an ATT effect is outlined below.

1. Estimate ATT effect for compliers. This is given by:

$$ATT_{compliers} = ITT \,/\, compliance\ rate \text{ (Eq. 1)}$$

where *ITT* is the effect from the meta-analysis, the compliance rate is the percentage of individuals in the treatment group who complied with treatment across all studies. This equation assumes that non-compliers experience zero impact relative to the control group.

2. Estimate the ATT effect for non-compliers if they had complied. This is given by:

$$ATT_{non-compliers} = ATT_{compliers} * [RE_{non-compliers} / RE_{compliers}] \text{ (Eq. 2)}$$

where *RE* is the average refractive error, measured in dioptres for compliers or non-compliers and $ATT_{compliers}$ is given by equation 1. This step accounts for the fact that non-compliers have lower refractive error than compliers.[4] Therefore, if non-compliers would have complied with treatment, they would likely experience lower benefits than the compliers. The equation assumes that the ratio of ATT effect between compliers and non-compliers is proportional to the ratio of refractive error strength between the two groups. For this analysis, we use the ratio of refractive error strength reported by Du and colleagues,[4] which is that compliers have a refractive error power of -1.66 while non-compliers have a refractive error power of -1.40.

[1] Since the meta-analysis only focused on low-and-middle-income countries, we augmented the pool of available studies by conducting a literature search for randomized-controlled trials conducted in high-income settings, including a forward and backward citation search. We identified two studies that were relevant. However, the structure of the RCTs and unavailability of relevant data such as compliance rates meant we could not include them in the EYOS calculation. Further details on these two studies are included in the appendix C.

3. Estimate the average ATT effect. This is given by:

$$ATT = \%share_{compliers} * ATT_{compliers} + \%share_{non-compliers} * ATT_{non-compliers} \quad \text{(Eq. 3)}$$

The third equation generates an average ATT effect as the weighted (by share of individuals complying or not complying) ATT effect of compliers and non-compliers from equations 1 and 2.

4. Estimate the equivalent years of schooling loss per child with refractive error.

$$Individual\ EYOS\ loss = ATT\ /\ BAU\ learning\ gain \quad \text{(Eq.4)}$$

where ATT is given from equation 3, and the 'BAU learning gain' is what a typical child, without refractive error learns in a year measured in standard deviation of test score improvements. The *individual EYOS* is a number that can be interpreted as the equivalent years of schooling that are lost because the child did not wear glasses for that year.

Box 1: Interpreting effect sizes from randomized controlled trials

Typically, the headline result of a trial is reported as the 'intent-to-treat' estimate. This is the effect of the metric of interest for those *assigned* to the treatment group, relative to those *assigned* to the control group. Importantly, there is no requirement that the individuals in the treatment group experience the intervention being tested in the trial. Therefore, the intent-to-treat estimate embeds 'real-world' implementation idiosyncrasies that typically lower the overall impact of the intervention, such as non-compliance with treatment.

In the case of the current study, this means that all children included in glasses treatment groups are analyzed together even if a proportion do not wear the glasses. This implies that reported effect sizes are a weighted average of those who wore glasses, presumably with some positive effect, and those that did not, presumably with a null or zero effect, relative to the control group. The intent-to-treat estimate is a useful measure for estimating the potential impacts if the intervention were to be scaled in a similar context and for related analyses such as economic evaluations since it incorporates real-world inefficiencies like non-compliance.

Randomized controlled trials often report 'average treatment effects on the treated' also known as the 'per-protocol effect'. This is the impact associated with those who actually experienced the intervention under investigation. For the purposes of this study, which aims to estimate the learning and economic losses with having uncorrected refractive error in school, this is a more appropriate measure to adopt, as it is not 'diluted' by those who did not wear glasses despite being assigned to treatment.

2.2 Estimate of equivalent years of schooling loss

We estimate the equivalent years of schooling loss by the following equation across 168 countries for which we have data:

$$Global\ EYOS\ loss = \sum_{j=1}^{168}\left[\sum_{a=5}^{11}\left(Indiv.\ EYOS\ loss * n_{j,a} * k_{j,pri}\right) + \sum_{a=12}^{17}\left(Indiv.\ EYOS\ loss * n_{j,a} * k_{j,sec}\right)\right] \quad \text{(Eq. 5)}$$

In the above, *Individual EYOS* is the equivalent year of schooling loss per child stemming from uncorrected refractive error (estimated in the equation 4), *n* is the number of children with refractive error for each age cohort, *a*, from 5 to 17 in country *j*, (linearly interpolated from Global Burden of Disease, 2021 country-specific 5-year age cohorts);[1] *k* is the net enrolment rate for primary or secondary school in each country, drawn from World Bank Development Indicators.[5] This reflects the fact that only children in school will experience a learning loss from refractive error. Learning loss is proportional to enrollment, meaning regions with lower enrollment will experience smaller losses from uncorrected refractive error. We provide further disaggregation of the total annual global loss by World Bank income classification, World Bank region and age groups.

2.3. Estimate of future income loss

For each age cohort and each country, we estimate the per child income loss according to the following equation:

$$Loss = Expected\ income\ with\ good\ vision - Expected\ income\ with\ uncorrected\ refractive\ error \quad \text{(Eq. 6)}$$

For each age-country cohort, we assume that the expected income with good vision is proxied by the time series of future GDP per capita of the country, multiplied by a constant labor force participation rate.[5] We assume each child enters the labor force at age 18 and works until age 64, such that for example, 17 year olds will start working one year from now while five-year olds will start working 13 years from now. The use of GDP per capita * labor force participation rate as a proxy for average income follows a recent study that estimated the employment losses associated with moderate and severe visual impairment as well as blindness.[6]

The time series of future GDP per capita is estimated by taking the most recent GDP per capita estimate for each country[5] and applying the time series of projected real GDP per capita growth rates from the International Institute of Applied Systems Analysis, using Shared Socioeconomic Pathways 'the middle-of-the-road' scenario.[7] Country specific discount rates are estimated by multiplying the short term (five-year) average of GDP per capita growth rate x 1.4 and adding 1 percent.[8] Country specific discount rates are used to estimate the present value of the time series of income.

