COST OF VISION PROBLEMS:

The Economic Burden of Vision Loss and Eye Disorders in the United States

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PRESENTED TO:
Prevent Blindness America

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Results in Brief

In an era where healthcare coverage and costs are at the forefront of public debate and concern, it is vital to understand the magnitude of the economic burden of disease. This is especially true for eye disorders and vision loss, as these conditions often lead to chronic, life-long direct and indirect costs, which are likely to continue to increase with an aging population and quickly growing healthcare expenses.

This report serves to update the prior estimate of the economic burden of eye problems released by Prevent Blindness America in 2007, which found the economic burden of eye problems among Americans aged 40 and older to be approximately $51.4 billion in 2004. While this landmark study has served as the benchmark estimate of the economic burden of eye problems in the United States, continued growth in medical costs, newly available data and methodologies, and a consensus for more comprehensive accounting of all costs for all ages have highlighted the need for an updated estimate of the economic burden of eye disorders and vision loss. [1]

In this report, we employ more current data and updated methodologies to update and expand the previous estimate. We expand the analysis to include children and adults younger than age 40 by incorporating results from CDC-funded research on the economic burden of vision loss and eye disorders in this population.[2] We capture medical costs for all diseases and conditions related to the eye and ocular adnexa. And we include costs for out-of-pocket and vision-plan paid expenses, such as routine eye examinations and vision correction.

Methodology and Data Sources

This analysis draws on a number of methodologies and data sources. We estimated costs by cost categories listed in consensus guidelines.[1] Direct costs include medical care attributable to diagnosed disorders, medical vision aids, undiagnosed vision loss, low vision aids/devices, special education, school screening, and Federal assistance programs. Indirect costs include productivity losses of adults, productivity losses of caregivers, long-term care, transfer payments (not included in total), and deadweight loss from transfer payments. Costs are also reported by payers' perspective, including government, private insurance and patient costs. All prices and costs were adjusted to 2013 U.S. dollars using the Consumer Price Index (CPI) for nonmedical costs and medical components of the Consumer Price Index for medical expenses. U.S. population values are based on 2011 census estimates.

The prevalence of visual impairment and blindness are based on a meta-analysis of epidemiological studies using gold-standard comprehensive eye examinations for the population aged 40 and older. [3, 4] For the younger population such data are not available. For the population aged 12-39, we estimated prevalence of visual loss based on National Health and Nutrition Examination Survey (NHANES) data from 2005 through 2008 in which autorefractors were used to measure corrected acuity loss. NHANES does not assess acuity in respondents younger than age 12; we imputed prevalence for children younger than age 12 based on the incidence of profound impairment or blindness.

We estimated medical costs attributable to diagnosed disorders, undiagnosed self-reported vision loss, and vision correction using 2003-2008 Medical Expenditure Panel Survey (MEPS) data. MEPS is a nationally representative panel survey of health and healthcare expenditures in which individuals self-report health history, while medical expenditures are measured and confirmed by the respondents' medical providers. Diagnosed disorders are defined as any diagnosis code related to the eyes, vision, or ocular adnexa, while undiagnosed vision loss is defined as self-reported low vision in the absence of any reported diagnosed disorder. Costs attributable to these two conditions were estimated using a "top-down" econometric approach whereby the incremental costs attributable to these conditions were estimated while controlling for socio-demographic conditions and comorbidities. This approach allows estimation of ancillary costs beyond those directly related to eye care services. Vision correction costs include the costs of optometry visits and the cost of vision aids including eyeglasses and contacts. These costs are measured separately from other medical costs in MEPS; they are not associated with diagnosis codes and are based on non-confirmed, self-reported expenditures. We estimated costs for these conditions using a "bottom-up" accounting approach whereby we measured the weighted sum of these costs.

We estimate productivity losses based on the difference in average incomes among persons self-reporting different levels of visual functionality in the Survey of Income and Program Participation, applied to our estimated prevalent population with impairment and blindness. [5, 6] Costs for other direct and indirect cost categories were estimated based on published parameter values and Federal budgets.

Economic Burden

We estimate the total economic burden of eye disorders and vision loss to be $139 billion, based on the 2011 U.S. population in 2013 dollars. We estimate that uncorrectable vision loss resulted in a social burden of 283,000 disability adjusted life years (DALYs) lost. We do not include a monetary value for DALYs lost in the primary burden estimate. If we had assumed a value of $50,000 per DALY, the economic burden would increase by $14 billion to a total of $153 billion.

Table R1. Economic Burden Results, in $ millions

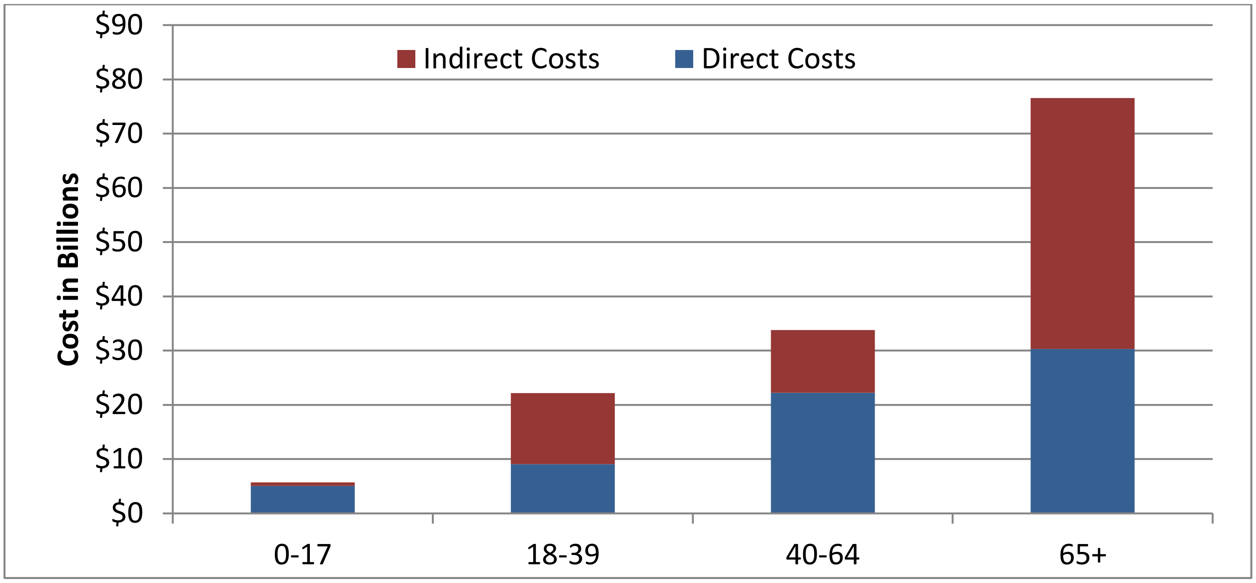
Age Group	Comprehensive Costs				
Perspective	**0-17**	**18-39**	**40-64**	**65+**	**All Ages**
Direct Costs					
Diagnosed Disorders	$2,844	$5,067	$14,218	$26,640	$48,769
Medical Vision Aids	$1,480	$3,335	$6,222	$2,199	$13,236
Undiagnosed Vision Loss	$48	$474	$1,702	$798	$3,022
Aids/Devices	$38	$77	$81	$553	$749
Education/School Screening	$651	$119	-	-	$769
Assistance Programs	$25	$13	$23	$145	$207
Total Direct Costs	**$5,086**	**$9,086**	**$22,246**	**$30,335**	**$66,752**
Indirect Costs					
Productivity Loss	-	$12,978	$10,828	$24,622	$48,427
Informal Care	$601	-	$187	$1,264	$2,052
Nursing Home	-	-	-	$20,248	$20,248
Entitlement Programs*	$0.5	$165	$279	$1,782	$2,226
Tax Deduction*	-	$6	$11	$10	$28
Transfer Deadweight Loss	$47	$98	$538	$808	$1,490
Total Indirect Costs	**$648**	**$13,075**	**$11,553**	**$46,941**	**$72,217**
Total Economic Burden	**$5,734**	**$22,161**	**$33,799**	**$77,276**	**$138,970**
Loss of Well-being Measures					
Disability adjusted life years lost	6.92	26.35	33.38	216.48	283.13

*Transfer payment costs are not included in total

Burden throughout the Lifespan

We estimated costs by four age groups: children aged 0-17 and adults aged 18-39, 40-64, and 65 and older. A majority of costs (55%) are incurred by the 65 and older age group. Children constitute 4% of total costs; while adults aged 18-39 and 40-64 accrue 16% and 24% of total costs, respectively.

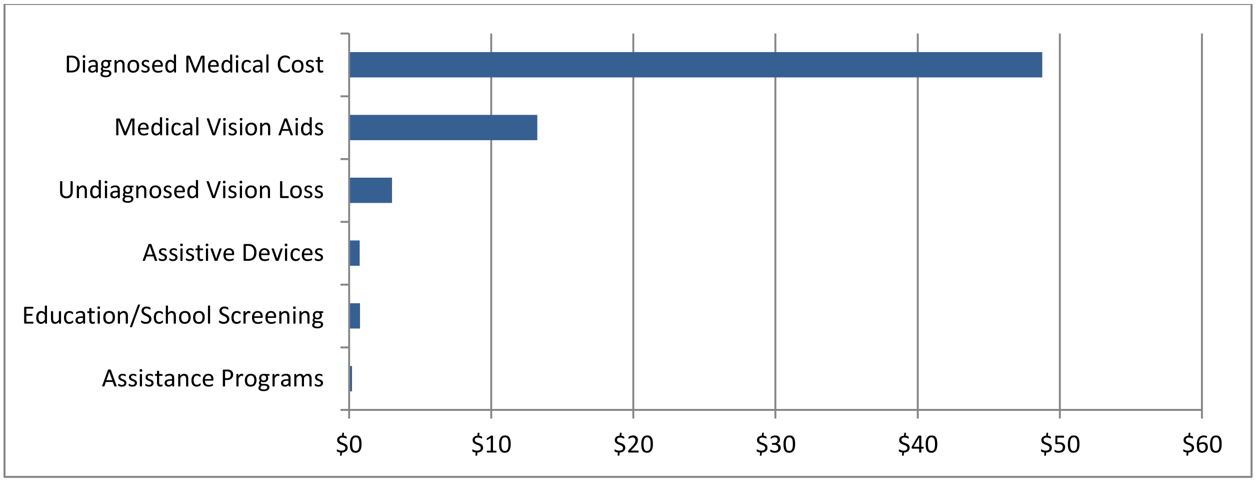
Figure 1. Direct and indirect costs by age group



Direct and Indirect Costs

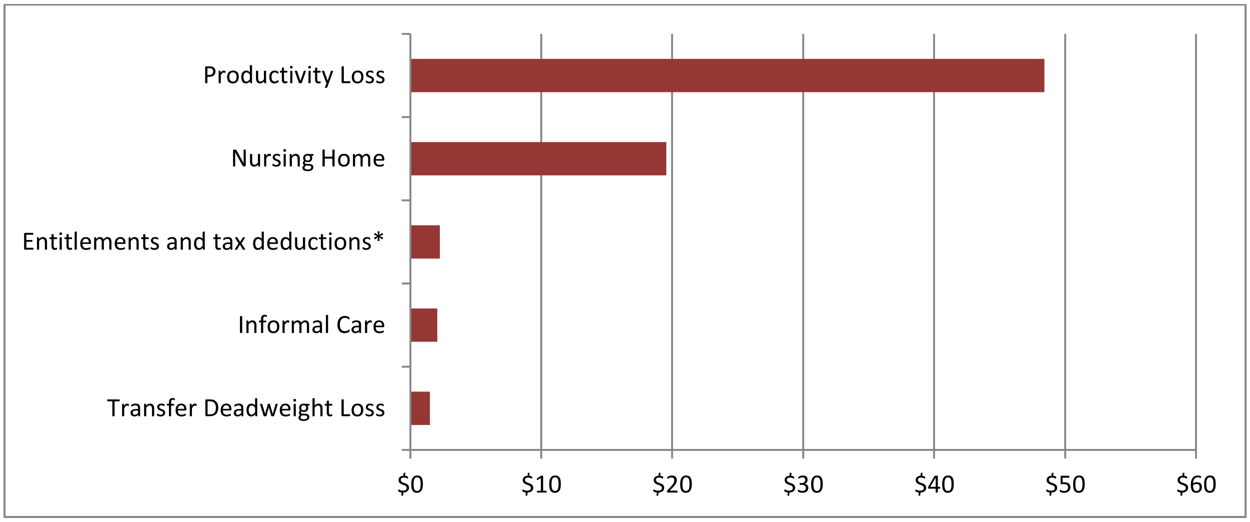
Direct costs are $66.8 billion (48% of total costs) and include medical costs for diagnosed disorders, medical costs attributable to low vision, medical vision aids, vision assistive devices and adaptations, and direct services including special education and assistance programs.

Figure 2. Direct costs by cost category



Indirect costs constitute 52% of total costs ($72.2billion), and capture the burden of consequences of low vision, including productivity losses, long-term care, informal care, and the costs of transfer and entitlement programs.

Figure 3. Indirect costs by cost category

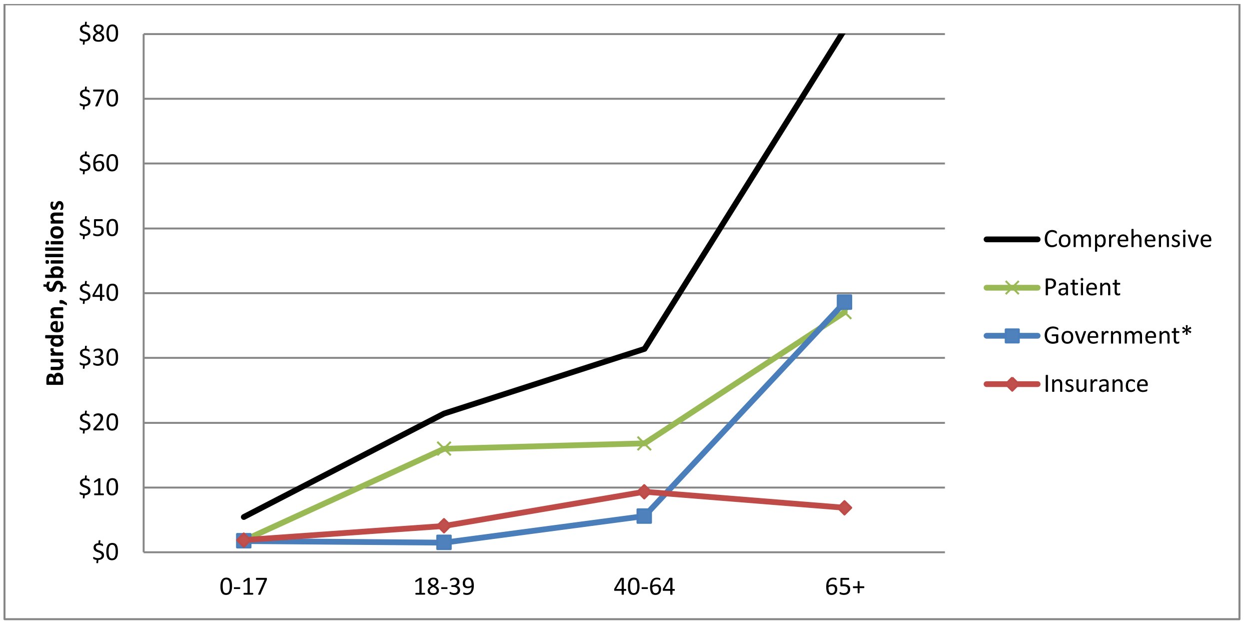


*Transfer payment costs are not included in total costs

Costs by Payer

We separately estimate the costs of eye disorders and vision loss from the perspective of three payers; government, private insurance, and individuals, which includes patients and their families. Individuals incur 52% of the total economic burden ($71.7 billion), largely due to productivity and informal care losses, which together constitute 36% of the total economic burden. Government pays approximately 34% of total costs ($47.4billion), most of this total consisting of direct medical costs and long-term care. Private insurers pay $20.8 billion in direct medical costs and $1.3 billion for long-term care, totaling about 16% of the total burden. Government pays more for direct medical costs than private insurance, largely due to the Medicare-aged population 65 and older. Among those aged 65 and older, government accounts for nearly half of the total burden due to an increase in medical and long-term care expenditures by government for Medicare and Medicaid beneficiaries in this age group.

