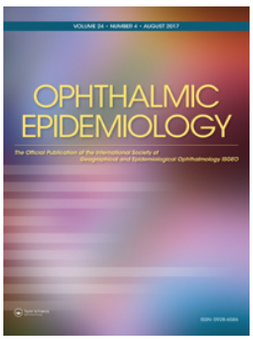

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ORIGINAL ARTICLE

The Economic Impact of Blindness in Europe

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ABSTRACT

Purpose: To estimate the annual loss of productivity from blindness and moderate to severe visual impairment (MSVI) in the population aged >50 years in the European Union (EU).

Methods: We estimated the cost of lost productivity using three simple models reported in the literature based on (1) minimum wage (MW), (2) gross national income (GNI), and (3) purchasing power parity-adjusted gross domestic product (GDP-PPP) losses. In the first two models, assumptions included that all individuals worked until 65 years of age, and that half of all visual impairment cases in the >50-year age group would be in those aged between 50 and 65 years. Loss of productivity was estimated to be 100% for blind individuals and 30% for those with MSVI. None of these models included direct medical costs related to visual impairment.

Results: The estimated number of blind people in the EU population aged >50 years is ~1.28 million, with a further 9.99 million living with MSVI. Based on the three models, the estimated cost of blindness is €7.81 billion, €6.29 billion and €17.29 billion and that of MSVI €18.02 billion, €24.80 billion and €39.23 billion, with their combined costs €25.83 billion, €31.09 billion and €56.52 billion, respectively. The estimates from the MW and adjusted GDP-PPP models were generally comparable, whereas the GNI model estimates were higher, probably reflecting the lack of adjustment for unemployment.

Conclusion: The cost of blindness and MSVI in the EU is substantial. Wider use of available cost-effective treatment and prevention strategies may reduce the burden significantly.

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Blindness; direct costs; productivity loss; visual impairment

Introduction

Blindness and visual impairment (VI) can have a substantial impact on individuals' quality of life[1–3] and are important from a societal and public health point of view.[4] The Vision Loss Expert Group of the Global Burden of Disease (GBD) study estimated that 285 million people are visually impaired worldwide, with 39 million classified as blind.[4] The profile of the causes of vision loss varies across the world, with age-related macular degeneration the main cause in high-income countries, and cataract in middle and low-income countries. Along with glaucoma and diabetic retinopathy, these represent the four main sight-impairing eye diseases globally and in Europe.[4]

In the European Union (EU), considerable variation exists across health care systems, economic strength, and cost of care. There are clear differences in the allocation of social care and resources to blind people across the EU, leading to significant variation in cost burden between different countries. While some prevalence data for VI and blindness are available in the literature for most EU countries,[4] studies dealing with the economic impact of vision loss are scarce. Where data exists, this is limited to highlighting VI as a chronic condition that is important in the measurement of health disability across populations.[5] Up-to-date robust knowledge on the overall clinical and cost burden of blindness and VI is vital for policy makers in order to ensure that the most appropriate strategies are implemented.

Economic consequences of VI may be a result of: (1) direct medical costs due to treatment and diagnosis of the current condition, or treatment of potential future health consequences (such as increased risk of falls, or accidents); (2) direct non-medical costs (e.g. home improvements or transport); or (3) indirect costs such as lost productivity due to unemployment of the individual with VI or their carers. There is no agreed international standard for measuring the cost burden of blindness.[6] Estimating all relevant costs using a methodology comparable across different countries is difficult, especially as major cost items are influenced by clinical

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practice and social support systems of any single country. Estimating direct medical costs are particularly difficult as these are calculated from country-level data on treatment episodes with the accuracy of the data and unit costs varying widely in different EU countries. A recent systematic review identified only four papers that reported VI-related costs in Europe[7] (one from the UK, two from France and one from Germany), and only one of these (UK) reported direct medical costs. However, estimating the costs due to productivity losses may be feasible by employing macroeconomic approaches, such as those recently suggested by Eckert and colleagues[8] and Smith and colleagues.[9]

The objective of this paper was to estimate the annual economic loss across the EU due to reduced productivity from blindness or moderate to severe VI (MSVI) in the population aged over 50 years.

Materials and methods

The cost of lost productivity for 28 EU countries was estimated using three simple models reported in the literature based on minimum wage (MW), gross national income (GNI), and purchasing power parity-adjusted gross domestic product (GDP-PPP) losses. The first two models followed the same methodology described by Eckert and colleagues,[8] whereas the third model was a modified version of that reported by Smith and colleagues.[9] We included only costs related to productivity losses, and excluded direct medical or non-medical costs. The attempt was made to use the most recent data, rather than indexing all data to a single year. Calculations were limited to the population >50 years, and all cost figures were converted to euros, where applicable (Table 1).