Income with uncorrected refractive error is estimated as a percentage reduction in the reference income that draws upon the findings of the meta-analysis. Specifically:

$$Expected\ income\ with\ uncorrected\ refractive\ error = \frac{Expected\ income\ with\ good\ vision}{(1+Individual\ EYOS\ loss * r)^{t}} \quad \text{(Eq. 7)}$$

Where *Individual EYOS loss* is given by equation 4 and *r* is the country specific returns to one year of schooling, and where country specific estimates were not available we assumed a return of 10%.[9] For example, if uncorrected refractive error causes learning loss equivalent to half a year of normal schooling, and each year of schooling delivers a 10% boost to future income, then the % income loss is 0.5 * 10% = 5%. The superscript *t* is the number of years in school with refractive error which for a five-year old is 13, and for a 17-year-old is 1.

The economic loss per child is given by the difference between the expected income with uncorrected refractive error less the expected income with good vision. Generally, *(1 + Individual EYOS loss * r) ^t* provides the expected loss of income in percentage terms for a child who experiences sub-optimal learning for *t* years.

Lastly, we sum up the entire losses for all children in 168 countries for which we have data, with each individual country denoted by the subscript *j*. Specifically:

$$Annual\ global\ loss = \sum_{j=1}^{168}\left[\sum_{a=5}^{11}\frac{(Indiv.\ economic\ loss * n_{j,a} * k_{j,pri})}{t_a} + \sum_{a=12}^{17}\frac{(Indiv.\ economic\ loss * n_{j,a} * k_{j,sec})}{t_a}\right] \quad \text{(Eq. 8)}$$

As discussed in Section 2.2, n is the number of children with refractive error for cohort a, in country *j,* with data drawn from the Global Burden of Disease, 2021;[1] *k* is the net enrolment rate for primary or secondary in each country, drawn from World Bank Development Indicators.[5] The division of each term in the summation operator by the number of relevant years of benefit for cohort *a,* t_a, converts the cumulative loss incurred over multiple years of refractive error to an (approximate) equivalent annual loss. We provide further disaggregation of the total annual global loss by World Bank income classification, World Bank region and age groups.

3. Results

3.1 Meta-analysis

The systematic review by Wong and colleagues[2] identified multiple randomized controlled trials that estimated the impacts of providing glasses on learning outcomes. Of these, four were included in the meta-analysis corresponding to five different effect sizes.[10–13] Two randomized-control trials were excluded because they appear to report impacts on a similar or the same study population as the included papers.[14,15] Lastly, one study was excluded[16] due to the large reported effect size, 9.5x the median effect size in global education RCTs.[17]

A summary of included studies is presented in Table 1.

Table 1: Summary of papers included in the meta-analysis of glasses provision on learning.

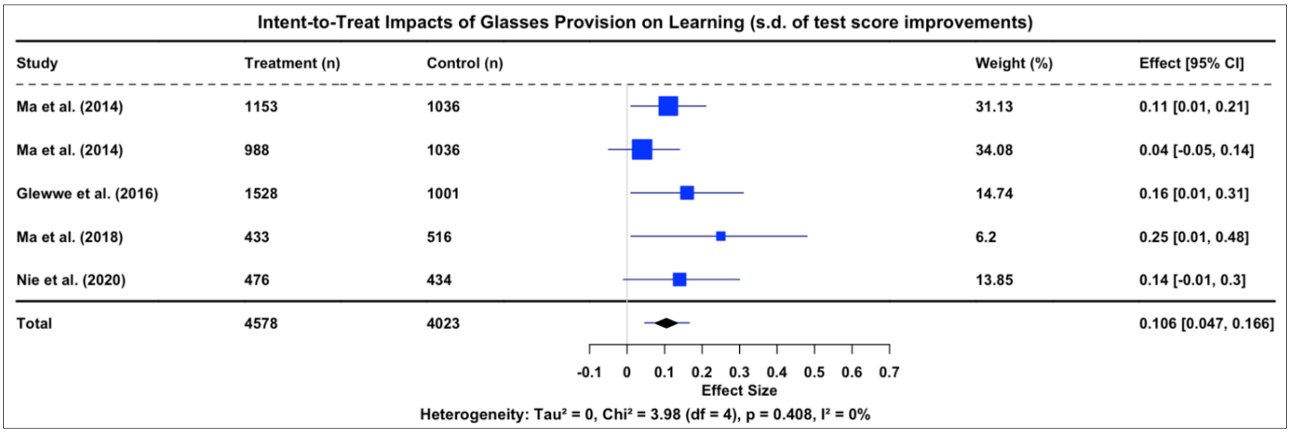
Paper	Description of Intervention and Study Setting	Intent-to-Treat Effect Size (s.d. improvement in test scores)	Type of Test	Acceptance or compliance with glasses*
Glewwe et al (2015)	Delivery of free eyeglasses at school following eye examination to students at rural primary schools in grades 4–6 in two counties of Gansu province, China, 2004	0.16	Chinese, mathematics, science	70%
Ma et al (2014)	Delivery of free eyeglasses at school following eye examination to students at rural primary schools in grades 4–5 in Tianshui prefecture, Gansu province and Yulin prefecture, Shaanxi province, China, 2012	0.11	Mathematics	41%
Ma et al (2014)	Provision of vouchers for eyeglasses collectable from vision center to students at rural primary schools in grades 4–5 in Tianshui prefecture, Gansu province and Yulin prefecture, Shaanxi province, China, 2012	0.04	Mathematics	37%
Ma et al (2018)	Teacher screening + referral to nearby vision center for students at rural primary schools in grades 4–6 in Yongshou county, Gansu province, China; 2014	0.25	Mathematics	75%
Nie et al (2020)	Vision screening + provision of free glasses to grade 7–8 junior high school students in Shaanxi province, China; 2014	0.14	Mathematics	72%

* Glewwe et al. (2016) reports acceptance of glasses by parents, Ma et al. (2014) represents observed compliance at end line, Ma et al. (2018) and Nie et al. (2020) report self-assessed compliance.

All studies are from just one country: China, and no experiments were conducted later than 2014. The effect sizes, measured as standard deviation improvement in test scores, range from 0.04 to 0.25, with all except one representing mathematics test score improvements. We include a measure of acceptance or compliance with glasses to contextualize the effect sizes. Of note, the lowest intent-to-treat effect sizes are associated with the lowest rates of compliance, particularly in the 2014 study by Ma and colleagues.