Figure 4. Costs by payer by age group

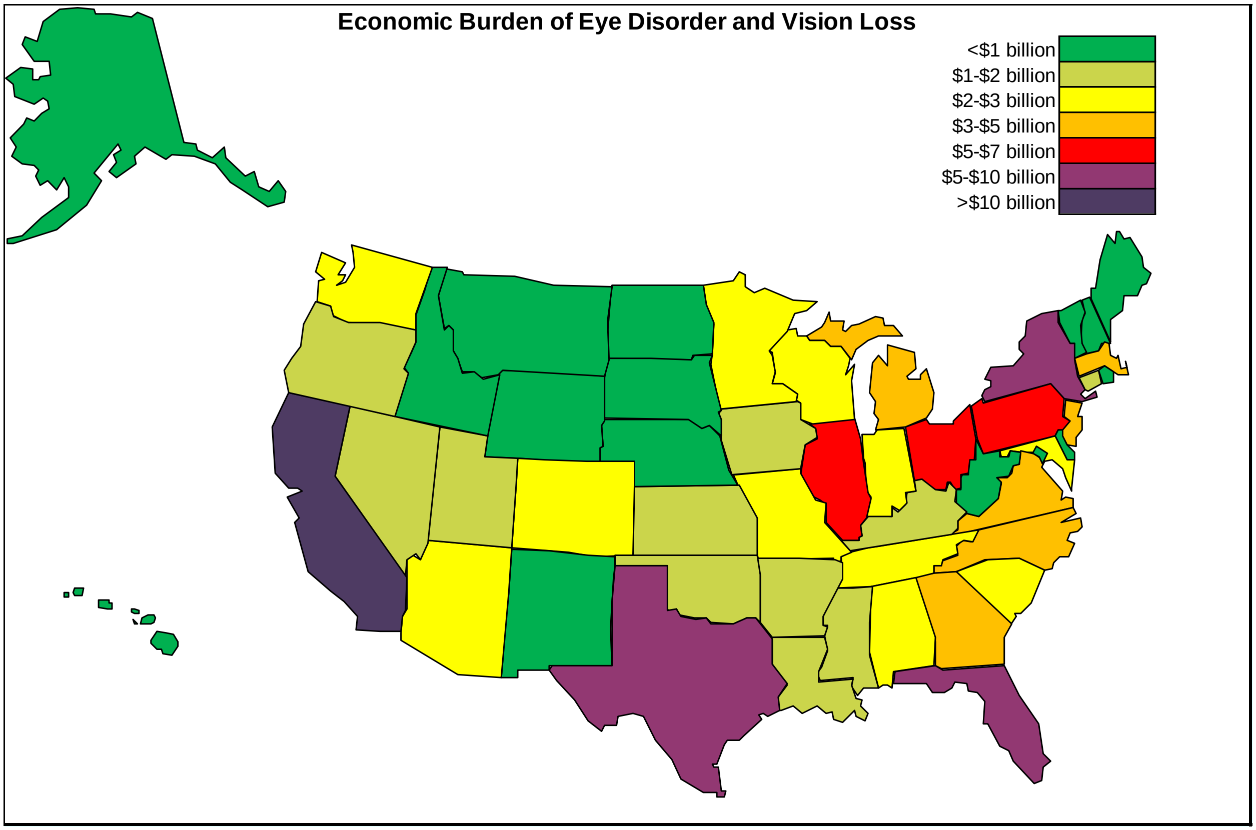


*Government total includes transfer payment costs that are not included in Comprehensive

Economic Burden by State

We estimated state-specific burden by allocating the costs to each state on the basis of their population for each age group. Our analysis does not include any differences in state-specific unit cost estimates, so state values are solely a function of the per-person burden estimate by age group and the population of each age group in each state. State burden estimates are indicated in **Figure 5.**

Figure 5. Economic Burden by State



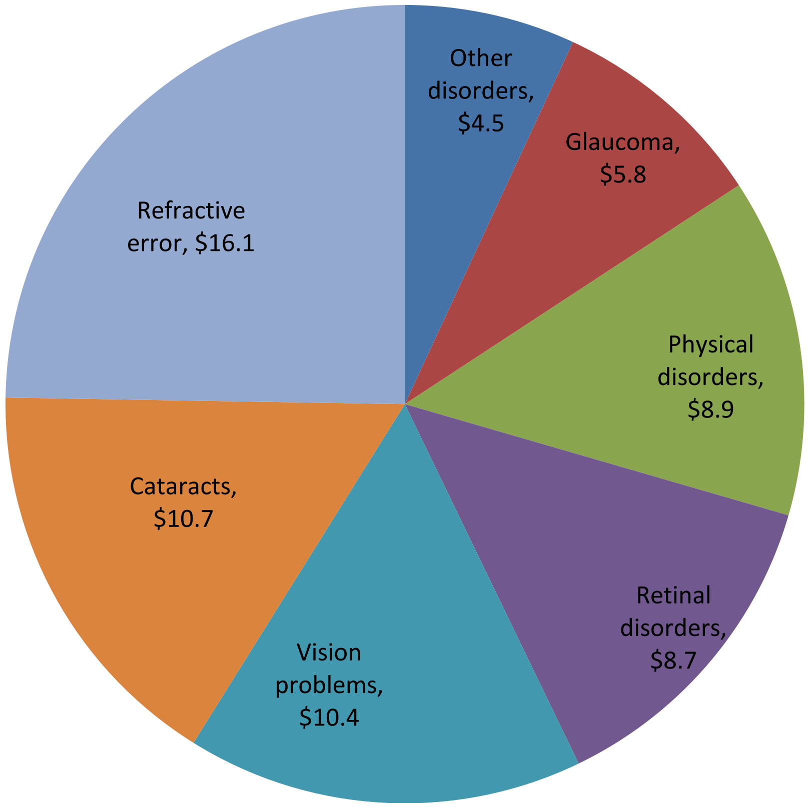
Economic Burden per Person

Based on a total economic burden of $139 billion, the cost of eye disorders and vision loss to the U.S. is $450 per person. The total burden due to low vision alone, excluding the cost of eye disorders, is $99 billion. Based on the prevalence of visual impairment and blindness, the cost of low vision alone is $15,900 per person with vision loss. While we cannot allocate all vision related costs between those who are blind versus those with impairment, we conservatively estimate that low vision costs are $26,900 per year for each person blind.

Medical Costs by Disorder

Refractive error is the most expensive eye or vision condition at $16.1 billion per year. At $10.7bn, cataracts are the second costliest disorder and the most expensive medical diagnosis. Vision problems total $10.4bn, and include undiagnosed low vision ($3bn), diagnosed blindness or low vision ($3.8bn), and visual disturbances ($3.6bn), which include conditions such as amblyopia. The next costliest conditions are physical disorders totaling $8.9bn, and include conjunctivitis and disorders of the eyelids and lacrimal system ($4.6bn), disorders of the globe ($2.4bn), injuries and burns to the eye ($1.3bn), and strabismus ($0.6bn). Retinal disorders total $8.7bn. Due to limitations in diagnosis codes, the MEPS data cannot distinguish major retinal disorders including age related macular degeneration and diabetic retinopathy. We can however approximate these diagnoses by separately estimating the costs of any retinal disorder among persons with and without diabetes. Doing so reveals that the cost of retinal disorders among persons without diabetes is $4.6bn while the cost of retinal disorders for persons with diabetes are nearly as high at $4.1bn. Glaucoma and disorders of the optic nerve cost $5.8bn.

Figure 6. Medical costs by disorder group

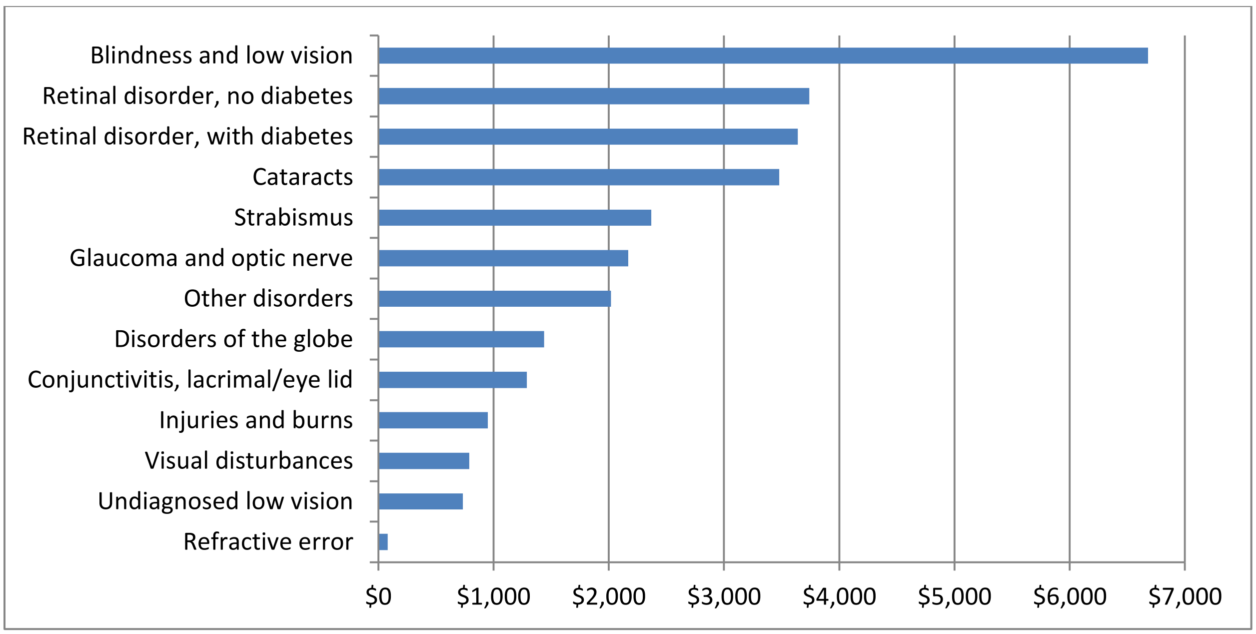


Medical Costs per Person

While vision correction of refractive error is the most costly disorder overall due to the high use of these services, per-person vision correction costs are lower than all other disorders at $81 per person, per year. Medical costs attributable to self-reported low vision without a diagnosis are the next least costly at $734 per year.

Medical costs for any diagnosed medical disorder averages $3,432 per year. Among the medical diagnoses, diagnosed blindness or low vision is the most costly condition at $6,680 per year. Retinal disorders among persons without or with diabetes are the next costly, at $3,740 and $3,640 per person, respectively. Cataracts cost $3,480 per year. All per-person medical costs are lowest among children and highest among the age 40-64 age group.

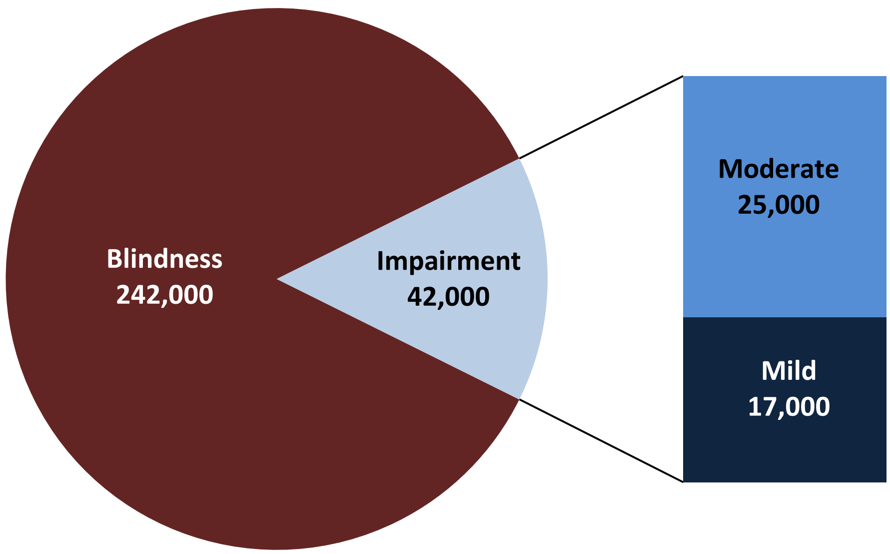
Figure 7. Per-person annual medical costs by disorder



Loss of Wellbeing

We estimate that vision loss results in the loss of 283,000 disability adjusted life years (DALYs) per year. We do not include a monetary value of this disability in the total estimate. If we did monetize this cost at the commonly cited value of $50,000 per adjusted life year, the burden estimate would increase by $14 billion. Our estimated DALY burden is based on the prevalent population with visual impairment and blindness multiplied by disability weights estimated by the recently released Global Burden of Disease project. We do not include the potential costs of increased mortality from low vision in our estimate.

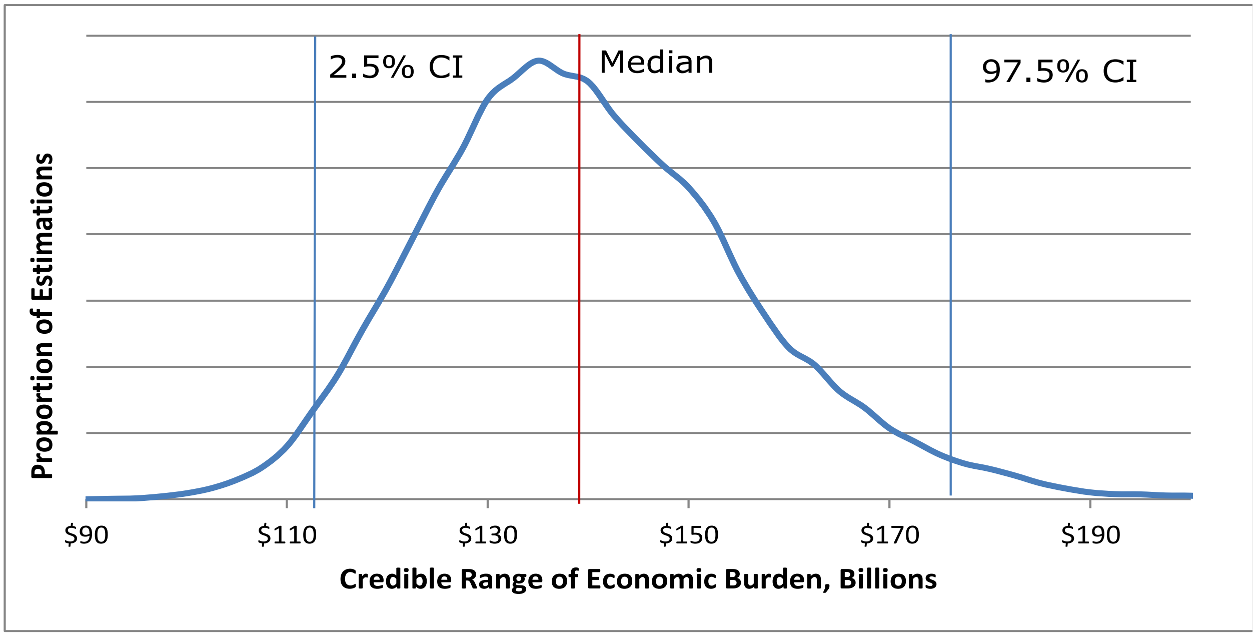
Figure 8. Disability adjusted life year losses



Certainty of Results

Sensitivity analysis provides information on the level of certainty of the results, and which underlying parameters contribute to uncertainty. Based on the underlying distributions of all parameters, we can report the 95% credible interval of the total economic burden of $139 billion to be $112 to $174 billion. The credible interval is analogous to a confidence interval, and indicates that assuming correct estimates for parameter distributions, 95% of all possible economic burden estimates based on uncertainty in all parameters would fall in this range. The distribution of burden estimates is shown in **Figure 9**. Most of the uncertainty in the total estimate is due to high uncertainty in productivity losses (95% C.I. $24.7-$80.6 billion). This uncertainty is a result of 1) high uncertainty in the prevalence of visual impairment and blindness, 2) high uncertainty in the productivity reduction attributable to low vision, and 3) the high cost estimate of productivity losses. Additional uncertainty is also attributable to the cost of diagnosed disorders (95% C.I. $33.9-$55 billion), long-term care costs (95% C.I. $12-$24.9 billion), the cost of undiagnosed low vision (95% C.I. $0.8-$9.1 billion) and the cost of informal care (95% C.I. $0.8-$3.8 billion). All other cost components exhibited less than $1 billion in uncertainty.

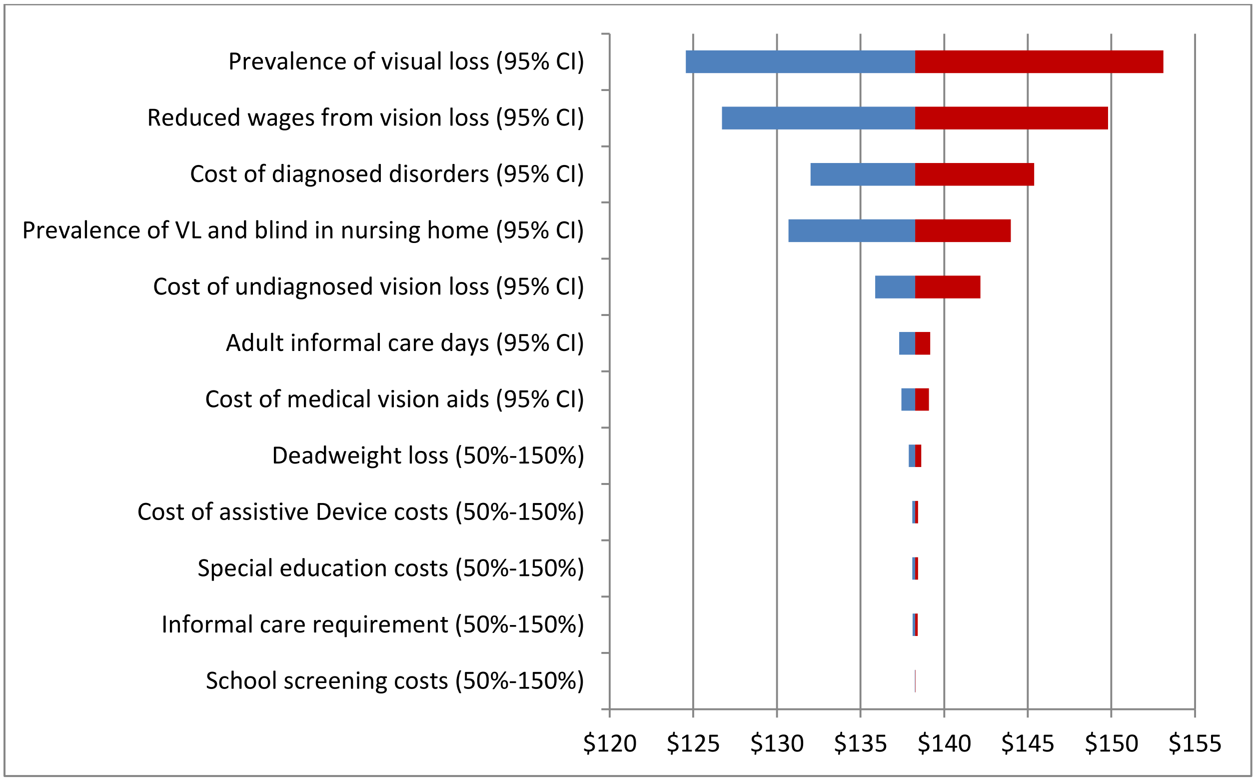
Figure 9. Credible Interval (CI) of Total Economic Burden Estimates



Impact of Parameter Uncertainty

We also conducted a one-way sensitivity analysis in which we measured the impact on the total economic burden estimates from changing individual parameters. We changed parameter values within their 95% confidence interval where available, or a 50%-150% range where not available. Results are most sensitive to the prevalence of visual loss, the impact on wages of vision loss, the cost of diagnosed disorders, the prevalence of visually impaired and blind persons in nursing homes, and the cost of undiagnosed vision loss. No other individual parameter or parameter group caused substantial changes in the overall estimate.

Figure 10. Impact of parameter uncertainty on the burden estimate



Limitations

This study is subject to a number of limitations and assumptions. Results are subject to uncertainty due to data limitations; we estimate a 95% credible interval for the economic burden to be $111 billion to $174 billion. We do not include a monetary value for health utility or disability loss in our primary results due to controversy over their inclusion in economic burden estimates, whether they include productivity losses, and the valuation of quality or disability adjusted life years.