Data sources

The prevalence of blindness and MSVI were obtained from the recently published analysis by the Vision Loss Expert Group of the GBD study,[10] where blindness was defined as presenting visual acuity <3/60 in the better eye, and MSVI as presenting visual acuity <6/18 but ≥3/60 in the better eye. The GBD analysis was based on a systematic review of 243 studies published between 1 January 1980 and 31 January 2012, with the country- and age-specific prevalences of blindness and MSVI obtained from the authors of this report. The most recent estimates were used, which related to the year 2010. The population data came from the 2015 revision of the world population data of the United Nations. Detailed age- and sex-specific data for each EU country were extracted online for 2015. The number of people with blindness and MSVI for each country and age group was estimated by applying the age and country-specific prevalence rates to the population data.

MW data were available for most European countries through the Statistical Office of the European

Table 1. Visual impairment prevalence and economic data by country, European Union.

Country	Population, *N* x 1,000	Population aged 50+ years, %	Blind, %	MSVI, %	Minimum wage, € per annum	Gross national income, € per capita	GDP-PPP, € per capita
Austria	8542	39.09	0.6	4.5	19,250	37,388	34,793
Belgium	11,301	38.15	0.5	4.2	18,022	35,574	32,050
Bulgaria	7149	40.62	0.6	4.5	2209	5736	12,508
Croatia	4242	40.48	0.9	8.7	4747	9770	15,966
Cyprus	1165	30.21	0.4	3.8	11,352	19,849	23,239
Czech Republic	10,544	37.64	0.5	5.5	3981	13,828	22,889
Denmark	5668	37.86	0.4	3.3	18,664	46,150	33,810
Estonia	1311	39.05	0.8	6.6	4680	14,324	20,283
Finland	5504	40.70	0.4	3.9	15,334	36,447	30,095
France	64,395	38.25	0.6	4.1	17,490	32,337	29,242
Germany	80,687	43.67	0.5	4.2	17,676	35,860	34,477
Greece	10,955	40.40	0.5	4.2	8205	17,072	19,478
Hungary	9856	37.47	0.9	8.1	3993	10,041	18,608
Ireland	4688	30.40	0.5	4.0	17,542	31,818	36,699
Italy	59,796	43.31	0.9	4.9	13,075	35,040	26,124
Latvia	1971	40.49	0.8	7.1	4320	11,502	17,217
Lithuania	2880	40.45	0.8	6.8	3600	11,615	20,130
Luxembourg	568	32.92	0.5	3.7	23,076	57,200	73,513
Malta	417	38.85	0.4	3.8	8646	15,807	21,925
Netherlands	16,924	39.11	0.4	2.9	18,022	39,059	35,877
Poland	38,613	36.58	0.7	7.1	4914	10,305	18,626
Portugal	10,352	41.09	1.0	6.2	7070	16,078	48,819
Romania	19,512	37.16	0.8	8.1	2610	7166	21,372
Slovakia	5426	34.30	0.6	6.6	4560	13,361	14,604
Slovenia	2068	39.85	0.8	7.7	9489	17,749	20,859
Spain	46,122	38.80	0.8	4.7	9080	22,160	22,554
Sweden	9777	37.66	0.5	4.1	15,425	46,376	24,999
UK	64,714	36.20	0.5	5.5	16,546	32,691	34,011

MSVI, moderate to severe visual impairment; GDP-PPP, purchasing power parity-adjusted gross domestic product.

Union (Eurostat) 2014 statistics (http://ec.europa.eu/eurostat/web/products-datasets/-/tps00155). Six EU countries (Austria, Cyprus, Italy, Denmark, Finland and Sweden) do not have officially set minimum wages. For these countries (except Cyprus), 50% of the country-specific average wage values reported by the Organisation for Economic Co-operation and Development (OECD) was used. This was in line with the average wage/MW ratios for other countries. OECD data was not reported for Cyprus, therefore average wage data from the Cypriot State Statistical Service were obtained online for the same year (http://www.mof.gov.cy/mof/cystat/statistics.nsf/labour_34main_en/labour_34main_en?OpenForm&sub=4&sel=2).

Data from Eurostat were used for unemployment and labor force participation rates (LFPRs). GNI per capita (Atlas method, in current US$) and GDP-PPP data for each country were available from the World Bank (http://data.worldbank.org/indicator/NY.GNP.PCAP.PP.CD). These were converted to euros, using the average exchange rate of the European Central Bank for 2014 (US$1 = €0.7527).