A forest plot of the meta-analysis is presented in Figure 2 and shows that the summary measure of learning impact from glasses across 8,593 subjects is 0.106 (95% CI: 0.047, 0.166).

Figure 2: Forest Plot of RCTs estimating learning impacts of eyeglasses in LMICs



As discussed in the methods section, the intent-to-treat estimate of 0.106 is not the most appropriate measure of the true estimate of learning losses from refractive error, as it embeds substantial non-compliance. We estimate the 'weighted-average' compliance across the interventions, using the same weightings used to estimate the effect size, identifying an overall compliance rate of 50%.

Using the approach documented in the methodology, Section 2.1, we estimate the average ATT effect at 0.197.

Specifically:

- The ATT effect of compliers is 0.213 standard deviation test score improvements (0.106 / 50% = 0.213)
- The ATT effect of non-compliers *if they had complied* is 0.180 (0.213 * 1.40/1.66) standard deviation test score improvements
- The average ATT effect is 0.197 (0.213 * 50% + 0.180 * 50%) standard deviation test score improvements

How many equivalent years of schooling does this represent? Different education systems deliver substantially different levels of learning.[16] Fortunately, all included studies are from one country, so we can benchmark the summary finding to the average improvement in that country from one year of schooling. Glewwe and colleagues[12] report that the average learning gain in their study of Chinese students with good vision was 0.44 standard deviation improvement in test scores. This suggests that the ATT effect can be described as just under half a year of 'business-as-usual' schooling in expectation (0.197 / 0.44 = 0.45) with a 95% confidence interval between a fifth (20%) and two-thirds (69%) of a school year. In other words, children with uncorrected refractive error learn about half as much as their peers with good vision.

3.2 Equivalent Years of Schooling and Economic Loss from Uncorrected Refractive Error in School Children

The annual economic loss in future income associated with uncorrected refractive error is $173 billion (PPP) with a 95% confidence interval between $83 billion and $246 billion (Table 2, Panel A). The average income loss per child is $9,753 (PPP) per year, and the total equivalent years of schooling lost per year is 6.3 million.

Table 2: Equivalent Years of Schooling and Economic loss from Uncorrected Refractive Error.

	NPV of economic loss from one year of uncorrected refractive error (PPP $millions)	**School going children with refractive error in 2021 (000s)**	**Average income loss per child with uncorrected refractive error per year (PPP)**	**Equivalent years of schooling lost per year**
Panel A: All countries				
All (n=168)	173,117	17,750	9,753	6,267,118
Panel B: Results by World Bank income classification				
High income (n =55)	96,936	2,508	38,648	1,042,508
Low-and-middle-income (n=113)	76,182	15,242	4,998	5,224,610
Low income (n=20)	1,227	1,140	1,076	274,649
Lower middle income (n=47)	19,665	8,159	2,409	2,685,186
Upper middle income (n=46)	55,300	5,943	9,305	2,264,775
Panel C: Results by World Bank region				
East Asia & Pacific (n=22)	44,577	4,374	10,190	1,630,721
Europe & Central Asia (n=47)	41,335	1,731	23,874	716,335
Latin America & Caribbean (n=28)	21,075	1,997	10,553	771,608
Middle East & North Africa (n=18)	13,831	1,696	8,154	661,256
North America (n=2)	37,874	637	59,378	266,850
South Asia (n=6)	9,472	4,801	1,973	1,581,289
Sub-Saharan Africa (n=45)	4,953	2,512	1,972	639,058
Panel D: Results by age group				
5-11 year old children	80,053	9,323	10,486	3,732,750
12-17 year old children	93,064	8,427	13,934	2,534,368

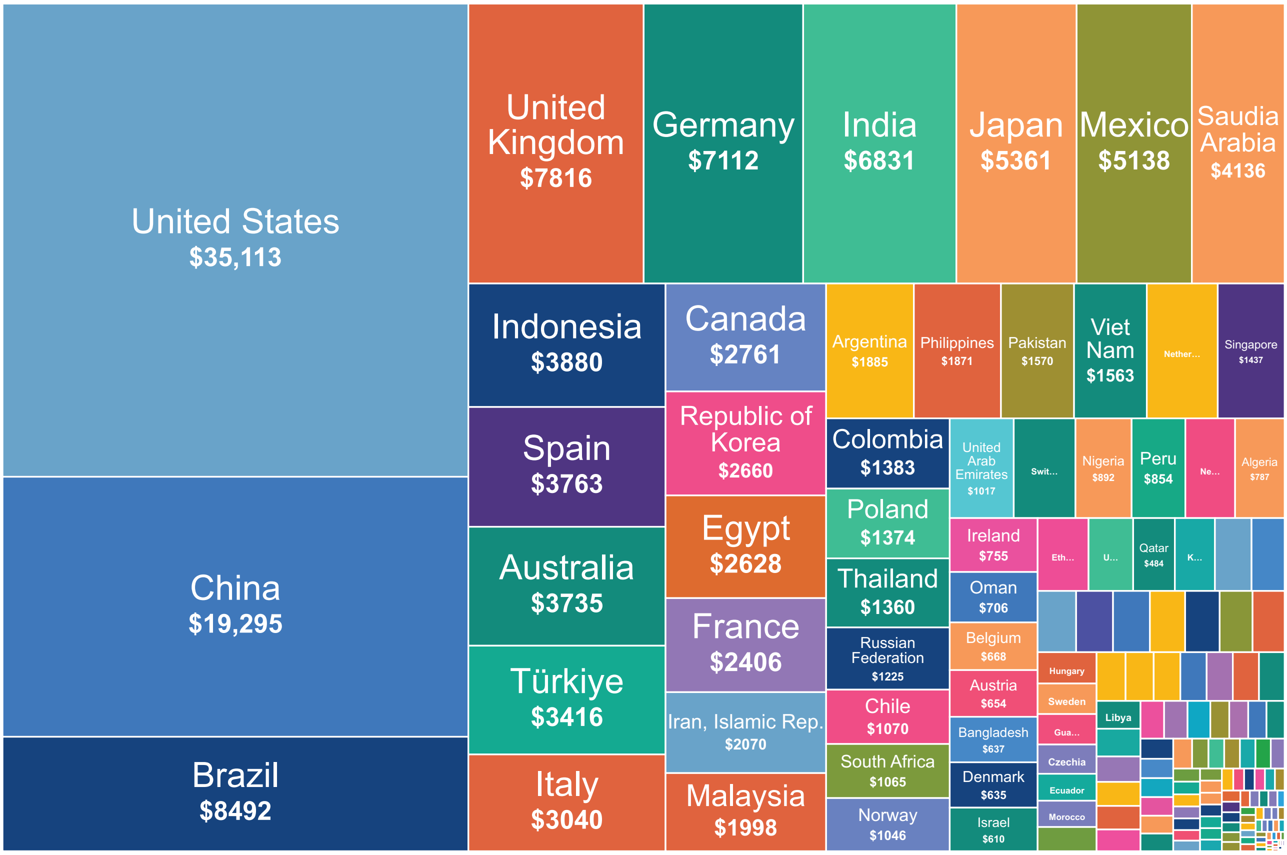
NPV: Net Present Value; PPP: Purchasing Power Parity