We believe the two greatest limitations to this analysis are uncertainty in the prevalence of visual impairment and blindness, and the quality of self-reported diagnosis data. The sensitivity analysis identified the prevalence of vision loss as the primary cause of uncertainty in results, due almost entirely to its impact on productivity losses, and to a lesser extent due to its impact on long-term care cost and informal care cost estimates. The prevalence of vision loss has no effect on our estimation of medical costs or other direct and indirect costs which are based on other data sources. Epidemiological evidence of prevalence is available only for the population aged 40 and older, but due to sample size limitations is still subject to substantial uncertainty. [3, 4]

The use of NHANES data to provide prevalence estimates for the population aged 12-39 may introduce bias as this data relies on autorefractors to provide estimates of best-corrected near distance acuity, and contrast sensitivity and visual field are not assessed among participants in this age group. In addition, NHANES does not assess acuity among participants younger than age 12. We imputed prevalence in this age group based on the incidence of blindness reported in the United Kingdom and the prevalence among older children in NHANES data; which may introduce bias and we expect this may underestimate the prevalence of visual impairment at very young ages. Using these disparate sources of data for prevalence for different age groups leads to a decrease in estimated visual impairment prevalence from ages 18-39 to ages 40-64. This counter-intuitive finding appears to be a failing of this approach; however this age pattern can be seen in NHANES data alone when comparing the prevalence from 18-39 to 40-64.[7]

The use of MEPS data for the estimation of medical costs has advantages and disadvantages versus an alternative of claims costs. Claims costs can provide much larger samples of diagnosed patients providing narrower confidence intervals of results. However, claims costs will not capture many costs attributable to eye disorders and vision loss due to poor diagnostic coding, indirect links between visual status and other health conditions, and the fact that available claims databases do not capture significant sources of payments for eye care services. The structure of MEPS relies on individuals to report health conditions, past diagnoses, and medical utilization. MEPS then confirms utilization and expenditures by surveying the medical providers of the individual respondents, and assigns 3-digit ICD-9 diagnosis codes to respondents on the basis of available information. This approach will underreport the true prevalence of disorders. The use of 3-digit ICD-9 codes precludes identification of disorders defined at the 4^{th} or 5^{th} digit, which include important diseases of diabetic retinopathy, age related macular degeneration and amblyopia, inhibiting the estimation of cost for these specific disorders. Due to the structure of MEPS, the costs for optometry visits and medical vision aids are self-reported by MEPS respondents and are not verified by providers. This structure eases the estimation of these costs, but the failure to verify these expenditures may lead to underreporting of costs due to poor recall or patients possibly reporting copayments as the total cost.

DALY losses are similarly sensitive to the prevalence of vision loss. The methodology of assessing quality of life losses based on self-reported quality of life among respondents reporting low vision in MEPS data used by the previous estimate cannot be replicated in the younger population. We used an alternative approach where we applied published disability loss weights to the prevalent populations mildly impaired, moderately impaired and blind to estimate disability adjusted life year (DALY) costs of low vision.

We found no data on the relative demand for assistive living devices or informal care for children due to vision loss in the United States. We assume the relative impact on demand due to vision loss in the United States is identical to rates observed in Europe, which might introduce bias. We do not include the cost of vision screening other than school and preschool screening and eye examinations, such as acuity chart screening in annual physicals or child well-checks.

Finally, we do not include the monetized value of quality of life or disability losses in our primary results because of limitations and uncertainty in the utility loss associated with vision loss, the monetary value of a QALY or DALY, and controversy over their inclusion in economic burden studies.

Conclusions

This report provides the most comprehensive and up-to-date estimate of the total economic burden of eye diseases and vision loss in the United States to date. Understanding the costs of disease provides vital information for identifying areas of need for future research and healthcare investment. This is particularly important for the areas of eye disease and vision loss, as the indirect costs of low vision greatly increase the total burden of these conditions beyond the healthcare sector. Our findings show that eye disorders and vision loss are among the costliest conditions to the U.S. economy, and based on ever-increasing healthcare costs and an aging population, this cost is set to continue to grow.

At $139 billion, our estimated burden more than doubles the previous cost estimate. Most of this increase is related to differences in approach and methodology. In part due to controversy over which costs should be included in the estimated cost of vision problems, recent consensus guidelines have delineated and defined which costs should be included, and how they should be reported.[1] Following these guidelines, this analysis provides a more comprehensive accounting of total costs, thus leading to the apparent increase in the cost estimate. The previous PBA estimate was limited to persons aged 40 and older, this report includes the total population. The previous report only included medical costs of four diagnosed eye disorders and vision aids, while this analysis includes all disorders related to the eyes and ocular adnexa. The prior report included productivity losses only for ages 40-64, which substantially underestimates these costs to the total population. This report captures the costs of routine eye examinations and costs paid out of pocket or by vision insurance plans, much of which may not have been included in the previous estimate.

This analysis also uses different data sources and methodologies designed to capture all medical costs attributable to eye disorders whereas the prior estimate captured the medical costs of claims directly related to the medical treatment of the four included eye diseases, an approach that will provide a more robust estimate of payer costs but will not capture ancillary medical costs that can be attributed to eye disorders, for example costs from falls, depression or lower physical activity. As the first comprehensive estimate of the costs of visual disorders, that analysis intentionally took a conservative cost estimation approach with the intent of creating an estimate of the floor of costs for those ages 40 and older. Finally, this analysis is simply more recent and will therefore reflect increases in medical costs and growth of the affected population that have occurred over the course of the nine years since the 2004 baseline year of prior estimate.

The differences in the results between this analysis and the prior PBA estimate highlight the difficulties and pitfalls of comparing disparate economic burden estimates. Nonetheless, it is apparent that vision loss and eye disorders are among the costliest conditions facing the United States. Although subject to significant methodological differences, a recent analysis of the cost of seven major chronic diseases in the United States, which did not include vision, only reported four conditions with direct costs higher than our findings of $66.8 billion.[8, 9] This is in line with findings from Australia, where vision disorders are estimated to be the seventh costliest health condition.[10]

These findings underscore the fact that chronic conditions are the largest drivers of cost for healthcare in United States and will continue to be so as the confluence of rising medical costs, increased access to care, and an aging population will continue to drive growth in medical costs. Another important finding of this analysis is that government pays the majority of healthcare costs and the majority of long-term care costs. Finally, due to the debilitating nature of vision loss, indirect costs including productivity losses and long-term care actually exceed direct costs for eye and vision problems, as eye disorders and visual loss incur a large burden on the overall U.S. economy even beyond the healthcare sector.

Introduction

Disorders of the eye and resulting vision loss impose a significant burden to the United States, both economically and socially. Eye disorders and vision loss are typically chronic conditions that will affect individuals for the duration of their lives, whether through on-going medical expenses to treat patients with chronic disorders, or through the high economic and social costs of debilitating vision loss. As with most chronic disease costs, the burden of eye disorders and vision loss are likely to continue to grow with an aging population and the continued rapid development of more effective, but more costly treatments. In an environment where the current and future cost and coverage of diseases and healthcare are at the forefront of public concern, establishing a comprehensive understanding of the cost of eye related conditions is of paramount importance.

The primary estimate of the burden of visual loss and eye disease is the landmark 2007 Prevent Blindness America report “The Economic Impact of Vision Problems, The Toll of Major Adult Eye Disorders, Visual Impairment and Blindness on the U.S. Economy”, which has stood as the primary estimate of the economic burden of eye and vision problems since its publication. However, this study was subject to a number of limitations which may have led to an underestimate of costs. Some costs not captured in the prior study include:

- Costs among persons younger than age 40.
- Medical costs for conditions other than AMD, cataract, glaucoma, and diabetic retinopathy
- Optometry visit costs,
- Costs paid by vision insurance plans,
- Costs paid out-of-pocket,
- Prescription drug costs for persons aged 65 or older, and
- Productivity losses for persons other than aged 40-64.

Finally, the prior estimates were based in 2004, using data from periods even earlier. In the subsequent 9 years, costs may have changed due to general increases in medical costs, and also due to the emergence of new but often costly therapies for eye diseases, particularly macular degeneration.

This report serves as an update to the 2007 PBA report. We build on the previous studies using more recent data and updated methodologies. We followed the consensus guidelines for research on the cost of vision loss which were developed and published under the auspices of the Association for Research in Vision and Ophthalmology in 2010.[1] These guidelines delineate definitions for analysis perspectives and specific cost categories that should be included in economic studies of vision loss. We include direct and indirect costs due to uncorrectable vision loss, refractive errors, and diagnosed disorders of the eye and ocular adnexa. We also report the impact of vision loss on disability and quality of life losses and separately estimate the possible monetized value of this burden. We include costs for all ages, all payers, all eye and vision disorders, and all providers to generate a comprehensive estimate of the complete economic burden of eye and vision disorders in the Unites States.

Review of the Literature

The Economic Impact of Vision Problems, 2007

The 2007 Prevent Blindness America report "The Economic Impact of Vision Problems, The Toll of Major Adult Eye Disorders, Visual Impairment and Blindness on the U.S. Economy" combined two separate but complementary studies on components of economic burden published in 2006 and 2007. Rein et al. (2006) estimated the annual burden of four major eye diseases at $35.4 billion in 2004, including $19.1 billion in nonmedical costs.[11] Frick et al. (2007) estimated the medical costs attributable to low vision ($5.5 billion per year) and the value of lost quality of life ($10.5 billion per year) in 2004.[12] Adding these amounts together indicated a total U.S. economic burden of $51.4 billion per year in 2004 for the U.S. population aged 40 and older.

The analysis by Rein et al. (2006) estimated direct medical costs, other direct costs, and productivity losses. Direct costs were based on two sets of medical insurance claims, MarketScan Commercial Claims and Encounters Research Database for ages 40-64, and a sample of year 2000 Medicare fee-for-service claims for ages 65 and older. Costs were calculated based on the value of claims where the primary ICD-9 diagnosis code for the claim indicated age-related macular degeneration, cataracts, diabetic retinopathy, or glaucoma. The cost of refractive error was estimated based on assumptions of eye glass or contact lens utilization per person in a population estimated by subtracting the prevalence of uncorrected refractive error from population estimates of low vision, and multiplying costs by the Medicare fee schedule for glasses or contact lenses assuming a 3.4 year replacement schedule. Rein et al. (2006) estimated productivity losses by applying the reduction in wages identified in the Survey of Income and Program Participation conducted by the U.S. Census Bureau to the estimated population with uncorrectable vision impairment and blindness. Rein et al. then captured a variety of other direct and indirect costs including the cost of dog guides, Federal assistance programs, and the cost of long-term care due to vision loss based on values in the literature and Federal budgets.

In updating this analysis, we follow the lead of Rein et al. (2006) for estimating the other direct costs and lost productivity, only differing by updating parameter values and costs where available. We use the same methodology as Rein et al. (2006) for estimating productivity losses, long-term care costs, and federal program costs. We include additional costs such as skilled-nursing facility placement, non-medical aids and the costs of programs focused on children, including special education and school screening.

Our approach differs is in the measurement of direct medical costs and in the inclusion of conditions and age ranges to be evaluated. Whereas Rein et al. (2006) utilized claims data to capture costs; we rely on a nationally representative health expenditure survey. An advantage for using claims for identifying costs is that claims data provides a robust estimate of payments by Medicare and private insurance plans for claims directly related to the treatment of the included conditions. However, this approach has several limitations which all were likely to reduce the overall cost estimate. First, medical costs were based only on four diagnosed disorders for persons aged 40 and older. Second, MarketScan claims data do not include vision insurance plans, and therefore will not capture most routine eye care services normally covered by such insurance plans. Third, neither MarketScan nor Medicare claims are likely to capture the cost of services paid out of pocket, which may be common for persons without a vision insurance plan or enrolled in Medicare fee-for-service. Fourth, at the time, prescription drug claims for Medicare patients were not available, forcing the authors to assume that prescription costs for the Medicare population were the same as the age 40-64 population, an assumption that almost certainly results in a substantial underestimate of these costs.

In addition to the estimates by Rein et al. (2006) on the direct medical costs of disorders, other direct and productivity costs of low vision, the 2007 PBA report included the annual excess monetary impact of low vision as estimated by Frick et al. (2007). In this analysis, Frick et al. (2007) used an econometric approach on Medical Expenditure Panel Survey (MEPS) data to estimate the medical costs, the number of informal care days, and the health utility costs attributable to self-reported low vision. In our analysis, we use MEPS data to estimate the medical cost of diagnosed disorders, and also the medical cost of undiagnosed low vision by replicating Frick et al.'s (2007) approach for defining low vision but controlling for diagnosis of any disorder to prevent double-counting of costs for persons with low vision and a diagnosed disorder. We use Frick et al.'s (2007) estimates for informal care days attributable for adults, but separately estimate informal care days for children. We could not replicate the previous approach for utility costs for the population younger than age 40 because this data are not collected for children, and we found unacceptable levels of co-linearity between self-reported quality of life and self-reported general health.

Other Burden Estimates

In addition to the 2007 PBA report and the two studies upon which it was based, several other studies have estimated medical and economic costs of vision problems. We conducted a literature review by searching PubMed and Google using search terms including “vision”, “eye”, “cost”, and “burden”, and by reviewing references. We identified a number of papers and reports on the cost and cost-effectiveness of individual conditions or interventions, but only a few estimates of the general economic burden of visual loss or eye problems in general. The first estimate of the economic burden of vision problems was the report *Economic Costs of Visual Disorders and Disabilities* by The-Wei Hu for the NEI in 1981. This benchmark estimate was subsequently updated by the NEI to account for inflation in 1991 and 2003. The total burden estimates from this study based on 1981, 1991 and 2003 baseline years were $14.1, $38.4, and $67.6 billion. Given that 32 years has passed since this study was conducted, we elected not to include it in our review. Below we describe two other analyses of the economic burden of visual impairment, both of which were developed by Access Economics Ltd., an Australian economics consulting firm. We summarize the findings of these two analyses along with the original 2007 PBA estimate and the results of this estimate in **Table 2.1**.

Access Economics 2006. The Cost of Visual Impairment in the US

In 2007 Access Economics produced a non-peer reviewed report of the cost of visual impairment in the United States for the University of Southern California.[13] We obtained a copy of this report through a request to Deloitte Access Economics, the current owner of the report. This analysis included a broad range of cost categories and found a total financial cost of $69.6 billion, including $50.1bn in health system expenditures and $19.5bn for other financial costs. The report also estimated that visual loss results in 600,000 DALYs lost per year.

Visual loss prevalence rates for the study were identified from the NEI website, based on underlying data from the same NEI prevalence study used for our analysis in the age 40 and older population. Healthcare costs were based on MEPS data; however the analysis did not use a regression approach to identify attributable costs. Costs were estimated based on the average medical costs for persons with difficulty seeing versus those without difficulty seeing, and multiplying the difference by an assumed attributable fraction of 42.9%.

The report included additional costs including the cost of nursing home visits. Using data from the 1999 National Nursing Home Survey, the authors estimated the cost of nursing home care for persons with a primary diagnosis of diseases of the nervous system and sense organs, while attempting to exclude the proportion with hearing impairment or other diseases of the nervous system. This process resulted in an estimated 14,079 persons placed in nursing home care due to visual loss, equating to a total cost of less than $1billion. This is markedly lower than our findings, where we estimated nursing home placement based on the age controlled relative prevalence of impairment in nursing homes versus in the community, and estimated 266,000 person years in nursing homes attributable to low vision or blindness.

The Access Economics report estimated productivity losses to be $2.7bn from reduced labor force participation, $111 million from absenteeism, and $9.7 million from premature mortality. Data on labor force participation was derived from relative employment rates for those who report low vision in data from the Employment and Disability Institute, multiplied by the prevalent impaired population and the average wage rate from BLS data. Absenteeism cost was estimated based on the addition number of work days lost for persons with vision loss in National Health Interview Survey-Disability (NHIS-D) data when controlling for age, sex, and socioeconomic status. Productivity losses from premature mortality were included for persons aged 40-64. The proportion of deaths due to visual impairment was estimated by multiplying the assumed total number of deaths among persons with visual impairment by an etiological fraction of 0.83%. The calculation of this fraction was not defined. This approach resulted in an estimated 57 deaths in the United States from visual loss, future lost earnings were monetized based on the average wage rate over life expectancy, discounted to the current year at 3% per year.

Informal care was estimated to cost $16.1bn, derived from hours of community care service utilization identified in NHIS-D for persons with and without visual impairment. It is unclear how these hours were derived, but they are substantially higher than similar rates sources from MEPS data in Frick et al. (2007), which found about $1.5 billion in informal care costs. The report also included an estimate of lost tax revenue of $400 million, deadweight loss from taxation of $63 million, deadweight loss due to social security payments of $106 million, eye research expenditures of $756 million based on NEI and OECD estimates, and aids and devices at $346 million.

Gordois et al. 2012 An estimation of the worldwide economic and health burden of visual impairment

In 2012 Gordois et al. released an estimate of the global burden of visual impairment.[14] Gordois and three co-authors of this paper are with Access Economics Ltd. and presumably were involved with Access Economic's 2007 report, which did not state any authors or editors. The 2012 analysis estimates the prevalence of visual loss and direct and indirect costs by WHO region, including mortality, direct health system costs, deadweight welfare loss, informal care costs, and productivity losses. Prevalence of impairment are based on WHO estimates, but inflated by assumed adjustment factors to account for mild impairment and uncorrected refractive error.[15] Premature mortality from vision loss was estimated by applying a relative risk of mortality calculated based on the proportion of deaths in Australia in which "diseases of the eye and adnexa" were cited as a primary cause of death. Direct health system costs were based on previously reported estimates for countries where these data were available, and applied to other countries on the basis of the ratio of direct cost per capita to GDP per capita. Neither the methodology nor baseline values for healthcare costs were reported, but among the sources cited, the only U.S.-based studies were Rein et al. (2006) and Frick et al. (2007), the two papers that served as the basis for the 2007 PBA estimate, and Access Economics' 2007 report.

Deadweight loss was estimated based on the percentage of healthcare spending by government and an assumed deadweight loss rate of 20%. Informal care costs were based on informal hour requirements in the UK and Australia, adjusted by a measure of the availability of formal care derived from the density of health workers per 1000 population in Australia (0.2) and the UK (8.43), and multiplied by hourly wages for each country. Productivity losses were based on the employment gap observed among persons with visual impairment applied to the employment rate. For the United States estimate, these data were inferred from Canadian data. Productivity losses were included for mortality due to vision impairment, with lifetime future productivity discounted to the current year by 3% annually. Gordois et al. (2012) also estimated disability-adjusted life years (DALYs) lost due to visual impairment by applying 2004 WHO disability weights to the impaired population and accounting for lost life years due to vision-related mortality.