Cost calculations

We used three simple models to calculate lost revenue due to lack of or reduced employment for those who are blind or have MSVI. In the first two models, it was assumed that all individuals worked only until 65 years of age, and then dropped out of employment, hence would no longer contribute to productivity losses. It has previously been estimated that half of all VI cases in the >50-year age group would be those in the 50–65-year age group.[11] Therefore, only half of the VI cases over 50 years of age were included in the calculations. Loss of productivity was estimated to be 100% for those who were blind and 30% for those with MSVI.[8] To calculate productivity losses arising from blindness, the total number of blind people was multiplied by the MW, and GNI per capita. To calculate productivity losses due to MSVI, the number of persons with MSVI was multiplied by 30% of the MW, and GNI per capita. For these two models, no further adjustments were made for employment rates or LFPRs.

The third model used the GDP-PPP method, and was based on that published by Smith and colleagues.[9] Losses to productivity were assumed to be 70% for the blind and 34.5% for those with MSVI, of which 10% accounted for the lost productivity of their carers. In the published model, Smith and colleagues assumed that all individuals over 15 years of age were economically active in their base-case, but performed adjustments on the basis of general employment rates and LFPRs. As our study population was over 50 years of age, applying general employment rates and LFPRs would lead to overestimation of productivity losses, with employment rates and LFPRs progressively reducing with advancing age. Although some age-specific data were reported from Eurostat, these were not available for each 5-year age band. Therefore, it was necessary to make some assumptions. In the Eurostat dataset, age-specific LFPR estimates were available for the >65-year age band. For those between 50 and 65 years of age, adult LFPRs were applied. For unemployment, age-specific rates were available for the >55-year population. For the 50–55-year group, again adult unemployment rates were applied. Productivity losses were first calculated by multiplying the total number of people with blindness and MSVI by the disability weights[8] (0.7 for blindness and 0.345 for MSVI) and by the GDP-PPP per capita. These estimates were then adjusted by the employment rates and LFPRs (Table 2).

Table 2. Adjustment factors for modeling economic cost of visual impairment based on age-specific employment and labor force participation rates[a] by country and age group, European Union.

	Age group, %		
Country	50–55 years	55–65 years	65+ years
Austria	83.69	21.15	2.37
Belgium	79.39	19.25	0.98
Bulgaria	74.37	28.32	2.01
Croatia	71.79	14.84	1.15
Cyprus	76.05	26.26	3.42
Czech Republic	83.98	30.68	2.68
Denmark	82.29	41.98	4.49
Estonia	81.13	43.29	13.30
Finland	80.50	37.75	5.97
France	80.39	23.86	1.15
Germany	83.46	45.32	3.81
Greece	63.42	13.98	0.96
Hungary	79.32	18.60	1.34
Ireland	72.92	30.80	5.31
Italy	68.82	22.60	1.71
Latvia	78.46	35.28	3.94
Lithuania	80.86	35.40	3.25
Luxembourg	83.62	18.89	1.76
Malta	75.70	15.23	2.03
Netherlands	81.42	38.87	4.62
Poland	78.55	19.36	2.05
Portugal	77.54	26.42	5.71
Romania	77.61	19.22	4.67
Slovakia	77.01	22.43	0.90
Slovenia	82.21	13.59	2.36
Spain	67.84	24.54	0.76
Sweden	85.59	58.04	12.58
UK	82.34	38.75	6.25

[a]For example, 83.69% of the Austrian population 50–55 years were estimated to be in employment.

None of these models included direct medical costs as a consequence of VI.

Results

The number of blind people in the EU population who are >50 years of age is estimated to be 1.28 million, with a further 9.99 million people living with MSVI (Table 3).

Table 3. People with blindness and moderate to severe visual impairment (MSVI) by country, European Union.