The total figure obscures substantial heterogeneity by income grouping. Table 2, Panel B demonstrates that the split of economic cost between high income countries (HICs) and LMICs is 56% to 44%. However, the loss of equivalent years of schooling is overwhelmingly in LMICs, which experience 83% of the total global learning loss. This is because most of the uncorrected refractive error is in LMICs. We can reconcile the two findings by noting that the average income loss per child is substantially higher in HICs ($38,648 PPP per child) than in LMICs ($4,998 PPP per child).

Additional disaggregation by regions demonstrate that the highest economic cost is in East Asia and the Pacific ($44,577 million PPP), Europe and Central Asia ($41,335 million PPP) and North America ($37,874 million PPP). The regions with the greatest equivalent years of schooling lost are East Asia and the Pacific (1.63 million) and South Asia (1.58 million), mostly driven by China and India respectively.

In terms of age groupings, there is a higher economic loss in 12-17 year olds ($93,064 million PPP) than in 5-11 year olds ($80,053 million PPP). This is predominantly because 12-17 year olds are closer to working age, and their future earnings are not discounted by as large a factor as their counterpart. With regard to equivalent years of schooling lost, 5-11 year olds (3.7 million) experience a greater loss than 12-17 year olds (2.5 million). This is primarily because the 5-11 year olds (primary school) have higher net enrolment rates than the 12-17 year olds (secondary school), and there is one extra grade year in primary school (seven years) compared to secondary school (six years).

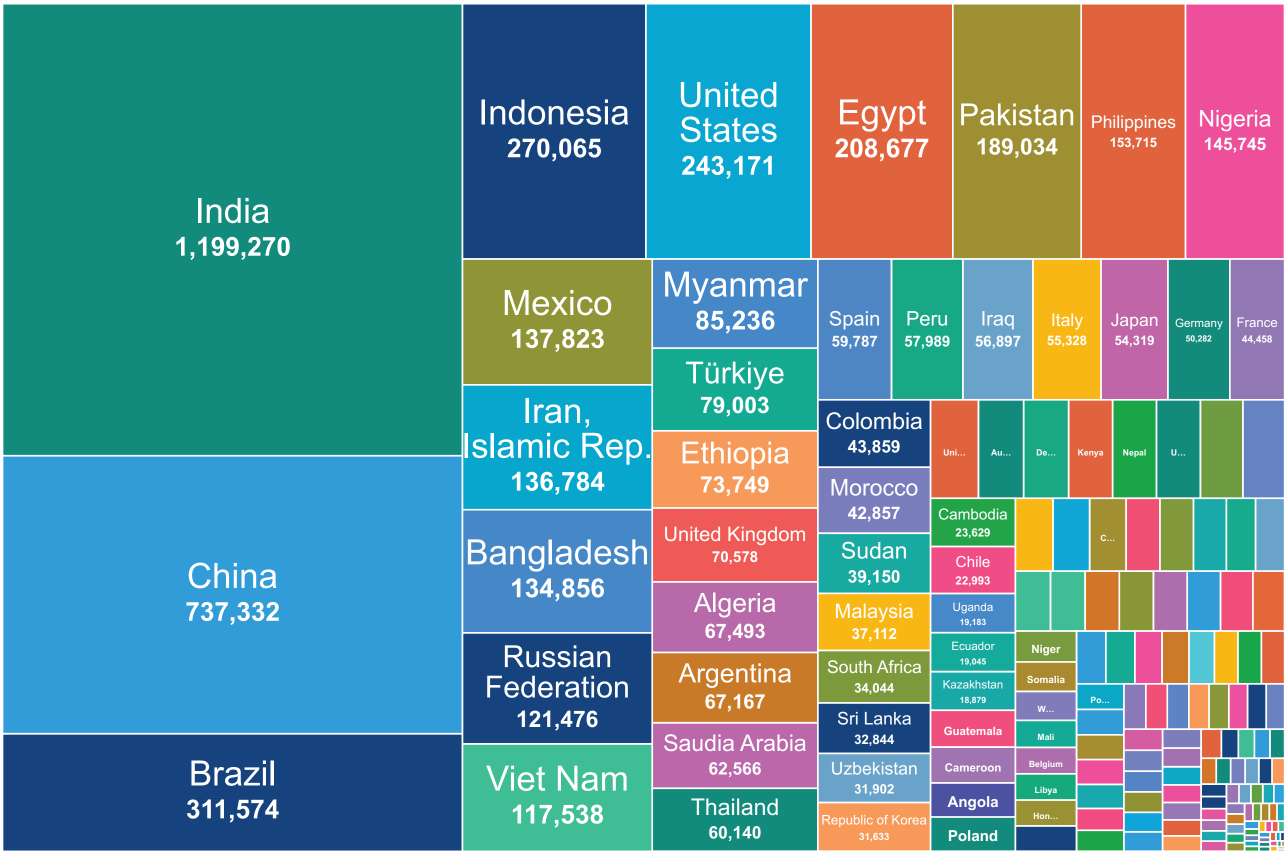
Figure 3: Economic loss from one year of uncorrected refractive error. One year of sub-optimal learning due to uncorrected refractive error costs $173 billion in future economic productivity loss.