Gordois et al. (2012) report outcomes based on WHO region, so the results for the United States are included in the AMR-A region along with Canada and Cuba. Of the three countries in AMR-A, the United States constitutes 87% of the total population and 94% of healthcare spending, so aggregating these three countries presumably only slightly overstates the burden to the United States alone.[16] For the AMR-A region, Gordois et al. (2012) estimated direct healthcare costs for visual loss to be $512.8 billion in 2010. Given that healthcare costs were stated to be based on prior reported estimates, and the only U.S. estimates cited were the Rein and Frick papers that reported total healthcare costs of $21.4 billion and the Access Economics 2007 report that estimated costs at $50.1 billion; it is unclear how the authors arrived at an estimate of over $500 billion in direct healthcare costs alone. Based on WHO estimates of total national healthcare spending for the U.S., Canada and Cuba, Gordois' estimate would imply that visual impairment causes one fifth of all healthcare spending. Gordois et al similarly report extremely high results for the AMR-A region for deadweight loss ($50.8 billion), productivity losses ($97.1 billion), and informal care ($30.9 billion).

Table 2.1. Results from the current and three previous burden estimates

	PBA, 2007	Access Economics, 2007	Gordois et al. 2012*	PBA, 2013
Medical Costs	$21.4	$50.1	$512.8	$65.0
Long-term Care	$11.0	$1.0	-	$19.5
Other Direct Costs	$0.2	$19.5	-	$1.7
Lost Productivity	$8.0	$2.8	$97.1	$48.4
Informal Care	$0.4	$16.1	$30.9	$2.1
Deadweight Loss	-	$0.2	$50.8	$1.5
Burden, without quality of life cost	**$40.87**	**$89.7**	**$691.6**	**$138.3**
Utility/disability adjusted life years**	209,200	600,000	3,242,000	283,000
Monetary cost**	$10.5	$103	$162	$14.2
Total burden with quality of life costs				
$50,000 per QALY or DALY	**$51.4**	**$192.7**	**$853.7**	**$153.1**

*Results from Gordois et al. (2012) include the US, Canada, and Cuba. Of note, the U.S. constitutes 87% of the total population of these three countries, and 94% of total healthcare expenditures.

**The current estimate, Access Economics 2007 and Gordois 2012 reported costs in disability adjusted life years (DALYs), while the PBA 2007 reported quality adjusted life years (QALYs). PBA 2007, Gordois 2012, and PBA 2013 assume a monetary cost of $50,000 per adjusted life year.

Prevalence of Visual Impairment and Treated Disorders

The Prevalence of Visual Impairment and Blindness

Our estimates of prevalence and the prevalent population with visual impairment and blindness are listed in table 3.1 and 3.2. A National Eye Institute (NEI) meta-analysis reports the prevalence of visual impairment and blindness based on eight population-based studies of persons aged 40 or older.[3, 4] We use the NEI prevalence rates for ages 40 and older. The NEI study did not include any persons younger than age 40, to our knowledge no nationally representative data on the prevalence visual impairment and blindness are available for this age group, except a study based on NHANES data that reported prevalence rates for persons with and without diabetes.[7]

For the overall population younger than age 40, we estimated the prevalence of visual impairment and blindness based on autorefractor-corrected visual acuity as measured in the National Health and Nutrition Examination Survey (NHANES) data from 2005 through 2008 (Table 3.1). We used SAS statistical software version 9.2 (Cary, NC) with SAS-Callable SUDAAN Version 10.0.1 (Research Triangle Park, NC) to adjust for the complex design of the NHANES sample. We assigned individuals to normal vision, mild impairment, moderate impairment, or blind based on the corrected visual acuity of the better-seeing eye. Cut-off values for impairment category were based on U.S. thresholds: >20/40 for mild impairment, >20/80–20/200 for moderate impairment, and >20/200 for blindness. Respondents who did not have an acuity test due to self-reported blindness were included in the prevalence of blindness. Acuity tests were not administered to NHANES respondents younger than age 12, and no nationally representative data exist on the prevalence of non-correctable bilateral vision loss in this population. We imputed the prevalence of vision loss among children younger than age 12 by adjusting the age 12 to 17 NHANES prevalence using age-specific incidence of severe impairment and blindness as identified in U.K. surveillance data.[17] We estimated the prevalence and confidence intervals (CIs) for each variable of interest using the Taylor Linearization Method. We estimated the population of each impairment category by multiplying prevalence rates by 2010 Census population estimates.

We assume the use of NHANES data includes certain limitations. Screening is based on acuity testing using near distance charts performed with whatever vision correction devices the participants are currently using, followed by autorefraction testing. Only a subsample of respondents aged 40 or older are assessed for reduced visual field or contrast sensitivity. Given the lack of appropriate validation data for persons younger than age 40, we compared the prevalence of visual impairment and blindness for persons aged 40 or older in NHANES to the NEI meta-analysis values for validation purposes. The NEI meta-analysis reports the prevalence of visual impairment and blindness based on eight population-based studies of persons aged 40 or older.[3, 4] The NEI study found prevalence of visual impairment and blindness among the population aged 40 or older to be 1.98% and 0.78%, respectively. For the population aged 40 or older, we estimated the prevalence of visual impairment and blindness in NHANES at 2.19% and 0.22%, respectively. Thus, the NHANES estimates identify higher overall prevalence of impairment but lower prevalence of blindness. Ordered based on prevalence of any impairment, the NHANES prevalence rates would fall fourth among the eight studies included in the NEI report.

Table 3.1. Prevalence of Visual Loss, 2005–2008 NHANES

Age Group	Mild Impairment	Moderate Impairment	Blind	Total Vision Loss
Age 0-17	1.07% (0.58% - 1.22%)	0.10% (0.01% - 0.20%)	0.01% (0.00% - 0.03%)	1.18% (0.59% - 1.44%)
Age 18-39	1.17% (0.74% - 1.60%)	0.14% (0.02% - 0.26%)	0.10% (0.01% - 0.34%)	1.41% (0.77% - 2.21%)
Age 40-64	0.27% (0.23% - 0.30%)	0.06% (0.05% - 0.07%)	0.15% (0.12% - 0.18%)	0.48% (0.40% - 0.55%)
Age 65+	5.00% (4.20% - 5.80%)	1.16% (0.97% - 1.34%)	2.41% (1.78% - 3.03%)	8.57% (6.95% - 10.18%)

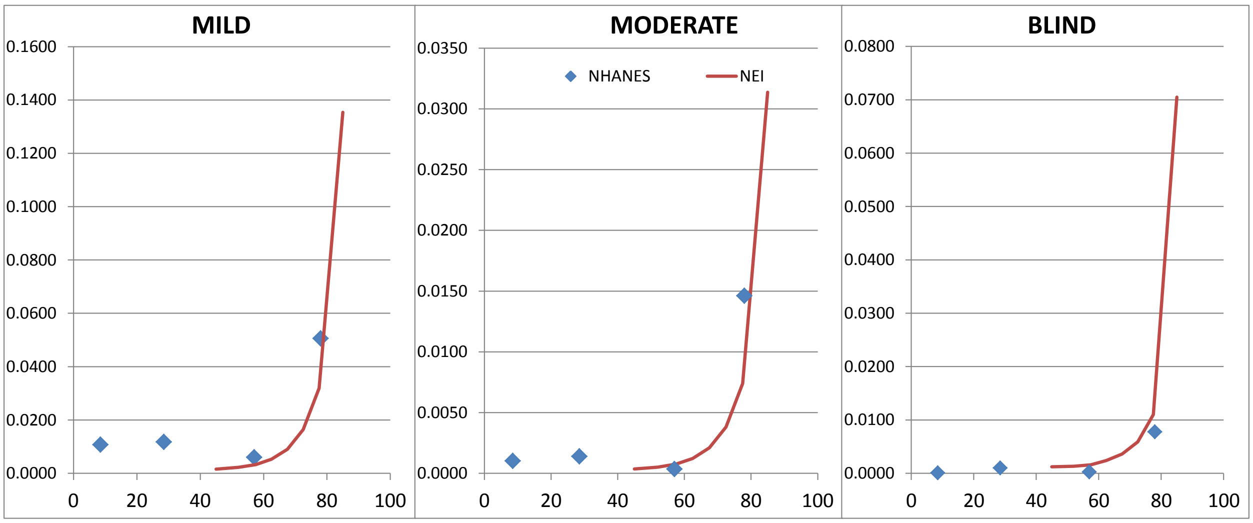
Table 3.2. Prevalent Population with Visual Loss, 2005–2008 NHANES

Age Group	Mild Impairment	Moderate Impairment	Blind	Total Vision Loss
Age 0-17	795 (434 - 903)	76 (6 - 145)	6 (0 - 20)	877 (440 - 1,069)
Age 18-39	1,082 (684 - 1,478)	128 (16 - 242)	92 (6 - 317)	1,302 (706 - 2,037)
Age 40-64	276 (240 - 0,311)	64 (56 - 72)	156 (123 - 185)	496 (418 - 0,568)
Age 65+	2,070 (1737 - 2,401)	480 (402 - 556)	997 (737 - 1256)	3,546 (2877 - 4,213)

One complication of using NHANES prevalence for younger ages and NEI prevalence for ages 40 and older is that mild and moderate impairment appear to decrease from ages 18-39 to ages 40-64. We assume that much of this difference is due to improved acuity testing and refraction correction in the NEI studies versus that achieved by autorefractor in NHANES. However, when assessing NHANES prevalence by age, we see nearly the same reduction in impairment from the 18-39 group to the 40-64 group. Indeed, this pattern is also apparent in the analysis of NHANES prevalence conducted by the CDC.[7] **Figure 10** shows age-specific prevalence of visual impairment and blindness from the NEI and NHANES. The figure shows the NHANES-derived prevalence rates for the median of each age group as blue diamonds, and the NEI-based prevalence rates for persons aged 40 and older as the red line. This analysis uses

NHANES prevalence for ages less than age 40 and the NEI prevalence for ages 40 and older, resulting in an apparent drop in mild and moderate impairment at age 40. However, even if we were to use NHANES prevalence for ages 40 and older, we would still see this apparent decrease in prevalence at age 40.

Figure 11. Comparing the prevalence of impairment and blindness between NHANES and NEI estimates



Treated Prevalence of Diagnosed Vision Disorders

Our estimates of treated prevalence and the treated prevalent population are listed in **tables 3.3 and 3.4**, respectively. To estimate the treated prevalence of diagnosed vision disorders, we identified International Classification of Diseases, Ninth Revision (ICD-9) diagnosis codes related to eye and vision conditions.[11, 18] We included a broad range of disorders, including conjunctivitis, eyelid problems, and eye injuries and burns, although these categories are reported separately. We grouped ICD-9 codes into like conditions. We then estimated the prevalence (and standard error) of each code as a primary diagnosis using pooled data from the 2003–2008 Medical Expenditure Panel (MEPS) data conditions file (Table 3.3).[19] MEPS assigns ICD-9 codes to survey respondents based on their descriptions of existing medical conditions, past diagnoses, or the nature of medical care received.

An important consideration of MEPS data are that visual correction and optometry care are not included in the medical provider component and are assessed separately. Possibly due to this structure, MEPS includes few persons with ICD-9 codes for Disorders of refraction and accommodation. Also, MEPS only includes 3-digit ICD-9 codes. This means that MEPS cannot identify conditions coded at the 4th or 5th digit, such as amblyopia and different types of retinal disorders other than retinal detachment (361).

Thus, both diabetic retinopathy (362.0) and macular degeneration (362.5) are coded under 362. To attempt to distinguish these, we created a condition "retinal disorders, with diabetes" for persons diagnosed with retinal disorders (361 or 362) and self-report diabetes, and "retinal disorder, no diabetes" for persons with retinal disorders (361 or 362) but do not report diabetes. While this approach is very limited, we assume it will provide an approximation of actual diagnoses of diabetic retinopathy and other retinal disorder including macular degeneration.

Table 3.3. Treated Prevalence of Vision Diagnoses, 2003–2008 MEPS

Disorder	ICD-9 Codes	0-17	18-39	40-64	65+	Overall
Visual Disturbances	367, 368	1.24% (1.14% - 1.34%)	1.52% (1.41% - 1.64%)	1.81% (1.70% - 1.93%)	2.21% (2.00% - 2.41%)	1.63% (1.57% - 1.69%)
Cataracts	366	0.02% (0.01% - 0.03%)	0.05% (0.03% - 0.07%)	0.88% (0.81% - 0.96%)	9.21% (8.82% - 9.60%)	1.44% (1.39% - 1.50%)
Conjunctivitis, lacrimal/eye Lid	372, 373, 374, 375	2.03% (1.90% - 2.17%)	0.79% (0.71% - 0.87%)	1.02% (0.93% - 1.11%)	2.10% (1.90% - 2.30%)	1.34% (1.28% - 1.39%)
Glaucoma and optic nerve	365, 377	0.05% (0.02% - 0.07%)	0.12% (0.09% - 0.15%)	1.14% (1.06% - 1.23%)	6.42% (6.08% - 6.75%)	1.21% (1.16% - 1.26%)
Other	363, 364, 370, 371, 376, 379	0.52% (0.45% - 0.59%)	0.46% (0.40% - 0.52%)	1.02% (0.94% - 1.10%)	2.41% (2.21% - 2.62%)	0.90% (0.85% - 0.94%)
Disorders of the globe	360	0.69% (0.61% - 0.76%)	0.43% (0.37% - 0.49%)	0.63% (0.57% - 0.70%)	1.14% (1.00% - 1.29%)	0.65% (0.61% - 0.69%)
Retina disorder, no diabetes	361, 362, no diabetes	0.04% (0.02% - 0.06%)	0.06% (0.04% - 0.08%)	0.39% (0.34% - 0.45%)	3.36% (3.11% - 3.61%)	0.57% (0.53% - 0.61%)
Retina disorder, with diabetes	361, 362, with diabetes	0.03% (0.02% - 0.05%)	0.03% (0.02% - 0.05%)	0.34% (0.29% - 0.38%)	3.20% (2.96% - 3.45%)	0.52% (0.49% - 0.56%)
Injuries and burns	870, 871, 918, 921, 930, 940	0.38% (0.32% - 0.43%)	0.57% (0.50% - 0.63%)	0.49% (0.43% - 0.55%)	0.52% (0.41% - 0.63%)	0.49% (0.45% - 0.52%)
Blindness and low vision	369	0.10% (0.07% - 0.13%)	0.12% (0.08% - 0.15%)	0.25% (0.21% - 0.29%)	0.80% (0.68% - 0.92%)	0.24% (0.22% - 0.26%)
Strabismus	378	0.25% (0.20% - 0.30%)	0.03% (0.02% - 0.05%)	0.02% (0.01% - 0.03%)	0.02% (0.00% - 0.04%)	0.08% (0.07% - 0.10%)

Table 3.4. Treated Prevalent Population in Thousands, 2003–2008 MEPS,

Disorder	ICD-9 Codes	0-17	18-39	40-64	65+	Overall
Visual Disturbances	367, 368	920 (0,843 - 0,996)	1,406 (1,301 - 1,511)	1,883 (1,765 - 2,000)	914 (0,830 - 0,998)	5,036 (4,845 - 5,227)
Cataracts	366	12 (0,004 - 0,021)	45 (0,029 - 0,062)	917 (0,839 - 0,996)	3,812 (3,651 - 3,973)	4,452 (4,279 - 4,625)
Conjunctivitis, lacrimal/ eye Lid	372, 373, 374, 375	1,508 (1,409 - 1,608)	727 (0,653 - 0,802)	1,059 (0,968 - 1,149)	869 (0,786 - 0,953)	4,131 (3,957 - 4,304)
Glaucoma and optic nerve	365, 377	35 (0,018 - 0,051)	115 (0,087 - 0,143)	1,188 (1,097 - 1,279)	2,657 (2,518 - 2,796)	3,744 (3,583 - 3,905)
Other	363, 364, 370, 371, 376, 379	385 (0,334 - 0,435)	424 (0,366 - 0,482)	1,060 (0,974 - 1,146)	999 (0,914 - 1,083)	2,771 (2,632 - 2,909)
Disorders of the globe	360	511 (0,456 - 0,567)	397 (0,342 - 0,452)	656 (0,588 - 0,725)	473 (0,414 - 0,532)	2,003 (1,885 - 2,121)
Retina disorder, no diabetes	361, 362, no diabetes	29 (0,018 - 0,041)	54 (0,034 - 0,073)	409 (0,354 - 0,464)	1,390 (1,286 - 1,494)	1,759 (1,645 - 1,872)
Retina disorder, with diabetes	361, 362, with diabetes	25 (0,014 - 0,036)	32 (0,018 - 0,046)	349 (0,298 - 0,399)	1,326 (1,224 - 1,428)	1,615 (1,506 - 1,723)
Injuries and burns	870, 871, 918, 921, 930, 940	279 (0,239 - 0,318)	522 (0,460 - 0,585)	507 (0,446 - 0,568)	215 (0,171 - 0,260)	1,506 (1,401 - 1,610)
Blindness and low vision	369	74 (0,055 - 0,094)	107 (0,078 - 0,135)	259 (0,219 - 0,299)	330 (0,281 - 0,379)	739 (0,670 - 0,808)
Strabismus	378	186 (0,151 - 0,222)	31 (0,014 - 0,047)	22 (0,010 - 0,035)	9 (0,002 - 0,016)	255 (0,213 - 0,298)

Medical Costs

Medical Costs Attributable to Diagnosed Vision Disorder and Undiagnosed Visual Loss

We calculated overall and per payer medical costs using a two-part generalized linear on 2003–2008 MEPS pooled event file data.[19, 20] MEPS is a nationally representative panel survey conducted on a sample of National Health Interview Survey respondents to capture additional detail including medical costs. In MEPS, respondents are queried on their medical history and medical care received in the past year. In the Medical Provider component, MEPS contacts the respondents' medical providers to confirm visits, events and costs. MEPS differentiates costs by payer. Based on medical history and treatment, MEPS assigns 3-digit ICD-9 diagnosis codes to individual respondents in the Medical Conditions File. MEPS does not include optometrists in the Medical Provider component. Respondents are asked to report visits to optometrists and their respective costs, and report the costs for vision aids (glasses and contact lenses). MEPS does not confirm these costs. Due to this structure, the cost of care provided by optometrists may not be included in the medical provider component and may not be associated with diagnosed conditions. Thus, we calculate the medical costs attributable to diagnosed disorders and undiagnosed disorders on total medical costs excluding costs for optometry services and vision aids, which we calculate separately.