Country	Blind, *N*	MSVI, *N*
Austria	20,034	150,255
Belgium	21,555	181,062
Bulgaria	17,424	130,680
Croatia	15,453	149,379
Cyprus	1408	13,376
Czech Republic	19,845	218,295
Denmark	8584	70,818
Estonia	4096	33,792
Finland	8960	87,360
France	147,786	1,009,871
Germany	176,190	1,479,996
Greece	22,130	185,892
Hungary	33,237	299,133
Ireland	7125	57,000
Italy	233,064	1,268,904
Latvia	6384	56,658
Lithuania	9320	79,220
Luxembourg	935	6919
Malta	648	6156
Netherlands	26,476	191,951
Poland	98,861	1,002,733
Portugal	42,540	263,748
Romania	58,000	587,250
Slovakia	11,166	122,826
Slovenia	6592	63448
Spain	143,152	841,018
Sweden	18,410	150,962
UK	117,145	1,288,595
TOTAL	1,276,520	9,997,297

The MW model estimated the cost of blindness at €7.81 billion and the cost of MSVI at €18.02 billion. The total cost of blindness and MSVI amounted to €25.8 billion for the entire EU. Detailed results for each country are given in billion euros (Table 4) and percentage of gross domestic product (Table 5). The highest cost burden was in Germany (€5.48 billion), and the lowest was in Malta (€11 million). A total of 68% of the total burden arose from four countries; France, Italy, Germany, and the UK. This is greater than the proportion of these four countries' total populations in the EU (53%; Figure 1).

Using the GNI method we estimated the cost to be €17.29 billion for blindness, €39.23 billion for MSVI, and €56.52 billion euros in total for the visually impaired population. The GDP-PPP model estimated the unadjusted costs to be €24.67 billion, €94.85 billion and €119.52 billion, respectively. However, when the adjustment factors based on employment rates and LFPRs were applied (Table 2), the total costs were similar to those estimated by the MW method (€6.29 billion, €24.80 billion and €31.09 billion, respectively; Table 4).

To test the robustness of our findings we performed a sensitivity analysis modelled on the confidence

Table 4. Cost of blindness and moderate to severe visual impairment (MSVI) by country, using three different models, European Union.

	Model, € billion											
	Minimum wage method			Gross national income method			GDP-PPP unadjusted			GDP-PPP adjusted[a]		
Country	Blind	MSVI	Total	Blind	MSVI	Total	Blind	MSVI	Total	Blind	MSVI	Total
Austria	0.19	0.43	0.63	0.37	0.84	1.22	0.49	1.80	2.29	0.12	0.45	0.57
Belgium	0.19	0.49	0.68	0.38	0.97	1.35	0.48	2.00	2.49	0.11	0.44	0.55
Bulgaria	0.02	0.04	0.06	0.05	0.11	0.16	0.15	0.56	0.72	0.04	0.13	0.16
Croatia	0.04	0.11	0.14	0.08	0.22	0.29	0.17	0.82	1.00	0.03	0.15	0.19
Cyprus	0.01	0.02	0.03	0.01	0.04	0.05	0.02	0.11	0.13	0.01	0.03	0.04
Czech Republic	0.04	0.13	0.17	0.14	0.45	0.59	0.32	1.72	2.04	0.08	0.45	0.54
Denmark	0.08	0.20	0.28	0.20	0.49	0.69	0.20	0.83	1.03	0.06	0.25	0.31
Estonia	0.01	0.02	0.03	0.03	0.07	0.10	0.06	0.24	0.29	0.02	0.08	0.10
Finland	0.07	0.20	0.27	0.16	0.48	0.64	0.19	0.91	1.10	0.05	0.26	0.32
France	1.29	2.65	3.94	2.39	4.90	7.29	3.03	10.19	13.21	0.68	2.28	2.96
Germany	1.56	3.92	5.48	3.16	7.96	11.12	4.25	17.60	21.86	1.39	5.74	7.13
Greece	0.09	0.23	0.32	0.19	0.48	0.66	0.30	1.25	1.55	0.05	0.19	0.24
Hungary	0.07	0.18	0.25	0.17	0.45	0.62	0.43	1.92	2.35	0.09	0.38	0.47
Ireland	0.06	0.15	0.21	0.11	0.27	0.39	0.18	0.72	0.90	0.05	0.21	0.26
Italy	1.52	2.49	4.01	4.08	6.67	10.75	4.26	11.44	15.70	0.86	2.31	3.17
Latvia	0.01	0.04	0.05	0.04	0.10	0.13	0.08	0.34	0.41	0.02	0.10	0.12
Lithuania	0.02	0.04	0.06	0.05	0.14	0.19	0.13	0.55	0.68	0.04	0.16	0.20
Luxembourg	0.01	0.02	0.03	0.03	0.06	0.09	0.05	0.18	0.22	0.01	0.05	0.06
Malta	0.00	0.01	0.01	0.01	0.01	0.02	0.01	0.05	0.06	0.00	0.01	0.01
Netherlands	0.24	0.52	0.76	0.52	1.12	1.64	0.66	2.38	3.04	0.21	0.74	0.95
Poland	0.24	0.74	0.98	0.51	1.55	2.06	1.29	6.44	7.73	0.29	1.43	1.71
Portugal	0.15	0.28	0.43	0.34	0.64	0.98	1.45	4.44	5.90	0.36	1.11	1.48
Romania	0.08	0.23	0.31	0.21	0.63	0.84	0.87	4.33	5.20	0.18	0.92	1.11
Slovakia	0.03	0.08	0.11	0.07	0.25	0.32	0.11	0.62	0.73	0.03	0.15	0.18
Slovenia	0.03	0.09	0.12	0.06	0.17	0.23	0.10	0.46	0.55	0.02	0.10	0.12
Spain	0.65	1.15	1.80	1.59	2.80	4.38	2.26	6.54	8.80	0.49	1.41	1.90
Sweden	0.14	0.35	0.49	0.43	1.05	1.48	0.32	1.30	1.62	0.12	0.50	0.63
UK	0.97	3.20	4.17	1.91	6.32	8.23	2.79	15.12	17.91	0.88	4.76	5.63
Total	7.81	18.02	25.83	17.29	39.23	56.52	24.67	94.85	119.52	6.29	24.80	31.09