PPP (purchasing power parity) in 2022 international dollars.
95% confidence interval: $83 billion to $246 billion (PPP) in present value terms.

Figure 3 provides the economic loss share by country. The top seven countries comprise half the total economic loss. Three of these countries are LMICs (China, Brazil and India), with four HICs (USA, UK, Germany, Japan). When considering equivalent years of schooling lost (Figure 4), roughly half of the loss is in seven countries, of which only one (USA) is a HIC. Country specific results are noted in the appendix as well as figures for economic / schooling loss by income classification and region.

Figure 4: Schooling loss from one year of uncorrected refractive error. One year of sub-optimal learning due to uncorrected refractive error costs 6.3 million years of schooling loss each year.



95% CI: 2.7 to 9.7 million years.

Discussion

Failing to address the large prevalence of uncorrected refractive error in school going children has substantial social and economic costs. Each child with uncorrected refractive error learns half as much as their peers with good or corrected vision. Globally, we estimate that for every year that school children go without glasses around the world, 6.3 million equivalent years of schooling loss and $173 billion PPP in future economic loss are generated. The global economic costs are split roughly 50:50 between high-income and low-and-middle-income economies, but the overwhelming schooling loss is in LMICs which experience 83% of the lost learning from uncorrected refractive error.

These findings have important implications for global education policy. It is now clear that children in low-and-middle-income countries, who comprise the vast majority of all children in school globally, are experiencing a 'learning crisis'. There has been minimal changes in overall learning levels despite large gains in enrolment over the last 25 years.[16] Governments will need a variety of tools to address this deficit including interventions that address children's health. Our results suggest addressing visual impairment, through comprehensive school eye health screening policies and programs, would generate substantial learning gains for children with uncorrected refractive error. Approximately half of the gain would come from vision screening and provision of glasses, and perhaps the remaining half could be addressed by interventions to improve compliance with wearing glasses.

Moreover, the costs of providing vision correction to school children are likely to be modest compared to the benefits. A recent systematic review and economic modeling analysis shows that screening plus the provision of glasses generates returns as large as $65 per $1 investment in China and $42 per $1 investment in India,[2] comparable to 'best buy' returns in global development[17] and in education.[16]

Our results have certain limitations. First, all the evidence comes from one country: China with uncertainty around how results could translate to other contexts. However, we have attempted to mitigate any differences in general education quality between countries by benchmarking the meta-analysis result against the usual learning gain in China, applying an equivalent years of schooling loss and using country-specific returns to education. Second, we did not implement time-varying labor force participation rates and our analysis assumes all children enter the workforce at age 18, which may be reasonably appropriate for upper-middle-income and high-income countries, but may be less so for low-income and lower-middle-income countries. Assuming a later start to working life implies conservatism in our loss estimates, due to the impacts of discounting on the present value of lifetime income. Third, the results are sensitive to assumptions about future economic growth of countries, which can be difficult to project accurately. Fourth, our estimates of lifetime income do not account for differences in productivity across the lifecycle, which can be difficult to estimate. Instead our approach adopts an approximation which assumes that income grows only with real changes in national growth rates. Lastly, our results can be considered conservative as they do not touch upon other potential costs of visual impairment in school going children, such as health losses, drop outs, future negative effects on labor force participation or externalities to the children's families.

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Appendix A: Country Level Results

Country	Number of children with URE, ages 5-11	Number of children with URE, ages 12-17	NPV of economic loss from one year of URE (PPP $millions)	NPV of economic loss from one year of URE (local currency $millions)	Years of schooling lost annually from URE	Average PV of individual lifetime income from correcting vision in Primary School in PPP $ thousand	Average PV of individual lifetime income from correcting vision in Secondary School in PPP$ thousand
Angola	43,507	32,288	360	77,290	16,728	40	2
Albania	1558	1409	19	733	1198	32	10
United Arab Emirates	10,247	8303	1017	2266	7762	245	100
Argentina	78,918	80,029	1885	126,667	67,167	55	20
Armenia	3054	2363	13	2093	2156	12	4
Australia	32,758	28,313	3735	5125	25,677	286	108
Austria	6948	7451	654	456	5625	214	78
Azerbaijan	12,438	9606	204	151	8900	46	16
Burundi	9111	6461	9	6483	4554	4	1
Belgium	10,607	11,026	668	464	9320	153	52
Benin	14,993	11,485	54	10,823	8867	13	2
Burkina Faso	23,994	18,284	25	5043	10,920	4	1
Bangladesh	202,137	180,389	637	19,984	134,856	9	3
Bulgaria	3430	2867	75	55	2455	54	22
Bahrain	2235	2275	152	28	1875	151	59
Bahamas	322	427	17	13	225	116	37
Bosnia and Herzegovina	1740	1496	18	12	1334	24	10
Belarus	7815	5683	66	61	5720	23	9
Belize	492	576	7	9	393	37	10
Bolivia	21,086	20,925	165	421	15,841	20	6
Brazil	379,243	409,843	8492	21,936	311,574	53	18
Barbados	107	129	3	7	100	62	22
Brunei Darussalam	505	520	41	30	401	193	66
Botswana	2442	2025	35	183	1491	43	12
Central African Republic	6557	5543	3	922	2248	2	0
Canada	25,923	27,370	2761	3215	23,679	235	91
Switzerland	7189	7257	981	963	5737	328	114
Chile	27,872	28,496	1070	456,014	22,993	86	33
China	1,138,586	847,701	19,295	76,971	737,332	45	17
Côte d'Ivoire	28,285	21,911	75	17,770	15,289	9	2
Cameroon	30,826	23,379	141	31,156	17,525	16	3
Democratic Republic of the Congo	83,810	70,501	17	17,059	25,560	1	0
Congo	6201	5710	17	6341	3383	9	2
Colombia	52,526	64,222	1383	1,861,589	43,859	58	19
Comoros	539	454	1	130	296	4	1
Cabo Verde	300	291	2	104	216	20	6
Costa Rica	4782	5380	137	45,299	4045	66	22
Cyprus	1174	1154	168	95	999	388	116
Czechia	5880	4690	275	3380	4227	117	48
Germany	63,545	65,315	7112	4939	50,282	256	95
Djibouti	950	750	2	160	407	5	1
Djibouti	950	750	2	160	407	5	1
Denmark	5426	6187	635	3906	4882	281	89
Dominican Republic	15,737	16,768	321	7833	11,761	51	15
Algeria	93,107	75,390	787	36,672	67,493	24	8
Ecuador	24,355	24,387	253	126	19,045	25	9
Egypt	278,199	240,398	2628	12,302	208,677	25	9
Spain	63,365	75,061	3763	2178	59,787	131	46
Estonia	674	550	19	11	512	71	29
Ethiopia	150,371	124,878	591	10,480	73,749	14	2
Finland	4815	5209	376	289	4341	182	63
Fiji	1139	918	19	16	836	48	15
France	49,606	53,695	2406	1622	44,458	104	41
Gabon	1855	1630	24	7868	945	44	8
United Kingdom	79,906	81,437	7816	5090	70,578	227	84
Georgia	3859	2757	50	48	2833	35	14
Ghana	40,680	33,563	227	640	24,147	16	5
Guinea	15,182	11,490	7	30,295	6782	2	0
Gambia	2516	2148	3	61	1221	5	1
Guinea-Bissau	2285	1806	2	401	793	4	0
Equatorial Guinea	1732	1608	11	2737	481	21	4
Greece	7703	8990	199	101	7102	56	20
Guatemala	29,709	33,407	286	1121	17,995	30	6
Guyana	822	851	11	971	652	33	10
Honduras	15,868	17,930	114	1261	9149	21	4
Croatia	2091	1834	114	48	1573	134	52
Haiti	16,868	16,579	40	2244	12,279	6	2
Hungary	4770	4121	294	46,161	3565	153	59
Indonesia	361,668	341,342	3880	18,822,936	270,065	25	10
India	1,785,607	1,699,837	6831	156,306	1,199,270	10	3
Ireland	5590	5750	755	557	4907	299	118
Iran, Islamic Rep.	180,612	156,441	2070	133,567,015	136,784	31	10
Iraq	93,255	91,500	207	164,164	56,897	7	1
Iceland	342	358	24	3348	297	166	58
Israel	14,248	13,163	610	2160	11,929	93	41
Italy	60,843	69,861	3040	1811	55,328	114	39
Jamaica	2319	2847	41	3188	1773	40	13
Jordan	21,142	23,331	78	21	14,107	8	3
Japan	73,888	75,432	5361	508,911	54,319	186	56
Kazakhstan	26,984	19,017	465	79,870	18,879	39	21
Kenya	46,281	40,232	344	14,771	24,959	23	6
Kyrgyzstan	8431	6002	31	719	5625	10	4
Cambodia	43,239	36,704	73	98,369	23,629	6	1