The first part of the two-part model used a logistic regression to predict the probability of positive expenditures. The dependent variable in the second part is defined as annual total medical expenditures excluding optometry expenses, which include the cost of medical vision aids (e.g., glasses, contact lenses) and optometrist visits. Using a generalized linear model with a gamma distribution and a log link, the second part of the model predicts expenditures conditional on having positive expenditures. Multiplying the predicted probability from the first part of the model with predicted (conditional) expenditures from the second part, we generated predicted annual expenditures for each individual in the data as a function of the individual's condition profile and demographics.[20]

Both parts of the model included the same set of independent variables. These included dichotomous variables identifying the comprehensive vision disorder variable, a variable representing self-reported difficulty seeing in the absence of a diagnosed disorder (undiagnosed visual loss), and expensive comorbidities: hypertension and diabetes. All regressions also included as independent variables the following demographic characteristics: age, age squared, sex, race/ethnicity (white non-Hispanic, other), education (missing degree, younger than 17 years of age, no degree, high school diploma, college degree, graduate degree), region (northeast, midwest, south, west), insurance status (private, public, uninsured), marital status, family size, family income (<100%, 100% to 199%, 200% to 399%, ≥400% of the poverty line), and year.[21] Bootstrapped standard errors that account for the sampling design of MEPS were generated for all estimates. Medical costs of diagnosed disorders and undiagnosed vision loss, excluding the cost of optometry visits and medical vision aids, are shown in **Tables 4.1 and 4.2**, respectively.

Table 4.1. Medical Costs Attributable to Diagnosed Disorders

Age Group	Total			Per person		
	Mean	95% CI		Mean	95% CI	
Ages 0-17	2,455,801,946	2,192,680,309	2,769,701,443	659	585	725
Ages 18-39	4,387,668,703	3,958,364,979	4,858,517,949	1,268	1,138	1,393
Ages 40-64	12,982,975,516	11,298,073,804	14,887,145,258	1,957	1,696	2,211
Ages 65+	26,092,895,681	22,503,824,227	30,235,907,423	3,097	2,674	3,560
Total	**45,919,341,846**	**39,952,943,320**	**52,751,272,073**	**2,470**	**2,139**	**2,820**

Table 4.2. Medical Costs Attributable to Undiagnosed Visual Loss

Age Group	Total			Per person		
	Mean	95% CI		Mean	95% CI	
Ages 0-17	47,527,024	22,042,207	80,090,533	117	50	196
Ages 18-39	474,311,372	207,727,608	810,137,672	205	88	337
Ages 40-64	1,702,212,345	424,687,555	3,866,041,598	272	68	586
Ages 65+*	798,135,633	-11,771,231	2,169,599,464	329	-5	877
Total	**3,022,186,374**	**642,686,139**	**6,925,869,268**	**274**	**51**	**618**

*Not statistically different from zero

Non-optometry medical costs per person attributable to each disease were calculated using the following method that minimizes double-counting of expenditures across diseases:[20]

1. Every unique combination of the chronic diseases listed among independent variables observed in the data was identified.
2. Expenditures were predicted for each individual.
3. For each unique combination of diseases, we subtracted from Step 2 the predicted expenditures for an otherwise identical person without the combination of diseases. This provides an estimate of the costs attributable to every unique combination of diseases.

4. The coefficients of the diseases from the second part of the two-part econometric model were used as importance weights to redistribute costs associated with jointly occurring diseases to constituent diseases (e.g., to redistribute the costs of vision disorders with hypertension back to vision disorders and hypertension separately).
5. The application averages the redistributed costs over the population with each disease.

Medical Vision Aid and Optometry Visit Costs

MEPS collects optometrist expenses separately from other medical expenses, and these costs are included in optometry-specific expenditure variables, including the cost of glasses and contact lenses and care provided by optometrists. While optometry services may be used for the treatment of diagnosed vision disorders, in MEPS data we found that only a small fraction of optometry costs were attributable to vision diagnoses, including diagnoses of vision problems. We therefore assume that most optometry, glasses, and contact lens costs, as recorded by MEPS, are unrelated to diagnosis of vision disorders. We estimated the total cost of optometry visits (**Table 5.1**) and medical vision aids (**Table 5.2**) through a simple accounting approach, summing the total optometry costs for all persons in the sample and estimating overall and per person costs.

Table 5.1. Optometry Visit Costs

Age Group	Total			Per person		
	Mean	95% CI		Mean	95% CI	
Ages 0-17	387,758,202	335,826,300	440,844,146	5	5	6
Ages 18-39	679,730,896	610,488,360	748,973,432	8	7	8
Ages 40-64	1,234,825,227	1,132,115,465	1,338,689,031	13	12	14
Ages 65+	547,016,035	489,313,922	604,718,148	15	14	17
Total	**2,849,330,360**	**2,654,297,217**	**3,046,671,588**	**11**	**10**	**12**

Table 5.2. Medical Vision Aid Costs

Age Group	Total			Per person		
	Mean	95% CI		Mean	95% CI	
Ages 0-17	1,479,977,160	1,386,175,790	1,573,778,529	20	19	21
Ages 18-39	3,335,159,796	3,105,867,560	3,574,874,407	38	37	39
Ages 40-64	6,222,157,495	5,867,796,767	6,576,518,223	66	64	67
Ages 65+	2,199,120,991	2,053,207,750	2,334,611,857	61	58	63

Age Group	Total			Per person		
	Mean	95% CI		Mean	95% CI	
Total	**13,236,415,441**	**12,506,849,236**	**13,965,981,647**	**53**	**51**	**55**

Medical Costs by Diagnosis

We estimated the total and per-person costs of diagnosed disorders in the MEPS data file using the 2-part model with individual disorder categories as the primary independent variable. We report the summed cost of optometrist visit care and vision aid costs as the cost of "Vision Correction", although some of this cost may include services provided by optometrists for diagnosed disorders that were not identified in the MEPS Medical Provider Component.

A major limitation of the MEPS structure is that diagnoses are tracked only at the 3-digit ICD-9 level, which means that some important conditions defined at the 4th or 5th digit are not separately identifiable. Such conditions include amblyopia, age-related macular degeneration (362.5) and diabetic retinopathy (362.0). We detail the identification of ICD-9 codes in section 3.2. We attempted to approximate the diagnoses of age-related macular degeneration and diabetic retinopathy by creating two conditions; "retinal disorder with diabetes" for persons diagnosed with retinal disorders and self-report diabetes, and "retinal disorder without diabetes" for persons with retinal disorders but do not report diabetes. We assume that this approach will approximate actual diagnoses of diabetic retinopathy and other retinal disorder including macular degeneration.

Total medical costs by disorder are listed in **Table 6.1**, while per-person medical costs by disorder are listed in **Table 6.**2. Due to limitations in the data and our approach, almost none of the cost estimates for each condition are statistically different from one another. While we list and describe the costs for each condition in order of our estimate, these results should not be construed as providing a definitive ranking of costs. In addition, due to sample size limitations, we estimated costs for each eye disorder without controlling for the presence of other eye disorders, thus double counting many costs. For the total costs, we controlled for this by deflating all costs per age group such that they summed to the overall cost estimate identified when we grouped all diagnosed disorders into a single independent variable. We did not control for such double counting when reporting per-person medical costs, thus summing costs across conditions would overstate total costs.

Our estimates for age related macular degeneration and diabetic retinopathy are likely to be overstated. Due to data limitations, we report the costs for all retinal disorders for persons with diabetes as analogous to diabetic retinopathy, and the cost for all retinal disorders without diabetes as analogous to the costs of age-related macular degeneration. While our estimated costs of AMD and diabetic retinopathy are much higher than found by Rein et al (2006), we include out-of-pocket and prescription drug costs not included in Rein et al and our results do appear in line with other estimates of these costs. Day et al found per-person Medicare costs for AMD to be $3,263 per year.[22] Based on our estimate of the treated prevalence, which may also be an overestimate, this would imply at total cost of $5.7 billion. Similarly, an analysis by Schmier et al found Medicare payments for persons with proliferative diabetic retinopathy to be $3,825 higher than controls.[23] Based on our estimate of treated prevalence, although likely an overestimate, this would indicate a possible cost of diabetic retinopathy of $6.2 billion.

Table 6.1. Total Medical Costs by Disorder, in $ millions *

	Total Costs by Age Group				
Vision Disorder	0-17	18-39	40-64	65+	All Ages
Vision correction	$1,868	$4,015	$7,457	$2,746	$16,086
Cataracts	$11	$75	$2,140	$8,430	$10,656
Glaucoma and optic nerve	$13	$124	$1,558	$4,059	$5,755
Retinal disorder, no diabetes	$27	$106	$988	$3,469	$4,590
Conjunctivitis, lacrimal/eye lid	$836	$860	$1,443	$1,417	$4,556
Other	$264	$646	$1,730	$1,856	$4,496
Retinal disorder, with diabetes	$21	$59	$901	$3,104	$4,086
Blindness and low vision	$122	$353	$1,326	$1,959	$3,760
Visual Disturbances	$393	$1,086	$1,440	$729	$3,648
Undiagnosed low vision	$48	$474	$1,702	$798	$3,022
Disorders of the globe	$279	$451	$930	$773	$2,435
Injuries and burns	$125	$515	$444	$244	$1,329
Strabismus	$364	$112	$81	$51	$608

*Costs adjusted to sum to overall total estimated costs. Differences in condition costs are not statistically significant.

Table 6.2. Per-person Medical Costs by Disorder*

	Per-Person Costs by Age Group				
Vision Disorder	0-17	18-39	40-64	65+	All Ages
Blindness and low vision	$1,490	$2,820	$5,870	$10,020	$6,680
Retinal disorder, no diabetes	$830	$1,690	$2,730	$4,210	$3,740
Retinal disorder, with diabetes	$770	$1,610	$2,930	$3,950	$3,640
Cataracts	$810	$1,410	$2,640	$3,730	$3,480
Strabismus	$1,750	$3,090	$4,120	$9,500	$2,370

Vision Disorder	Per-Person Costs by Age Group				
	0-17	18-39	40-64	65+	All Ages
Glaucoma and optic nerve	$350	$910	$1,490	$2,580	$2,170
Other	$630	$1,290	$1,850	$3,130	$2,020
Disorders of the globe	$500	$960	$1,610	$2,780	$1,440
Conjunctivitis, lacrimal/eye lid	$500	$1,000	$1,540	$2,750	$1,290
Injuries and burns	$410	$830	$990	$1,910	$950
Visual Disturbances	$380	$650	$870	$1,350	$790
Undiagnosed low vision	$189	$505	$825	$703	$734
Refractive error	$36	$61	$103	$83	$81

*Costs not controlled for presence of other disorders, Differences in condition costs are not statistically significant.

School Screening Cost

Identification of School Screening Programs

Naser and Hartman conducted a survey identifying the ages at which preschool and school-based vision screening is conducted in each state.[24] The authors identified school screening programs in 46 states and the District of Columbia, with screening occurring in nearly five grade levels on average per state with school screening. Naser and Hartman identified 15 states with preschool screening, and we have identified an additional 3 states for a total of 18 states with preschool screening. We assume that preschool screening programs target only 3-year-olds.

Screening Costs and Uptake

We based per student preschool screening costs on the program and volunteer labor costs incurred by Prevent Blindness Georgia (PBGA).[25] PBGA conducts symbol acuity and stereopsis tests on all 3-year-olds enrolled in state-funded preschools. Contract costs for PBGA were $6.49 per child screened. About 10% of screens were conducted by volunteers, typically preschool teachers or administrators. We assigned costs for volunteer labor based on the average per capita hourly wage and the time per child screened as estimated by PBGA staff.[26] Including these costs, we estimate the total economic cost of screening to be $6.72 per child screened in 2008. Because Georgia's state-funded preschool program is unique, we based preschool screening penetration on the rates achieved by North Carolina's Prevent Blindness Screening Program, which reaches approximately 44% of state residents in the targeted age group per year. We do not base costs on the North Carolina program because it uses a unique and relatively costly universal photoscreening program that costs $17 per child.

We estimate the cost of school-based vision screening to be $4.15 per child screened, which is the average estimated program and volunteer labor cost per child screened observed in North Carolina and Virginia. Both programs report near universal screening compliance for targeted age groups, and therefore we assume that 100% of residents at each targeted age level in school screening programs will receive a screen.

Tables 7.1 and 7.2 show the total per state costs for preschool and school vision screening, respectively. Costs were updated to 2013 levels based on the Consumer Price Index.

Table 7.1. Preschool Screening Costs, by State

State	Age 3 Population	Estimated # Screened	Screening Costs
Arizona	90,501	39,268	$283,697
Arkansas	39,526	17,150	$123,903
California	516,391	224,061	$1,618,762
Colorado	68,089	29,544	$213,445
Connecticut	45,390	19,695	$142,289
District of Columbia	5,601	2,430	$17,556
Georgia	138,420	60,060	$433,912
Idaho	23,837	10,343	$74,725
Iowa	40,444	17,549	$126,785
Kansas	40,386	17,523	$126,598
Michigan	130,226	56,505	$408,229
Minnesota	71,337	30,953	$223,625
Nevada	36,945	16,030	$115,811
New Mexico	28,815	12,503	$90,330
North Carolina	126,758	55,000	$397,356
Oregon	48,136	20,886	$150,894
Virginia	102,982	44,684	$67,471
West Virginia	21,523	9,339	$283,697
Total	**1,207,147**	**523,779**	**$4,615,387**

Table 7.2. School Screening Costs, by State

State	Average Grade Level Population	# of Grades Screened	Estimated # Screened	Screening Costs
Alabama	62,914	3	188,742	$842,101
Alaska	10,410	1	10,410	$46,446
Arizona	90,501	6	543,006	$2,422,703
Arkansas	39,526	6	237,156	$1,058,107
California	516,391	4	2,065,564	$9,215,824
Colorado	68,089	7	476,623	$2,126,525
Connecticut	45,390	8	363,120	$1,620,114
Delaware	11,431	5	57,155	$255,006
District of Columbia	5,601	5	28,005	$124,949
Florida	222,338	1	222,338	$991,994
Georgia	138,420	3	415,260	$1,852,745
Hawaii	16,879	14	236,306	$1,054,315
Idaho	23,837	5	119,185	$531,762
Illinois	173,843	2	347,686	$1,551,253
Indiana	89,350	2	178,700	$797,297
Iowa	40,444	7	283,108	$1,263,129
Kansas	40,386	5	201,930	$900,941
Louisiana	62,112	1	62,112	$277,122
Maine	15,252	13	198,276	$884,638
Maryland	75,165	5	375,825	$1,676,800
Massachusetts	78,829	1	78,829	$351,707
Michigan	130,226	6	781,356	$3,486,137
Minnesota	71,337	6	428,022	$1,909,684
Mississippi	41,975	14	587,650	$2,621,889
Missouri	79,191	2	158,382	$706,645
Montana	12,420	1	12,420	$55,414
Nebraska	25,512	1	25,512	$113,826
Nevada	36,945	3	110,835	$494,507
New Hampshire	15,957	1	15,957	$71,195
New Jersey	114,734	2	229,468	$1,023,806
New Mexico	28,815	3	86,445	$385,687
New York	240,274	13	3,123,562	$13,936,241
North Carolina	126,758	1	126,758	$565,550
Ohio	151,708	5	758,540	$3,384,340
Oklahoma	51,648	3	154,944	$691,306
Oregon	48,136	4	192,544	$859,064
Pennsylvania	155,120	13	2,016,560	$8,997,185
Rhode Island	12,442	8	99,536	$444,095
Tennessee	83,111	9	747,999	$3,337,310
Texas	381,435	6	2,288,610	$10,210,977
Utah	48,390	5	241,950	$1,079,496
Vermont	7,180	4	28,720	$128,139
Virginia	102,982	6	617,892	$2,756,818
Washington	87,853	6	527,118	$2,351,816
West Virginia	21,523	1	21,523	$96,028
Wisconsin	74,416	1	74,416	$332,018
Total	**4,121,191**		**20,146,055**	**89,884,650**

Federal Assistance Programs

American Printing House for the Blind

Established in 1879 and administered by the Department of Education, the American Printing House for the Blind (APH) supplies accessible educational materials for legally blind students who are enrolled in primary and secondary education programs. APH provides textbooks in large type and Braille, special education tools such as Braille printers and computer software and interfaces, teaching aids, and other special supplies.[27] APH is funded by an annual federal appropriation, and credits for APH materials and services are allocated to state education programs in proportion to the number of legally blind individuals in each state. In fiscal year 2012, $24.505 million was appropriated by Congress for use by APH.[27] Because this program is utilized primarily by school-aged children, we allocate all of its cost to children aged 0 to 17 (**Table 8.1**).

Table 8.1. Budgetary Cost of American Printing House for the Blind

Age group	Costs
0-17	$24,505,000
18-39	$0
46-64	$0
65+	$0
Total	**$24,505,000**

National Library Service for the Blind and Physically Handicapped

The National Library Service for the Blind and Physically Handicapped (NLS) is a federal service administered by the Library of Congress that supplies adapted reading materials to individuals who are blind or physically handicapped. Materials delivered by mail to clients free of charge include books and magazines available in both Braille and audio formats, with more than 26 million titles circulated each year. In fiscal year 2010, Congress appropriated more than $70.1 million in support of NLS services.[28] Although a small portion of these funds was used to support services for physically handicapped individuals who are not legally blind, the majority of NLS services are provided for the blind and visually impaired. Assuming that non-blindness-related expenditures by NLS are negligible and that services are used equally across age groups, we allocate the federal budgetary cost of the program based on the proportion of blind persons in each age group. (**Table 8.2**).

Table 8.2. Budgetary Cost of National Library Services for the Blind

Age group	National Library
0-17	$936,700
18-39	$13,406,668
46-64	$22,727,210
65+	$144,929,422
Total	**$182,000,000**

Low Vision Adaptations and Devices

Assistive Devices

As part of the 1999 French census, the Institut National de la Statistique et des Etudes Economiques conducted the Handicap Incapacity Dependency (HID) and Everyday Life and Health (ELH) surveys. These nationally representative surveys included 18 items that were used to assess the self-reported level of disability of more than 359,000 respondents of all ages. Using these data, Brézin et al. categorized respondents into four categories of visual impairment, ranging from blind to no visual problems.[29, 30] These data were controlled for age, number of handicaps, and size of household to calculate the extent to which blindness and low vision necessitated the purchase of assistive devices, such as walking aids and computer software. Brézin et al. also estimated the cost of home adaptations; however, because most of these adaptations focus on wheelchair access for the elderly, we did not include these costs in this analysis.

Using these differential usage rates for blind and visually impaired individuals and applying similar methods to other national registers, Lafuma et al. estimated direct nonmedical costs attributable to visual impairment in France, Italy, Germany, and the United Kingdom based on the prevalence of blindness and low vision as well as the unit costs of home adaptations and assistive devices in each of these four countries depreciated over 3 years.[31, 32] Lafuma et al. estimate that the non-institutionalized visually impaired and blind in these four countries spent on average an additional €536 on assistive devices relative to the general population in 2004. We assume the relative demand for assistive devices by persons with low vision in the United States is similar to the demand for these devices in Europe. Home adaptations included in the analysis focused on handicap accessibility and elderly care, and thus we exclude these costs while focusing on the younger population. We also excluded wheelchairs and the cost of guide dogs, which has been previously studied in the United States. We estimated U.S. market costs for white sticks and audio players based on the average February 2012 costs for all category items at MaxiAids.com, a large online retailer of low vision assistance devices. The assistive devices in Lafuma et al. included three baskets of goods that were not individually described (optical assistance devices, computer interface devices, and software). We were unable to identify U.S. market costs for these items. We converted the unit costs reported by Lafuma et al. to U.S. dollars using the 2004 average exchange rate and then inflated them to 2013 dollars based on the Consumer Price Index. We then used our estimates of the prevalence of blindness and visual impairment in the United States to derive U.S., age-specific differential usage rates and applied these to the average unit costs to determine the per capita costs of these devices. Estimated annual costs per individual with low vision and overall costs per assistive device are shown in **Table 9.1**.