Country	Number of children with URE, ages 5-11	Number of children with URE, ages 12-17	NPV of economic loss from one year of URE (PPP $millions)	NPV of economic loss from one year of URE (local currency $millions)	Years of schooling lost annually from URE	Average PV of individual lifetime income from correcting vision in Primary School in PPP $ thousand	Average PV of individual lifetime income from correcting vision in Secondary School in PPP$ thousand
Republic of Korea	36,059	36,748	2660	2,155,617	31,633	156	66
Kuwait	5881	5573	360	78	4308	136	58
Lao People's Democratic Republic	10,730	9054	34	103,414	6785	9	2
Liberia	5423	4691	2	1	1396	1	0
Libya	11,112	12,959	195	270	9221	38	14
Saint Lucia	116	145	3	6	102	55	18
Sri Lanka	39,697	37,857	337	25,447	32,844	19	8
Lesotho	2306	1978	5	31	1321	8	1
Lithuania	1882	1497	90	42	1478	112	50
Luxembourg	549	571	99	80	445	431	147
Latvia	1407	1108	52	26	1065	91	38
Morocco	58,841	58,915	247	905	42,857	11	3
Republic of Moldova	3193	2723	109	749	2171	98	30
Madagascar	26,948	20,692	45	53,195	14,213	7	1
Maldives	576	478	6	43	345	34	7
Mexico	167,264	185,212	5138	49,746	137,823	73	24
North Macedonia	1170	997	11	205	844	27	8
Mali	26,364	19,861	41	8537	9560	5	1
Malta	344	342	33	18	294	239	81
Myanmar	123,126	110,776	384	176,986	85,236	9	2
Montenegro	384	329	12	4	296	81	28
Mongolia	5104	3258	36	39,925	3406	20	8
Mozambique	32,198	22,468	45	1093	15,386	6	1
Mauritania	4387	3564	8	100	2045	7	1
Mauritius	1320	1451	51	862	1101	86	31
Malawi	21,447	18,348	29	10,316	12,115	5	1
Malaysia	50,415	45,923	1998	3146	37,112	109	32
Namibia	2910	2354	37	264	1808	40	9
Niger	30,693	22,674	42	10,258	10,920	6	1
Nigeria	341,477	287,640	892	140,852	145,745	8	2
Nicaragua	10,108	10,775	40	476	6590	13	2
Netherlands	13,059	14,751	1524	1107	11,848	264	92
Norway	5435	5637	1046	8810	4814	469	158
Nepal	35,996	34,559	92	3132	24,941	7	2
New Zealand	7146	6419	790	1148	5919	293	98
Oman	16,066	12,544	706	163	11,536	108	47
Pakistan	435,913	348,200	1570	69,834	189,034	12	3
Panama	6130	6327	203	90	4149	85	25
Peru	70,209	70,715	854	1550	57,989	27	11
Philippines	229,697	198,339	1871	35,171	153,715	24	6
Papua New Guinea	20,347	15,562	30	74	8911	5	1
Poland	21,765	17,765	1374	2455	16,715	168	61
Puerto Rico	2161	2753	97	84	1664	90	34
Portugal	7293	9068	425	222	6986	121	44
Paraguay	17,230	18,870	225	605,483	12,218	32	10
West Bank and Gaza	12,949	12,127	25	14	10,173	5	2
Qatar	3699	2791	484	1355	2715	334	139
Romania	10,417	9116	313	535	7172	71	29
Russian Federation	166,137	126,810	1225	36,986	121,476	20	7
Rwanda	9364	7630	29	10,201	5168	11	2
Saudia Arabia	74,793	72,523	4136	7967	62,566	121	51
Sudan	97,641	93,294	194	28,159	39,150	6	1
Senegal	14,741	12,641	40	9587	7064	9	2
Singapore	5729	4714	1437	1285	4634	650	244
Solomon Islands	1000	790	1	7	409	4	1
Sierra Leone	8917	7514	5	17	5290	2	0
El Salvador	10,670	11,234	110	51	6937	27	8
Somalia	21,847	14,814	13	118,657	10,388	2	0
Serbia	4616	4682	178	7583	3860	91	33
São Tomé and Príncipe	200	184	0	4	136	4	1
Suriname	598	645	6	51	395	27	7
Slovakia	2917	2378	105	52	1976	93	35
Slovenia	1101	851	56	30	844	137	51
Sweden	5560	5118	287	2401	4710	132	46
Eswatini	1504	1212	11	68	777	26	5
Chad	21,125	15,645	16	4241	8190	3	0
Togo	8420	6830	16	3529	4646	7	1
Thailand	75,129	79,535	1360	15,930	60,140	43	14
Tajikistan	15,784	11,577	38	90	11,191	7	2
Timor-Leste	3940	3500	9	4	2596	6	2
Trinidad and Tobago	1163	1236	27	131	893	59	18
Tunisia	15,179	14,079	93	87	11,656	15	5
Türkiye	103,581	99,152	3416	15,735	79,003	75	30
United Republic of Tanzania	59,860	46,669	203	180,150	27,178	13	2
Uganda	38,425	28,672	101	128,554	19,183	11	1
Ukraine	34,166	28,799	518	5991	24,916	44	13
Uruguay	4599	4784	142	4206	3912	71	25
United States	277,367	307,182	35,113	35,113	243,171	269	105
Uzbekistan	44,206	32,879	218	569,702	31,902	12	5
Saint Vincent and the Grenadines	103	112	2	3	88	51	19
Viet Nam	169,083	138,332	1563	11,246,975	117,538	25	8
Vanuatu	405	305	1	115	210	8	2
Samoa	307	235	2	3	218	16	5
South Africa	52,097	43,338	1065	7405	34,044	51	19
Zambia	16,418	12,951	42	260	8250	9	2
Zimbabwe	23,722	17,952	74	21,487	13,832	11	2