Table 9.1. Cost of Assistive Devices for the Visually Impaired, per Individual

Age group	Cost
0-17	$38,071,681
18-39	$71,259,642
46-64	$71,862,878
65+	$494,587,411
Total	**$675,781,612**

Dog Guides for the Blind

We based the cost of dog guides on the findings of a cost-benefit analysis that surveyed 10 of the 12 major guide dog training schools in the United States.[33] Training guide dogs entails costs associated with breeding, veterinary expenses, and staff. Recipients of guide dogs also travel to the school for training prior to placement of the dog. The majority of these costs are covered by charitable donations, allowing blind individuals to obtain guide dogs for free or at a substantially reduced price. In 2003, 2,015 guide dogs were provided to blind individuals, and more than 9,000 guide dogs were known to be working in the United States. The average total cost of training and providing a guide dog was $35,536. The average annual maintenance cost over a dog’s 8-year working life was $700 per year. The total cost of guide dog training and maintenance was estimated to be $62 million per year in 2004. We again assume that use of guide dogs is equally distributed across ages. We adjusted the cost of guide dogs to 2013 dollars using the Consumer Price Index, resulting in an annual burden of approximately $73 million (**Table 9.3**).

Table 9.2. Cost of Dog Guides for the Blind

Age group	Cost
0-17	$376,439
18-39	$5,387,840
46-64	$9,133,557
65+	$58,243,892
Total	**$73,141,728**

Education Costs

The Individuals with Disabilities Education Act requires states to provide education and intervention services for children who meet certain eligibility criteria from birth through age 21. When this bill was passed, Congress authorized the federal government to pay up to 40% of the excess cost of educating students with disabilities, although it routinely funds considerably less than this amount.[34] For congressional purposes, the excess cost of educating a student with a disability is equal to the national average per pupil expenditure (APPE), suggesting that it is approximately twice as expensive to educate a student with a disability than it is to educate a student without a disability.[34] This assumption is supported by a report for the Department of Education by the Special Education Expenditure Project, which found that per pupil expenditures on disabled students were approximately double the per pupil expenditures on students who are not disabled.[35] Thus, we assume that the excess cost associated with educating a disabled student is equal to the APPE. In 2008, the National Center for Education Statistics reported the APPE to be $10,297. We adjusted this value for inflation using the Consumer Price Index, resulting in an estimated APPE of $11,371 in 2013.

We assumed that only blind students would require special education accommodations. The APH maintains a registry of children registered by state departments of education to receive special education materials due to blindness. We excluded individuals registered as adult, postgraduate, or vocational students, resulting in an estimate of 51,388 blind students requiring special education (**Table 10.1**). Multiplying this number by the APPE, we estimate that education costs in 2013 were approximately $675 million (**Table 10.2**).

Table 10.1. Number of Children Registered to Receive APH Services in 2010

Program	State Departments of Education	Schools for the Blind	Rehabilitation Programs	Multiple Disabilities Programs	Totals
Infant	3,860	1,513	286	27	5,686
Preschool	5,163	418	16	13	5,610
Kindergarten	2,331	125	1	0	2,457
Grade 1	2,262	52	2	1	2,317
Grade 2	2,233	86	3	2	2,324
Grade 3	2,085	102	5	1	2,193
Grade 4	2,077	118	1	3	2,199
Grade 5	2,015	130	6	4	2,124
Grade 6	2,027	130	0	1	2,158
Grade 7	1,963	135	3	1	2,103
Grade 8	1,896	179	1	3	2,079
Grade 9	1,897	195	1	1	2,094
Grade 10	1,886	203	2	2	2,093
Grade 11	1,776	232	6	2	2,016
Grade 12	2,101	321	26	2	2,450
Nongraded	1,366	348	2	8	1,724
Other registrants	8,803	747	25	136	9,711
Total					**51,338**

Note: APH = American Printing House for the Blind

Table 10.2. Cost for special education for the blind, 2013

Age group	Cost
0-17	$555,931,194
18-39	$118,866,568
46-64	$0
65+	$0
Total	$674,797,762

Federal Assistance Program Transfer Payments

Supplemental Security Income

Supplemental Security Income (SSI) is a public benefit program paid for by the U.S. Treasury that supports individuals of all ages who are unable to work as the result of a disability. Managed by the Social Security Administration, eligibility for this program is based on the income and resources available to the disabled individual or, in the case of disabled children, the income and resources available to their parents. SSI recipients may also be eligible for other government assistance programs, including Social Security benefits and the Supplemental Nutrition Assistance Program. The Social Security Administration reports that 70,000 blind individuals received $416 million in SSI benefits in 2008.[36] After adjusting for inflation and excluding the share of expenditures attributable to individuals outside of the target age group, we estimate total SSI payments for blind persons to be $459 million in 2013 (**Table 11.1**).

Table 11.1. Budgetary Cost of Supplemental Security Income for the Blind

Age group	Cost
0-17	$0
18-39	$34,016,671
46-64	$57,665,636
65+	$367,728,694
Total	**$459,411,001**

Supplemental Nutrition Assistance Program

We assume that SSI beneficiaries are also eligible for assistance through the Supplemental Nutrition Assistance Program. In 2008, the average benefit for individuals receiving food stamps was $1,212 annually.[37] Adjusting for inflation, we apply this yearly benefit to the estimated 24,510 blind SSI recipients within the target age group, resulting in an additional $93.7 million in government transfer payments to blind individuals in 2013 (**Table 11.2**).

Table 11.2. Cost of Supplemental Nutrition Assistance Program for the Blind

Age group	Cost
0-17	$482,212
18-39	$6,901,733
46-64	$11,699,935
65+	$74,609,459
Total	**$93,693,340**

Social Security Disability Insurance

Social Security Disability Insurance (SSDI) is a public benefit program that is administered by the Social Security Administration. This program allows adults who become disabled prior to retirement to collect Social Security benefits early on the basis of their payroll contributions to the Social Security system. Adults who become disabled before age 22 may also be eligible for SSDI payments based on the work record and contributions of their parents. Individuals younger than age 18 are not eligible for SSDI benefits. The Social Security Administration reports that 122,696 blind individuals were receiving SSDI benefits in December 2009.[38] In 2009, the average benefit for recipients in the diagnostic group "diseases of the nervous system and sense organs" was $1,053.70 per month.[38] Adjusting this value for inflation using the Consumer Price Index suggests that SSDI payments constituted a total government transfer of $1.7 billion in 2013 (**Table 11.3**).

Table 11.3. Cost of Social Security Disability Insurance for the Blind

Age group	Cost
0-17	$0
18-39	$123,499,862
46-64	$209,359,056
65+	$1,335,064,294
Total	**$1,667,923,211**

Committee for Purchase from People Who Are Blind or Severely Disabled

Under the Javits-Wagner-O'Day Act signed into law in 1971, the federal government is required to purchase certain products and services from nonprofit organizations that primarily employ individuals who are blind or severely disabled. In accordance with this law, the Committee for Purchase from People who are Blind or Severely Disabled ensures that 75% of the labor used to produce materials purchased under the Javits-Wagner-O'Day Act is completed by individuals who are blind or severely disabled. Materials that fall under the Javits-Wagner-O'Day Act include furniture, office supplies, janitorial supplies, and numerous other products and services. In the 2013 fiscal year, approximately $5.4 million was appropriated by Congress for use by the Committee for Purchase from People who are Blind or Severely Disabled.[39] (**Table 11.4**).

Table 11.4. Budgetary Cost of the Committee for Purchase from People Who Are Blind

Age group	Cost
0-17	$0
18-39	$399,542
46-64	$677,310
65+	$4,319,148
Total	**$5,396,000**

Tax Losses (Deductions)

Although the majority of tax losses attributable to blindness result from lost productivity in the workforce, blind individuals are also eligible for an increased standard deduction on their federal income taxes. In 2010, the additional standard deduction for blind adults filing as a head of household was $1,400, while dependents were eligible for an additional $1,100.[40] Given that the median household income for persons who are blind is $23,294 based on Survey of Income and Program Participation (SIPP) data, we assume that these deductions would be taxed at the 15% marginal rate specified by the Internal Revenue Service if unclaimed.[5, 40] We also assume that all blind adults who are employed will file as a head of household and claim the additional $1,400 standard deduction and that all blind individuals younger than age 18 will not have sufficient income to claim the $1,100 standard deduction for dependents. Based on SIPP data, the labor force participation rate for working age blind individuals was approximately 26.2% in 2005. Using these estimates, we project that the use of this deduction by blind persons reduces federal tax revenue by $27.6 million annually (**Table 11.5**).

Table 11.5. Tax Losses Resulting from Deductions for Blind Individuals

Age Group	Number of Blind	Employment Rate	Costs
0-17	6,442	0%	$0
18-39	92,202	33%	$6,350,896
46-64	156,303	33%	$10,766,146
65+	996,730	5%	$10,479,283
Total			**$27,596,325**

Deadweight Loss

Deadweight loss is the measure of cost of a loss of economic efficiency due to a market operating at non-equilibrium level. Vedder and Gallaway estimate that the marginal deadweight loss associated with social security taxation in the United States is $0.38 for every dollar distributed.[41, 42] We calculated deadweight loss associated with payments for SSI, Supplemental Nutrition Assistance Program, SSDI, and the Committee for Purchase from People who are Blind or Severely Disabled attributable to visual loss by multiplying visual loss-attributable transfer payments by 38% (**Table 11.6**).

Table 11.6. Deadweight Loss from Federal Transfer Payments

Age Group	Supplemental Security Income	Supplemental Nutrition Assistance	Social Security Disability Insurance	Committee for Purchas	Tax Deductions	Total
0-17	$0	$183,241	$46,929,947	$0	$0	$47,113,188
18-39	$12,926,335	$2,622,659	$79,556,441	$151,826	$2,413,340	$97,670,601
46-64	$21,912,942	$4,445,975	$507,324,432	$257,378	$4,091,136	$538,031,862
65+	$139,736,904	$28,351,594	$633,810,820	$1,641,276	$3,982,127	$807,522,722
Total	**$174,576,181**	**$35,603,469**	**$1,267,621,640**	**$2,050,480**	**$10,486,603**	**$1,490,338,373**

Lost Productivity

Lost Productivity due to Lower Wages and Reduced Workforce Participation

Productivity losses include the value of labor lost due to blindness and visual impairment. We identified median income by self-reported visual function for persons aged 18 to 39, 40-64 and 65 and older in SIPP data (**Table 12.1**).[5, 6] We assume that self-reported blindness and severe difficulty seeing is analogous to blindness and that self-reported moderate difficulty seeing is analogous to moderate visual impairment. We estimate productivity losses by applying the number of moderately impaired and blind persons in each age group to the average reduction in median household income associated with visual impairment and blindness for that age group. We estimate that total productivity lost due to visual loss was $48.4 billion in 2013.

Table 12.1. Productivity Losses

Age Group	Visual Impairment	Blind	Total
0-17	$0	$0	$0
18-39	$11,400,339,873	$1,577,176,319	$12,977,516,191
46-64	$6,798,546,344	$4,029,229,475	$10,827,775,819
65+	$17,701,291,441	$6,920,311,587	$24,621,603,028
Total	**$35,900,177,657**	**$12,526,717,381**	**$48,426,895,038**

Lost Productivity due to Informal Care

Care for visually impaired family members constitutes a significant cost from lost productivity. The number of hours and estimated cost for informal care due to low vision among persons aged 40 and older was previously estimated by Frick et al (2007).[12] Following their approach, assuming 8 hours of care per "care day", we multiplied the hours of informal care by our estimate of the prevalent population of visually impairment and blind aged 40 and older to estimate the total number of care hours, and then multiplied these hours by the US national average wage. We estimate informal care costs for persons aged 40-64 to be $187 million and for persons aged 65 or older to be $1.26 billion. Our costs are higher than those reported by Frick, et al. (2007) because we assume an average wage rate and a more current population estimate, while Frick, et al. (2007) used the minimum wage rate.

The Frick, et al. (2007) study did not include informal care rates for children. Data on baseline rates of informal care are available for children, but not for young adults. We assume that adults aged 18 to 39 would require zero informal care due to visual loss. We used the American Time Use Survey (ATUS) conducted by the Bureau of Labor Statistics to obtain estimates of the number of hours spent on childcare by adults in households with children younger than age 18.[43] This survey found that caregivers spend an average of 2 hours per day providing primary care for children younger than age 6 and 47 minutes per day caring for children aged 6 to 17. As part of the HID survey conducted by the Institut National de la Statistique et des Etudes Economiques in France, respondents were asked to indicate the limitations placed on them as a result of their work as the caregiver of a disabled individual. Using these data, Lafuma et al. estimated that, compared with control individuals, relatives reported spending 3.3-fold more time caring for blind individuals and 2.0 times as much time caring for those with low vision when controlling for age.[31] As a result, the study suggests that caregivers for the visually impaired in France, Germany, Italy, and the United Kingdom spend an average of 525.25 extra hours per year caring for their relatives as compared to the general population.

We applied the multipliers derived by Lafuma et al. to the base hours of informal care for children from the ATUS to calculate the number of hours of excess care per year for children with blindness and visual impairment. Following the methods employed by Lafuma et al., we then multiplied this estimate by the average hourly wage rate of $19.17 reported by the Bureau of Labor Statistics to obtain the total cost of informal care for children with blindness and visual impairment.[44]. We report the $601.6 million attributable to blindness as the cost of informal care for children in **Table 12.2**.

In 2011, the American Time Use Survey added a new component on elder care. While this survey reported the time spent on elderly care from the perspective of the person providing care, instead of the person receiving care, we were able to approximately replicate the process we used for children for the adult population. When doing so, we estimated a total cost of informal care among adults to be approximately $300 million, less than a quarter of the estimated cost based on Frick et al. (2007) Because Frick et al. (2007) is a direct estimate, and because the structure of the ATUS elder care component required inferring care hours, we rely on the Frick et al approach, but this may indicate that our similar approach for valuing informal care for children may be an underestimate.

Table 12.2. Productivity Losses Resulting from Informal Care

Age group	Cost
0-17	$601,368,206
18-39	$0
46-64	$187,155,915
65+	$1,263,957,002
Total	**$2,052,481,123**

Long Term Care

Nursing Home Care

We included the cost of long-term care attributable to visual impairment and blindness for persons aged 65 and older. Long-term care includes residential care services including nursing homes and skilled nursing facilities. Skilled nursing facilities are generally short-term duration facilities and are covered by Medicare in the age 65 and older population. Nursing home care is typically longer term, with costs paid out-of-pocket, through private insurance, or Medicaid. We identified the number of Americans in nursing homes and the proportion of Americans in nursing homes by age based on the 2004 National Nursing Home Survey. The prevalence of visual impairment and blindness among nursing home residents by age group was observed in the Baltimore Eye Study.[45] We calculated the marginal rate of institutionalization in nursing home care due to visual impairment or blindness based on the relative difference in prevalence in nursing home populations versus the prevalence in the age-matched general population. We then multiplied this marginal rate of institutionalization by the prevalent visually impaired or blind population to estimate the number of persons nursing home care at any point during the year due to visual impairment or blindness. We then multiplied this by the average duration of nursing home stays per year and by the annual cost of nursing home care from the 2011 Genworth Financial Cost of Care Survey.[46] The total nursing home care cost estimate was $16.8 billion, as shown in Table 13.1.

Table 13.1. Nursing Home Cost Estimates

	Visually Impaired	Blind	Total
65-74	$1,151,673,904	$747,843,332	$1,899,517,235
75-84	$2,756,047,902	$2,056,147,072	$4,812,194,973
85+	$5,357,417,985	$4,752,910,393	$10,110,328,377
Total	**$9,265,139,790**	**$7,556,900,796**	**$16,822,040,586**

Nursing home costs are paid by patients, government and private insurers. Some individuals have private insurance or retirement insurance plans that cover all or part of nursing home costs. Medicare offers short-term coverage for nursing home care, but most government spending on nursing home care is through the Medicaid program. Often, individuals will pay for nursing home care out-of-pocket until their funds are exhausted and then quality for Medicaid assistance. In a Georgetown University policy brief, Ellen O'Brien details the breakdown of nursing home care spending by payer, reporting that Medicaid and Medicare cover 46% and 12.4%, respectively, while private insurance pays 7.7%. 27.9% is paid out of pocket while another 6.1% is paid through other private sources. We allocate nursing home costs to government, insurance, and patient payers based on these allocations, such that payment by government is $13.2 billion, payment by insurance companies is $1.3 billion, and out-of-pocket costs are $5.7 billion.

Skilled Nursing Facility Care

The nursing home estimate does not include skilled nursing facilities, which offer short-term acute care and are mostly paid for by Medicare. Javitt, et al. (2007) estimated excess Medicare costs for skilled nursing facility placement attributable to visual impairment and blindness.[47] We updated these excess costs per person to 2013 US$, and multiplied by our estimates of the 2011 prevalent population for each corresponding visual acuity level. This yields a total estimate of $3.4 billion in Medicare costs for skilled nursing facility placement due to vision loss.(**Table 13.2**)

Table 13.2. Medical Skilled Nursing Facility Cost Estimates

Vision Loss	Excess Costs per Person 2013 $	# of persons with vision loss	Total Costs
Moderate	$758.35	2,069,877	$1,569,691,418
Severe	$1,165.24	479,634	$558,888,257
Blind	$1,301.29	996,730	$1,297,033,427
Total			**$3,425,613,102**

Loss of Wellbeing

Disability Adjusted Life Years (DALYs)

Disability adjusted life years (DALYs) provide a measurement of the personal burden of health conditions. DALYs are the most commonly cited measure of patient disability or well-being internationally. The 2010 Global Burden of Disease Study conducted a multi-country survey of approximately 20,000 households to estimate disability weights for 220 unique health states and conditions, including visual impairment and blindness.[48] Disability weights related to vision are listed in Table 14.1. International definitions for severe impairment includes distance acuity of 20/200 or worse in the better-seeing eye, which is the U.S. based threshold for blindness used in this analysis. We therefor averaged the disability weights for severe impairment and blindness (0.193) to determine the disability weight applied to the U.S. defined blindness population in our study.

Table 14.1. Disability Weights from 2010 Global Burden of Disease Project

	Disability Weights		
Visual Status	**Baseline**	**95% Confidence Interval**	
Distance vision: mild impairment	0.004	0.001	0.010
Distance vision: moderate impairment	0.033	0.020	0.052
Distance vision: severe impairment	0.191	0.129	0.269
Distance vision: blindness	0.195	0.132	0.272

We estimated total DALY losses by multiplying the disability weights by the prevalent population with the corresponding level of vision loss. As the disability weights were measured controlling for other conditions, we did not adjust the disability losses based on any assumed background disability weights. We find a total loss of 283,000 DALYs. DALYs are not intended to be monetized, nonetheless using a commonly cited value for utility or disability weighted life years of $50,000, monetizing the DALY losses would indicate a loss of $14.2 billion.

Table 14.2. DALY Losses and Monetized Value of DALYs in $millions

Age Group	Total DALYS	Monetized Value*
0-17	6,921	$346
18-39	26,351	$1,318
46-64	33,379	$1,669
65+	216,476	$10,824
Total	**283,127**	$14,156

Note: DALY = disability adjusted life years
*Valued at $50,000 per DALY

Quality Adjusted Life Years (QALYs)

In addition to DALY losses, we also estimate loss of well-being by calculating the quality adjusted life years (QALYs) cost due to prevalent low vision. QALYs are a summary outcome measure in which years of life are adjusted to account for patient utility and are the most commonly cited measure of patient well-being in U.S. based economic studies. In the 2007 PBA vision problem burden estimate, Frick, et al. (2007) estimated QALY losses directly from MEPS data based on self-reported quality of life among respondents reporting low vision. This approach is not feasible for the younger than age 40 populations due to MEPS' structure and we found co-linearity between quality of life measures and self-reported overall health, which was one of the independent variables in the regression.

We used an alternative methodology in which we multiply utility loss estimates from the literature by population background utility levels and apply these utility rates to the affected population to estimate total QALYs. We identified 13 studies in the literature reporting utility losses from low vision or vision disorders (**Table 14.3**). [14, 49-59] However, the wide range of results, differences in methodology, inclusion of other impacts of disease, and limitations in reporting resulted in a wide range of utility values and an inability to distinguish between mild and moderate impairment.

Table 14.3. Literature Values of Utility Costs of Visual Loss

Study	Main Results		
	Normal	Impairment	Blindness
Crew et al. (2011)[60]	1		0.79
Smith et al. (2008)	0.82	0.73	
Shah et al. (2004)	0.94	0.96	0.8
Brown et al. (2002)[59]	0.85	0.755	0.595
Brown et al. (2001)[53]			0.51
Brown et al. (2001)[61]	0.93		
Clemons et al. (2003)[51]	0.94	0.865	
Coffey et al. (2002)[54]	0.69		0.3925
Fryback et al. (1993)[55]	0.93	0.789	
Mittmann et al. (1999)[56]	0.93	0.78	
Sharma et al. (2000)[57]	0.81	0.62	0.55
Chadha, R.K. et al. (2011)[62]	1	.65	
Average	**0.89**	**0.77**	**0.61**

Although these values are based only on utility valuation studies conducted on adults, we also apply this function to children due to the lack of empirical evidence on utility losses from visual impairment among children. Chadha et al. estimate that visual loss results in a 35.6% decrease in quality of life among children aged 3 to 16 with acuity of 20/40 or worse.[62] The values we identified among adults do not find this level of utility loss even for U.S. defined legal blindness. Given that 92% of children with visual loss had only mild impairment of 20/80 or better, the adult-based utility values predict much lower and therefore more conservative levels of utility loss among children than the overall utility loss value reported by Chadha et al. We also estimate the monetary value of loss of well-being based on $50,000 per QALY, a commonly cited although largely baseless value.

We elected to use utility values reported by Brown et al 2003, as this paper included a table synthesized from multiple analyses from the same authors that were conducted in comparable manners to produce utility values for a range of acuity in the better-seeing eye (**Table 14.4**).[58, 63]

Table 14.4. Utility Losses by Better-seeing Eye Acuity used in Analysis, Brown et al 2003

Acuity in Better-seeing Eye	Utility
20	0.97
20 with <=40 other eye	0.92
25	0.87
30	0.84
40	0.8
50	0.77
70	0.74
100	0.67
200	0.66
300	0.63
400	0.54
LP	0.35
NLP	0.26

Table 14.5 reports the quality-adjusted life years (QALYs) and monetary value of QALYs lost due to low vision. We estimated the impact of low vision on personal well-being based on QALY losses. We adjusted the utility values based on age-specific background utilities.[64] We then multiplied the adjusted utility values by the prevalent visually impaired and blind population and calculated QALY losses based on the reduction from normal vision utilities.

Table 14.5. QALY Losses and Monetized Value of QALYs in $millions

Age Group	Total QALYS	Monetized Value*
0-17	64,802	$3,240
18-39	110,304	$5,515
46-64	60,682	$3,034
65+	364,732	$18,237
Total	**600,520**	**$30,026**

Note: QALY = quality-adjusted life years
QALYs monetized at $50,000 per QALY

Economic Burden Results

Burden by Age Group

We estimated the total economic burden of eye disorders among the total U.S. population to be $138 billion per year in 2013 dollars (**Table 15.1**). Diagnosed disorders, including costs for optometry visits, total $48.8 billion. Medical vision aids including glasses and contact lenses cost $13.2 billion. Medical costs attributable to undiagnosed vision loss are $3 billion. All other direct costs total $1.7 billion, with the largest components consisting of the cost of special education and school screening ($770 million) followed by the cost of non-medical assistive devices ($750 million). Federal assistance programs add $207 million. Indirect costs, including productivity losses ($48.4 billion), informal care ($2 billion), long-term care (20.2 billion) and deadweight loss from transfer payments ($1.5 billion), total $72.2 billion.

Table 15.1. Economic burden estimates by cost category and age group, in $ millions

Cost Category	Age Group				
	0-17	18-39	40-64	65+	All Ages
Direct Costs					
Diagnosed Disorders	2,844	5,067	14,218	26,640	48,769
Medical Vision Aids	1,480	3,335	6,222	2,199	13,236
Undiagnosed Vision Loss	48	474	1,702	798	3,022
Aids/Devices	38	77	81	553	749
Education/School Screening	651	119	0	0	769
Assistance Programs	25	13	23	145	207
Total Direct Costs	**5,086**	**9,086**	**22,246**	**30,335**	**66,752**
Indirect Costs					
Productivity Loss	0	12,978	10,828	24,622	48,427
Informal Care	601	0	187	1,264	2,052
Long-term Care	0	0	0	20,248	20,248
Entitlement Programs*	0.5	165	279	1,782	2,226
Tax Deduction*	0	6	11	10	28
Transfer Deadweight Loss	47	98	538	808	1,490
Total Indirect Costs	**648**	**13,075**	**11,553**	**46,941**	**72,217**
Total Costs	**5,734**	**22,161**	**33,799**	**77,276**	**138,970**

*Not included in Total Costs

Burden by Payer

Patients and their families bear 52% of the total economic burden of eye disorders and vision loss.(**Table 15.2**) Patients pay 10% of costs for diagnosed disorders but nearly three-quarters of the cost for medical vision aids. Private insurance, including vision plans, pays $22.1 billion, including $20.8 in combined medical costs and $1.3 billion for long-term care. Government pays $47.4 billion in total costs, including $29.5 billion in medical costs, $3.4 billion for skilled nursing facilities, $9.8 billion for nursing home care, and $4 billion in assistance programs, transfer payments, and deadweight loss. Government spending also includes $770 million for special education and school screening, which is paid primarily through state and local governments.

Table 15.2. Economic burden estimates by cost category and payer, in $ millions

Age Group	Comprehensive Costs			
Perspective	**Government**	**Insurance**	**Patient**	**Comprehensive**
Direct Costs				
Diagnosed Disorders	26,860	17,249	4,660	48,769
Medical Vision Aids	900	2,667	9,669	13,236
Undiagnosed Vision Loss	1,722	928	372	3,022
Aids/Devices	-	-	749	749
Education/School Screening	769	-	-	769
Assistance Programs	207	-	-	207
Total Direct Costs	**30,458**	**20,844**	**15,450**	**66,752**
Indirect Costs				
Productivity Loss	-	-	48,427	48,427
Informal Care	-	-	2,052	2,052
Long-term Care	13,233	1,295	5,719	20,248
Entitlement Programs*	2,226	-	-	-
Tax Deduction*	28	-	-	-
Transfer Deadweight Loss	1,490	-	-	1,490
Total Indirect Costs	**16,977**	**1,295**	**56,199**	**72,217**
Total Costs	**47,435**	**22,140**	**71,649**	**138,970**

Economic Burden by State

We estimated the state burden results by allocating total cost on the basis of state population for each age group. Our analysis does not include any state-specific unit cost or utilization estimates; therefore the state breakdown of costs is a function of the states' population within each age group. We identified state populations for the age groups 0-17, 18-39, 40-64, and 65 and older based on the 2010 U.S. census data. We then divided the burden estimate by age by the 2010 total US population for that age group to derive per-person costs for each age group. We then multiplied these per-person costs by the state population costs for each age group. **Table 15.3** lists the economic burden estimate for each state and the District of Columbia.

Table 15.3. Economic burden estimates by State, in $ millions

	0-17	18-39	40-64	65+	Total
US Total	$5,734	$22,161	$33,799	$77,276	$138,970
ALASKA	$15	$54	$81	$106	$255
ALABAMA	$88	$335	$527	$1,265	$2,215
ARKANSAS	$55	$202	$312	$806	$1,375
ARIZONA	$126	$457	$656	$1,693	$2,931
CALIFORNIA	$718	$2,844	$3,935	$8,148	$15,645
COLORADO	$95	$375	$560	$1,055	$2,085
CONNECTICUT	$62	$240	$418	$973	$1,693
WASHINGTON DC	$9	$57	$60	$132	$258
DELAWARE	$16	$62	$100	$248	$426
FLORIDA	$310	$1,257	$2,085	$6,256	$9,909
GEORGIA	$192	$723	$1,047	$1,980	$3,943
HAWAII	$24	$96	$152	$374	$646
IOWA	$57	$208	$330	$871	$1,466
IDAHO	$33	$111	$161	$374	$679
ILLINOIS	$240	$938	$1,394	$3,090	$5,662
INDIANA	$124	$456	$708	$1,614	$2,902
KANSAS	$56	$201	$302	$720	$1,279
KENTUCKY	$79	$304	$487	$1,109	$1,980
LOUISIANA	$87	$331	$488	$1,071	$1,977
MASSACHUSETTS	$111	$468	$748	$1,731	$3,058
MARYLAND	$104	$414	$661	$1,357	$2,536
MAINE	$21	$84	$164	$405	$674
MICHIGAN	$180	$671	$1,127	$2,614	$4,591
MINNESOTA	$99	$376	$589	$1,311	$2,374
MISSOURI	$110	$417	$658	$1,608	$2,794
MISSISSIPPI	$58	$212	$315	$729	$1,314
MONTANA	$17	$66	$114	$282	$480
NORTH CAROLINA	$177	$682	$1,051	$2,368	$4,278
NORTH DAKOTA	$12	$49	$72	$188	$320
NEBRASKA	$36	$129	$193	$472	$830
NEW HAMPSHIRE	$22	$86	$163	$344	$615
NEW JERSEY	$157	$608	$1,008	$2,276	$4,049
NEW MEXICO	$40	$143	$223	$522	$928
NEVADA	$51	$200	$293	$622	$1,165
NEW YORK	$337	$1,421	$2,149	$5,024	$8,931
OHIO	$210	$784	$1,303	$3,111	$5,408
OKLAHOMA	$72	$267	$396	$971	$1,707
OREGON	$67	$272	$430	$1,025	$1,794
PENNSYLVANIA	$217	$857	$1,448	$3,761	$6,283
RHODE ISLAND	$18	$74	$120	$292	$503
SOUTH CAROLINA	$84	$326	$511	$1,213	$2,134
SOUTH DAKOTA	$16	$56	$87	$225	$383
TENNESSEE	$116	$446	$709	$1,637	$2,907
TEXAS	$528	$1,908	$2,571	$4,992	$9,999
UTAH	$68	$223	$236	$478	$1,004
VIRGINIA	$144	$585	$902	$1,875	$3,506
VERMONT	$10	$41	$77	$177	$305
WASHINGTON	$122	$489	$754	$1,587	$2,953
WISCONSIN	$103	$393	$642	$1,491	$2,629
WEST VIRGINIA	$30	$122	$218	$572	$942
WYOMING	$11	$40	$63	$136	$250

One-Way Sensitivity Analysis

We conducted two sensitivity analyses to investigate the impact of parameter uncertainty on overall results. In a one-way sensitivity analysis, we varied a single parameter between a low to high range based on the 95% confidence interval of the parameter estimate where available and a 50% range where a confidence interval was not available. Total cost estimates based on the one-way sensitivity analyses are listed in **Table 16.1** and **Figure 12**. **Figure 13** shows the results of one-way sensitivity analysis for QALY and DALY losses.

Table 16.1. Impact on Overall Burden of Variation in Individual Parameters, total burden in $ billions

Parameter Varied (range)	Low	High
Prevalence of visual loss (95% CI)	$124.55	$153.12
Reduced wages from vision loss (95% CI)	$126.72	$149.81
Cost of diagnosed disorders (95% CI)	$132.02	$145.38
Prevalence of VL and blind in nursing home (95% CI)	$130.69	$143.99
Cost of Undiagnosed vision loss (95% CI)	$135.88	$142.17
Adult informal care days (95% CI)	$137.31	$139.17
Cost of medical vision aids (95% CI)	$137.44	$139.09
Deadweight loss (50%-150%)	$137.89	$138.64
Cost of assistive device costs (50%-150%)	$138.09	$138.43
Special education costs (50%-150%)	$138.09	$138.43
Child informal care hours (50%-150%)	$138.11	$138.41
School screening costs (50%-150%)	$138.24	$138.29

Figure 12. Tornado Diagram of One-way Sensitivity Analysis Results, Range of Economic Burden Associated with Range of each Parameter, $bn

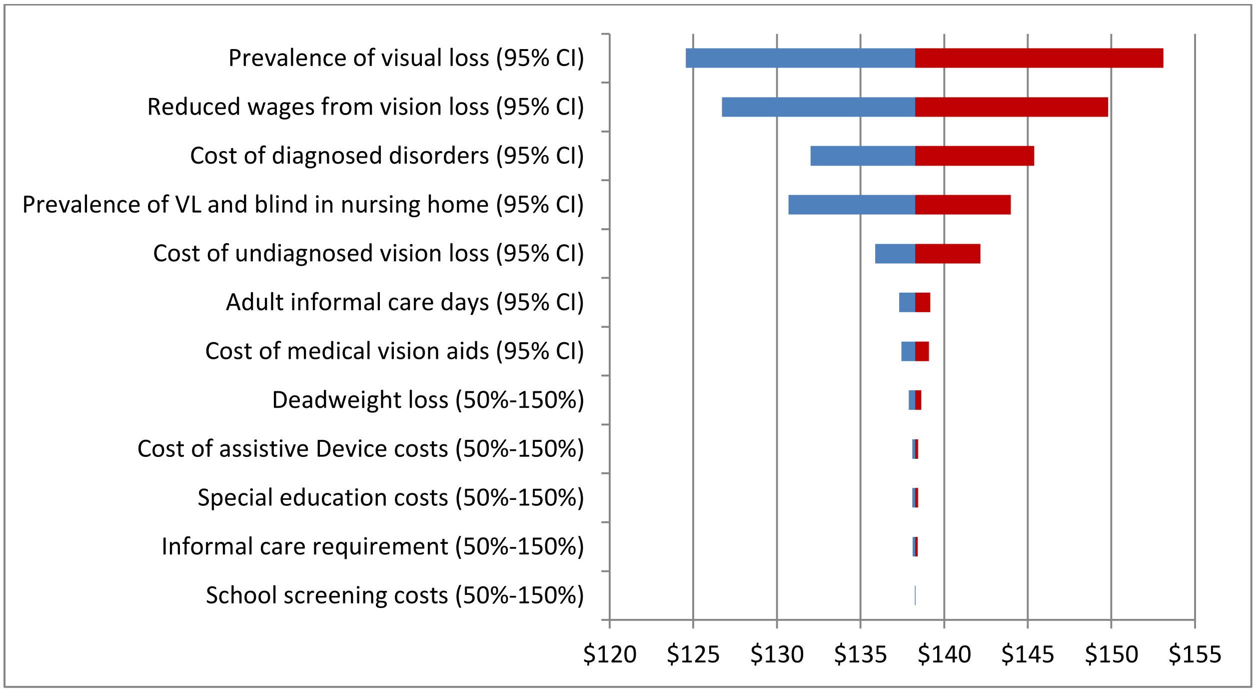
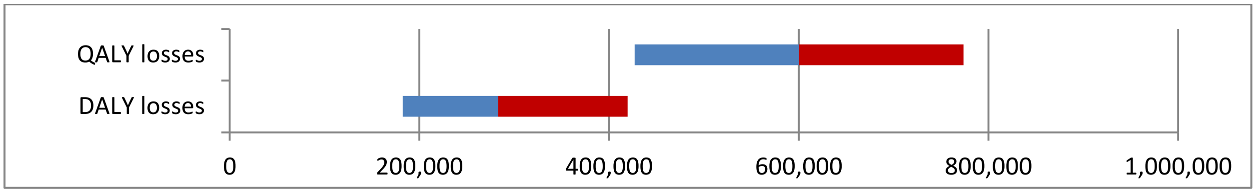


Figure 13. Tornado Diagram of One-way Sensitivity Analysis Results for QALY and DALY Losses



Probabilistic Sensitivity Analysis

We conducted a probabilistic sensitivity analysis (PSA) in which we varied all major parameters in the analysis based on random draws from each parameter's respective distribution in a Monte Carlo simulation.[65] Probabilities and proportions were varied based on beta distributions, large cost estimates were based on lognormal distributions, and small costs and multiplier parameters were varied based on a normal distribution as shown in **Tables 17.1, 17.2, and 17.3**.[66] Distribution parameters were imputed based on mean values and confidence intervals where known. Where no confidence interval was known, we assumed a 50% change in the point estimate represented a deviation of 2 standard deviations from the mean. We re-sampled all parameters simultaneously while recalculating the costs for 10,000 iterations. We calculated a 95% credible interval of results representing the 2.5 and 97.5 percentile values of the output. Credible intervals, sometimes referred to as probability intervals, are the Bayesian statistical alternative to the more widely referenced confidence interval from frequentist statistics.