NPV: Net Present Value
PPP: Purchase Power Parity
URE: Uncorrected Refractive Error

Appendix B: Additional figures

Figure 5: Economic loss by region, from one year of uncorrected refractive error.

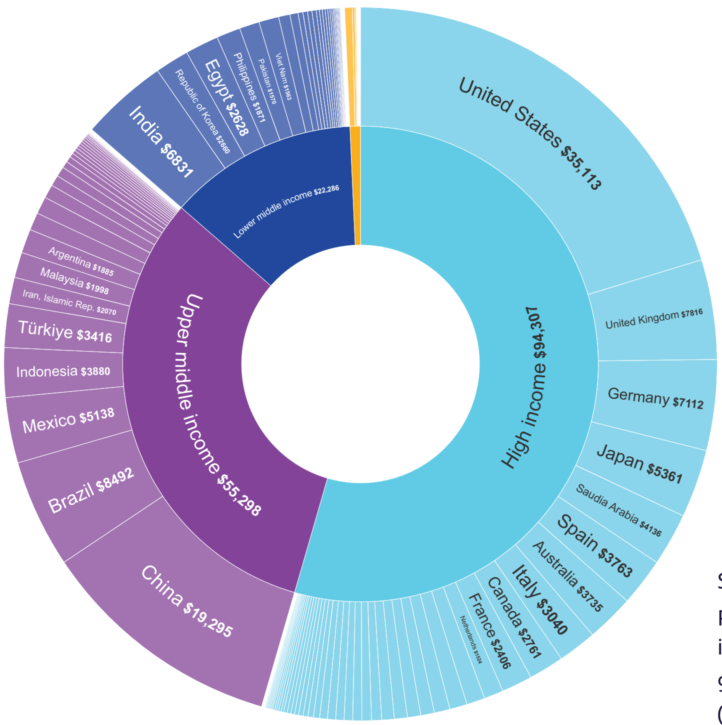
One year of sub-optimal learning due to uncorrected refractive error costs **$173 billion** in future economic productivity loss.

PPP (purchasing power parity) in 2022 international dollars.

95% confidence interval: $83 billion to $246 billion (PPP) in present value terms.

Figure 6: Economic loss by income classification, from one year of uncorrected refractive error.

One year of sub-optimal learning due to uncorrected refractive error costs **$173 billion** in future economic productivity loss. The global economic costs are split roughly 50:50 between high-income and low-and-middle-income economies.



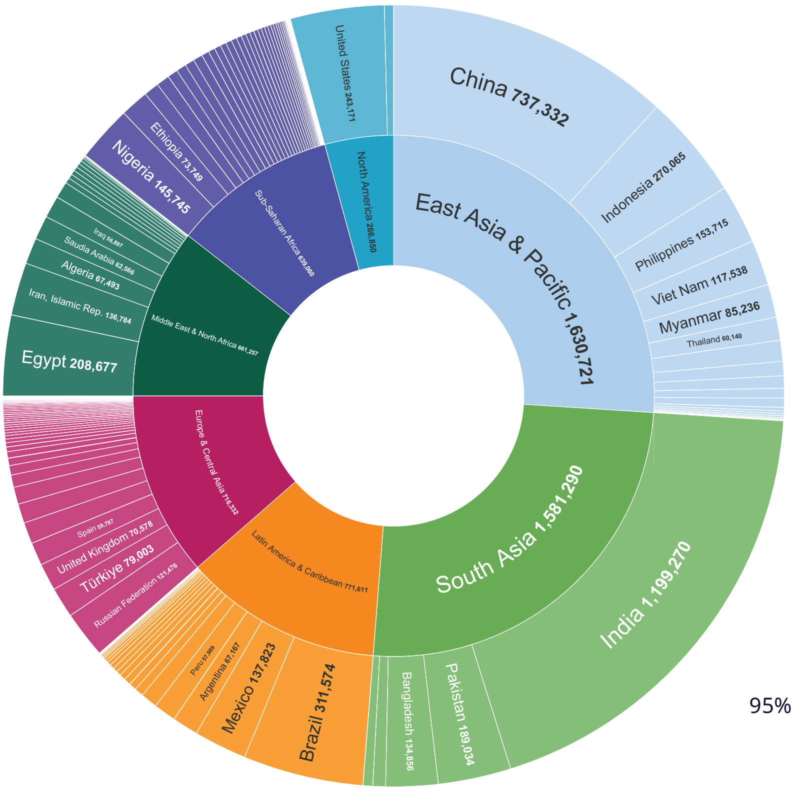
Source: World Bank Country Groups

PPP (purchasing power parity) in 2022 international dollars.