Table 17.4 and **Figure 14** show the results of the PSA. The 95% credible interval of total costs is $112 billion to $174 billion. The preponderance of uncertainty in the results is attributable to the productivity losses of vision loss, which in turn is a function of uncertainty in the prevalence of vision loss and the average reduction in productivity for persons with vision loss. The cost of diagnosed disorders, nonmedical vision aids, and lost productivity due to informal care were the next most uncertain values, with credible intervals spanning over $1 billion each.

Table 17.1. PSA Values, Beta Distribution Parameters

Parameter	Baseline	Low CI	High CI	alpha	beta
Prevalence of vision loss in nursing homes (95% CI)					
Impairment 65-74	0.193548	0.105994	0.299786	12	50
Impairment, 75-84	0.187135	0.147644	0.230089	64	278
Impairment, 85+	0.265306	0.152782	0.395959	13	36
Blind, 65-74	0.129032	0.058361	0.222249	8	54
Blind, 75-84	0.163743	0.126501	0.204708	56	286
Blind, 85+	0.285714	0.169531	0.418456	14	35

Table 17.2. PSA Values, Normal Distribution Parameters

Parameter	Baseline	Low CI	High CI	Std Dev
Prevalence of vision loss				
0-17, mild impairment	0.01072	0.00585	0.01217	0.003227
0-17, moderate impairment	0.00102	0.00008	0.00196	0.00096
0-17, blind	0.00009	0.00000	0.00027	0.00014
18-39, mild impairment	0.01173	0.00742	0.01603	0.004393
18-39, moderate impairment	0.00139	0.00017	0.00262	0.00125
18-39, blind	0.00100	0.00007	0.00344	0.001719
40-49, mild impairment	0.00154	0.00122	0.00187	0.000331
40-49, moderate impairment	0.00036	0.00028	0.00043	7.68E-05
40-49, blind	0.00120	0.00080	0.00150	0.000357
50-54, mild impairment	0.00219	0.00195	0.00244	0.000249
50-54, moderate impairment	0.00051	0.00045	0.00056	5.76E-05
50-54, blind	0.00130	0.00110	0.00150	0.000204
55-59, mild impairment	0.00325	0.00292	0.00357	0.000331
55-59, moderate impairment	0.00075	0.00068	0.00083	7.68E-05
55-59, blind	0.00160	0.00140	0.00190	0.000255
60-64, mild impairment	0.00528	0.00471	0.00576	0.000538
60-64, moderate impairment	0.00122	0.00109	0.00134	0.000125
60-64, blind	0.00240	0.00200	0.00270	0.000357
65-69, mild impairment	0.00901	0.00804	0.00999	0.000994
65-69, moderate impairment	0.00209	0.00186	0.00231	0.00023
65-69, blind	0.00360	0.00300	0.00410	0.000561
70-74, mild impairment	0.01640	0.01469	0.01802	0.001698
70-74, moderate impairment	0.00380	0.00341	0.00418	0.000394
70-74, blind	0.00590	0.00500	0.00680	0.000918
75-79, mild impairment	0.03191	0.02850	0.03532	0.003479
75-79, blind	0.00739	0.00660	0.00818	0.000806
80+, mild impairment	0.01100	0.00930	0.01270	0.001735
80+, moderate impairment	0.13542	0.11123	0.15953	0.024646
80+, blind	0.03138	0.02577	0.03697	0.005711
Cost of Medical Vision Aids (95% CI)				
0-17	$1,442,456,612	$1,386,175,790	$1,573,778,529	$95,715,683
18-39	$3,296,597,011	$3,105,867,560	$3,574,874,407	$239,289,207
40-64	$6,107,511,377	$5,867,796,767	$6,576,518,223	$361,592,580
65+	$2,156,389,256	$2,053,207,750	$2,334,611,857	$143,573,524
Productivity Losses				
Impaired, 18-39	$644	$374	$914	$276
Blind, 18-40	$1,168	$647	$1,689	$532
Impaired, 40-64	$1,367	$1,187	$1,547	$183
Blind, 40-64	$1,761	$1,181	$2,341	$592
Impaired or Blind, 65+	$474	$400	$548	$75
Informal Care days, Adults				
Impaired	1.2	0.6	1.7	0.56122
Blind	5.2	1.3	9.1	3.97959
QALY losses				
Mild impairment	0.07	0.04	0.1	0.03061
Moderate impairment	0.16	0.11	0.21	0.05102
Blind	0.27	0.23	0.31	0.04082
DALY losses				
Mild impairment	0.004	0.001	0.010	0.004592
Moderate impairment	0.033	0.020	0.052	0.016327
Blind	0.193	0.131	0.271	0.071429
Other parameters				
Assistive device costs (50%–150%)	1	0.75	1.25	0.2551
School screening costs (50%–150%)	1	0.75	1.25	0.2551
Informal care requirement (50%–150%)	1	0.75	1.25	0.2551
Special Education Costs (50%-150%)	1	0.75	1.25	0.2551
Deadweight loss (50%–150%)	1	0.75	1.25	0.2551

Table 17.3. PSA Values, Lognormal Distribution Parameters

Parameter	Baseline	Low CI	High CI	ln(mean)	ln(SD)
Cost of diagnosed disorders (95% CI)					
0–17	$2,327,883,276	$1,901,400,041	$2,777,087,314	21.56823	0.096636
18–39	$3,952,952,023	$3,283,942,678	$4,648,713,064	22.09773	0.08866
40-64	$10,754,289,088	$8,298,717,950	$13,326,880,112	23.09857	0.120837
65+	$26,073,276,962	$19,334,824,159	$32,190,855,025	23.98418	0.130045
Cost of undiagnosed vision loss (95% CI)					
0–17	$36,905,646	$22,042,207	$80,090,533	17.42388	0.329132
18–39	$388,981,062	$207,727,608	$810,137,672	19.77904	0.347188
40-64	$1,716,522,470	$424,687,555	$3,866,041,598	21.26357	0.563427
65+	$1,517,219,370	$0	$2,169,599,464	21.14015	5.484135

Figure 14. Credible Range of Economic Burden Estimates

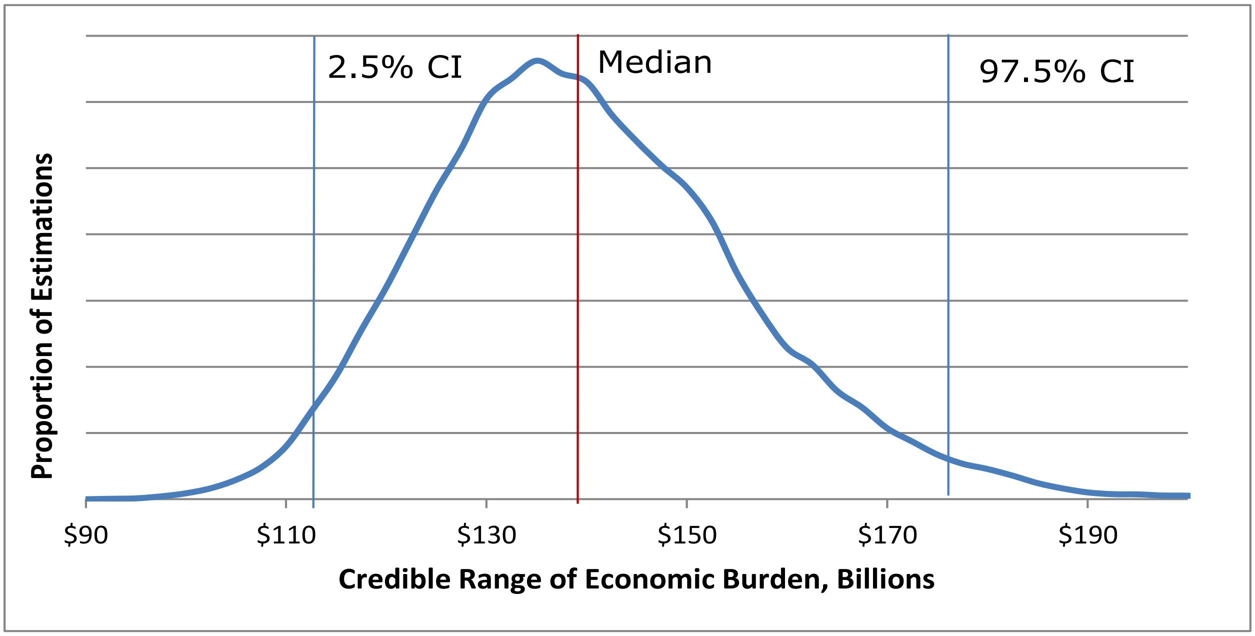


Table 17.4. PSA Results, Costs, and 95% Credible Intervals by Cost Component

	Cost and 95% CI
Direct costs	
Diagnosed Disorders	$48,769 $42,468 - $55,919
Medical Vision Aids	$13,236 $11,615 - $14,892
Undiagnosed Vision Loss	$3,022 $820 - $9,090
Aids/Devices	$749 $412 - $1,110
Education	$769 $425 - $1,107
Assistance Programs	$207 $207 - $0,207
Indirect costs	
Productivity Loss	$48,427 $24,379 - $81,730
Informal Care	$2,052 $0,821 - $3,790
Nursing Home	$19,541 $11,946 - $25,557
Entitlement Programs*	$559 $0,559 - $0,559
Tax Deduction*	$28 $0,017 - $0,050
Transfer Deadweight Loss	$1,490 $0,738 - $2,224
Total costs	**$138,263** **$111,669 - $173,692**

[a]Not included in total costs.

Conclusions

Limitations

This study is subject to a number of limitations and assumptions. Epidemiological evidence of prevalence is available only for the population aged 40 and older. [3, 4] The use of NHANES data to provide prevalence estimates for the population aged 12-39 may introduce bias. Visual impairment and blindness in NHANES are based on auto-refractor corrected near distance acuity or self-reported blindness. Contrast sensitivity and visual field are not assessed among participants younger than age 40. In addition, NHANES does not assess acuity among participants younger than age 12. We imputed prevalence in this age group based on the incidence of blindness reported in the United Kingdom and the prevalence among older children in NHANES data; which may introduce bias and we expect this may underestimates the prevalence of visual impairment at very young ages.

The prevalence of visual impairment and blindness in the population aged 40 and older was estimated in an NEI-sponsored meta-analysis combining a number of population-based epidemiological studies employing gold-standard comprehensive eye examinations. [3, 4] While this study's methodology provides more robust measurement of uncorrectable vision loss, limited sample size and the meta-analysis structure still result in wide confidence intervals that impart substantial uncertainty to our results. In addition, using these two disparate sources of data for prevalence appears to result in a decrease in impairment prevalence from ages 18-39 to ages 40-64, although this pattern can be seen in NHANES data alone.[7]

The sensitivity analysis identified the prevalence of vision loss as the primary cause of uncertainty in results, due almost entirely to its impact on productivity losses. QALY and DALY losses are similarly sensitive to the prevalence of vision loss. The methodology of assessing quality of life losses based on self-reported quality of life among respondents reporting low vision in MEPS data used by the previous estimate cannot be replicated in the younger population. We used an alternative approach where we applied published utility loss estimates to age-adjusted background utility values of the prevalent mildly impaired, moderately impaired and blind populations to estimate QALY costs of low vision. This approach is valid and cited as the gold-standard methodology, but nonetheless results in a much higher QALY cost estimate than would have been found if we used the previous methodology employed by Frick et al to estimate utility loss directly in MEPS data.[64]

The treated prevalence of diagnosed disorders is based on self-reported conditions and verified medical encounters in MEPS data. This approach is likely to underestimate the true prevalence of conditions, as it will typically only capture diagnoses for conditions which the respondent is already aware and remembers to report. This is more likely for conditions for which the respondent is currently or recently receiving medical services that were captured in MEPS's provider component. Unlike other medical costs, the costs for optometry visits and medical vision aids are not verified by MEPS and are based on self-reported costs.

We found no data on the relative demand for assistive living devices or informal care due to vision loss for persons in the United States. We assume the relative impact on demand due to vision loss in the United States is identical to rates observed in Europe, which might introduce bias. We do not include the cost of vision screening other than school and preschool screening, such as acuity chart screening in annual physicals or child well-checks.

Finally, we do not include the monetized value of quality of life losses in our primary results because of limitations and uncertainty in the utility loss associated with vision loss, the monetary value of a QALY, and controversy over their inclusion in economic burden studies.

Findings of this Report versus the 2007 PBA Estimate

Costs for specific categories from the current and prior PBA estimate are listed in Table 18.1. Our cost estimates for specific conditions are generally much higher than in the previous estimate. This is due primarily to the different data and methodology we employ; using survey data on all costs will capture costs paid by vision insurance plans, costs paid out of pocket, and prescription drug costs which were not captured in the earlier report. Our econometric approach also will identify non-eye care costs that can be attributed to eye and vision disorders. These differences account for an addition of $14.2 billion in the current estimate. Frick et al 2007 found higher costs due to low vision than are reported in the current report, this apparent reduction is due to us controlling for the presence of a diagnosed disorder. We also capture medical costs for ages younger than age 40, which adds another $13.2 billion.

We find productivity losses to by $40.4 billion higher than in the 2007 estimate ($48.4bn versus $8bn), but most of this difference can be attributed to the assumption by Rein et al that productivity losses accrue only in the age 40-64 group. When looking only at this age group, we find productivity losses only $2.8 billion higher ($10.8 billion total) than Rein et al., a difference entirely attributable to increases in wages and population growth.

Our estimate of nursing home costs nearly doubles that found by Rein et al, but almost all of this difference is attributable to us using a higher estimated cost of long term care, and also the inclusion of skilled nursing facilities in the current estimate.

We also find higher costs of informal care. We add informal care costs for children which was not included in the 2007 report. The increase in informal care costs for adults is primarily due to our assumption of valuing informal care hours based on the U.S. average wage, versus the then U.S. minimum wage employed by Frick et al (2007).

An additional $5.3 billion of the increase in the estimate occurs among other direct and indirect costs, primarily due to the inclusion of additional costs such as aids and devices, special education, and entitlement programs.

The 2007 PBA report included $10.5 billion in monetized quality of life losses, based on an assumed value of $50,000 per QALY. We do not include monetized quality of life in the primary economic burden results. If we had assumed $50,000 per DALY, our estimated burden would be $14.1 billion. If we had instead used QALYs, the monetary cost at $50,000 per QALY would be $30 billion. This increase from the $10.5 billion found by Frick et al is due to methodological differences.

Table 18.1. Comparing results between the 2007 and 2013 PBA estimates

	PBA Estimate, 2007	PBA Estimate 2013
Age 40 and older medical costs		
Age related macular degeneration*	$0.58	$4.46
Glaucoma	$2.86	$5.62
Diabetic retinopathy*	$0.49	$4.01
Cataracts	$6.80	$10.57
Vision Aids	$5.51	$8.42
Low vision**	$5.12	$2.50
Other disorders		$14.43
Younger than age 40 medical costs		
All disorder and low vision		$13.25
Productivity losses		
Total productivity losses	$8.03	$48.43
Long-term and informal care		
Nursing Home Care	$10.96	$20.25
Informal Care	$0.36	$2.05
Other Direct and Indirect Costs		
Aids and devices		$0.68
Dog Guides	$0.06	$0.07
Education/School Screening		$0.77
Assistance Programs	$0.10	$0.21
Entitlement Programs		$2.23
Tax Deduction*		$0.03
Transfer Deadweight Loss		$1.49
Loss of Well-being		
QALYs or DALYs lost	209,200	283,127
Monetary value included in total	$10.50	
Total Economic Burden	**$51.40**	**$138.97**

*2013 values for age related macular degeneration and diabetic retinopathy are based on any diagnosed retinal disorder without or with diabetes, respectively.
**2007 report is cost of low vision, 2013 report is cost of *undiagnosed* low vision

Discussion

This report provides the most comprehensive and up-to-date estimate of the total economic burden of eye diseases and vision loss in the United States to date. Understanding the costs of disease provides vital information for identifying areas of need for future research and healthcare investment. This is particularly important for the areas of eye disease and vision loss, as the indirect costs of low vision greatly increase the total burden of these conditions beyond the healthcare sector. Our findings show that eye disorders and vision loss are among the costliest conditions to the U.S. economy, and based on ever-increasing healthcare costs and an aging population, this cost is set to continue to grow.

At $139 billion, our estimated burden more than doubles the previous cost estimate. Most of this increase is related to differences in data, approach and methodology. In part due to controversy over which costs should be included in the estimated cost of vision problems, recent consensus guidelines have delineated and defined which costs should be included, and how they should be reported.[1] Following these guidelines, this analysis provides a more comprehensive accounting of total costs, thus leading to the apparent increase in the cost estimate. The previous PBA estimate was limited to persons aged 40 and older, this report includes the total population. The previous report only included medical costs for four diagnosed eye disorders and vision aids, while this analysis includes all disorders related to the eyes and ocular adnexa. This report captures the costs of routine eye examinations and costs paid out of pocket or by vision insurance plans, much which may not have been included in the previous estimate. This analysis also uses different data sources and methodologies designed to capture all medical costs attributable to eye disorders whereas the prior estimate captured the medical costs of claims directly related to the medical treatment of the four included eye diseases, an approach that will provide a more robust estimate of payer costs, but will not capture ancillary medical costs that can be attributed to eye disorders, for example, costs from falls or depression. Finally, this analysis is simply more recent and will therefor reflect increases in medical costs and growth of the affected population that have occurred over the course of the nine years since the 2004 baseline year of prior estimate.

The differences in the results between this analysis and the prior PBA estimate highlight the difficulties and pitfalls of comparing disparate economic burden estimates. Nonetheless, it is apparent that vision loss and eye disorders are among the costliest conditions facing the United States. Although subject to significant methodological differences, a recent analysis of the cost of seven major chronic diseases in the United States, which did not include vision, only reported four conditions with direct costs higher than our findings of $66.8 billion.[8, 9] This is in line with findings from Australia, where vision disorders are estimated to be the seventh costliest health condition.[10]

These findings underscore the fact that chronic are the largest drivers of cost for healthcare in United States and will continue to be so as the confluence of rising medical costs, increased access to care, and an aging population continue to drive growth in costs. Another important finding of this analysis is that government pays the majority of healthcare costs and the majority of long-term care costs, which along with productivity costs are by far the highest cost categories. Finally, due to the debilitating nature of vision loss, indirect costs including productivity losses and long-term care actually exceed direct costs for eye and vision problems, as eye disorders and visual loss incur a large burden on the overall U.S. economy even beyond the healthcare sector.

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