95% confidence interval: $83 billion to $246 billion (PPP) in present value terms.

Figure 7: Schooling loss from one year of uncorrected refractive error.

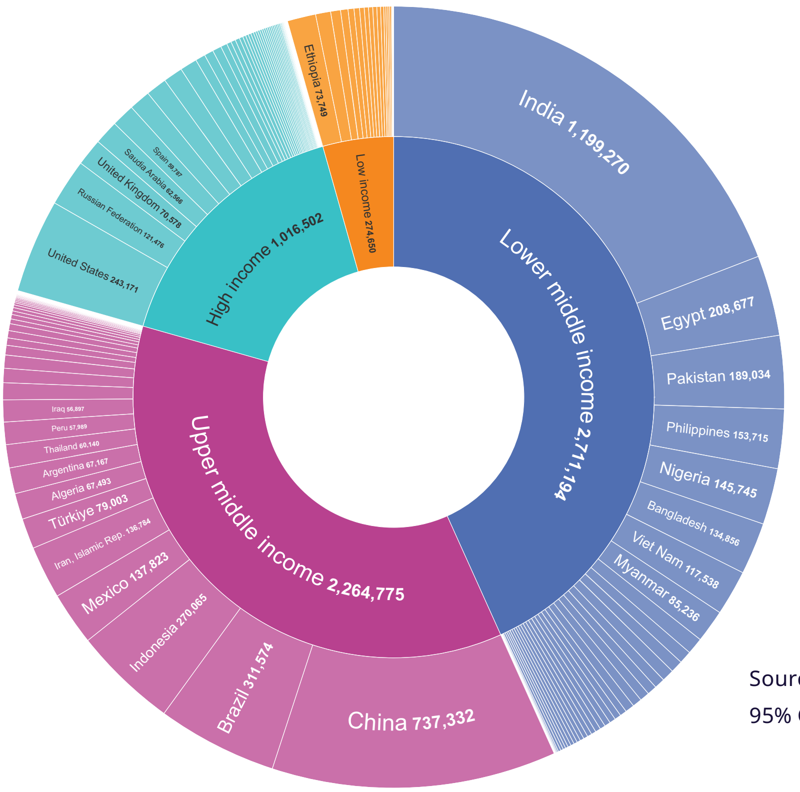
One year of sub-optimal learning due to uncorrected refractive error costs **6.3 million years** of schooling loss each year.



95% CI: 2.7 to 9.7 million years.

Figure 8: Schooling loss from one year of uncorrected refractive error by income group.

One year of sub-optimal learning due to uncorrected refractive error costs **6.3 million years** of schooling loss each year.

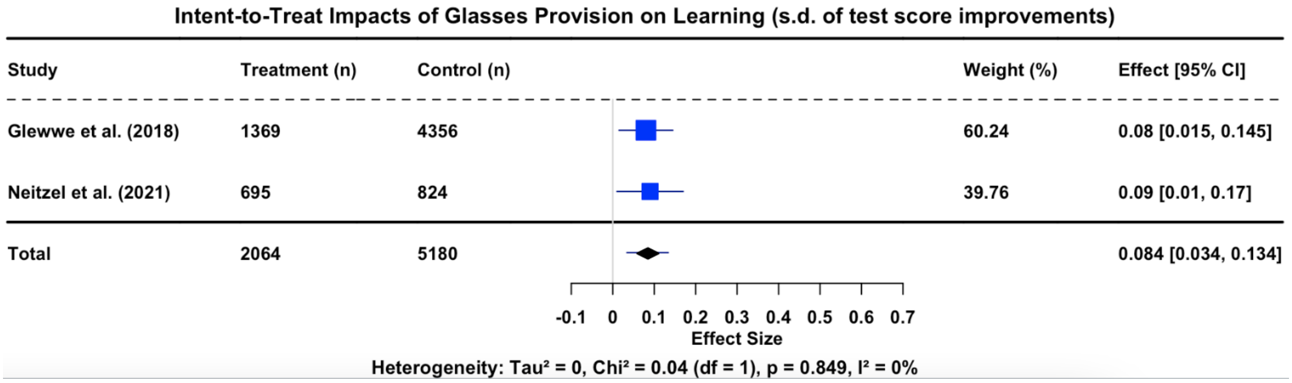


Source: World Bank Country Lending Groups

95% CI: 2.7 to 9.7 million years.

Appendix C: Meta-analysis of results from High Income Countries

Our literature search identified two relevant randomized controlled trials from high-income studies: one study by Glewwe and colleagues in 2018[20] and another by Neitzel and colleagues in 2021.[21] Both studies were conducted in the USA. We conducted a meta-analysis for these two high-income studies with a forest plot noted below.



The intent-to-treat impact from the two studies is 0.084 standard deviation test score improvements.

We decided to not include these studies with the studies from China. First, neither study documented compliance rates which made it difficult to estimate the ATT effect. Second, the Glewwe et al. (2016) study's treatment group mostly included children with good vision. Table 4 of that study notes that the 'full treatment group' included 3,772 students of which only 975 (25%) failed the screening and 596 (16%) were given glasses. This methodological set up is different to the other studies from China in which both treatment and control groups generally included only children with poor vision which complicates its inclusion into the meta-analysis.

Note that if we treat the 'compliance rate' from Glewwe et al. (2016) as 16%, a naive estimate of that study's ATT effect is very large at 0.5 standard deviation of test score improvements (0.08 / 0.16). This is potentially a much larger EYOS loss than the one reported from the China studies, where the meta-analytic ATT effect is estimated at 0.20 standard deviation of test score improvements, suggesting that the omission of Glewwe et al. (2016) might underestimate the costs to HICs.

Image: Arpan Chowdhury