[a]Adjusted for employment and labor force participation rates (see Table 2).
GDP-PPP, purchasing power parity-adjusted gross domestic product.

Table 5. Cost of blindness and moderate to severe visual impairment (MSVI) by country, using three different models, European Union.

	Model, % gross domestic product											
	Minimum wage method			Gross national income method			GDP-PPP unadjusted			GDP-PPP adjusted[a]		
Country	Blind	MSVI	Total	Blind	MSVI	Total	Blind	MSVI	Total	Blind	MSVI	Total
Austria	0.06	0.13	0.19	0.11	0.26	0.37	0.15	0.55	0.70	0.04	0.14	0.17
Belgium	0.05	0.12	0.17	0.10	0.24	0.34	0.12	0.50	0.62	0.03	0.11	0.14
Bulgaria	0.05	0.10	0.15	0.12	0.26	0.38	0.36	1.32	1.68	0.08	0.30	0.39
Croatia	0.09	0.25	0.33	0.18	0.51	0.68	0.40	1.91	2.31	0.07	0.36	0.43
Cyprus	0.05	0.13	0.18	0.08	0.23	0.31	0.13	0.61	0.74	0.04	0.17	0.20
Czech Republic	0.03	0.08	0.11	0.09	0.29	0.38	0.21	1.12	1.32	0.05	0.29	0.35
Denmark	0.03	0.08	0.11	0.08	0.19	0.26	0.08	0.32	0.40	0.02	0.10	0.12
Estonia	0.05	0.12	0.17	0.15	0.36	0.51	0.29	1.19	1.48	0.10	0.42	0.53
Finland	0.03	0.10	0.13	0.08	0.23	0.31	0.09	0.44	0.53	0.03	0.13	0.15
France	0.06	0.12	0.19	0.11	0.23	0.34	0.14	0.48	0.62	0.03	0.11	0.14
Germany	0.05	0.13	0.19	0.11	0.27	0.38	0.15	0.60	0.75	0.05	0.20	0.24
Greece	0.05	0.13	0.18	0.11	0.27	0.37	0.17	0.70	0.87	0.03	0.11	0.14
Hungary	0.06	0.17	0.24	0.16	0.43	0.59	0.42	1.84	2.26	0.08	0.36	0.45
Ireland	0.03	0.08	0.11	0.06	0.14	0.20	0.10	0.38	0.48	0.03	0.11	0.14
Italy	0.09	0.15	0.25	0.25	0.41	0.67	0.26	0.71	0.98	0.05	0.14	0.20
Latvia	0.06	0.16	0.21	0.16	0.42	0.57	0.33	1.43	1.76	0.09	0.41	0.50
Lithuania	0.05	0.12	0.16	0.15	0.38	0.53	0.36	1.51	1.87	0.11	0.45	0.56
Luxembourg	0.02	0.05	0.07	0.05	0.12	0.18	0.10	0.36	0.46	0.03	0.09	0.12
Malta	0.04	0.11	0.15	0.07	0.20	0.27	0.14	0.64	0.78	0.03	0.12	0.15
Netherlands	0.04	0.08	0.11	0.08	0.17	0.25	0.10	0.36	0.46	0.03	0.11	0.14
Poland	0.06	0.18	0.24	0.12	0.38	0.50	0.31	1.57	1.88	0.07	0.35	0.42
Portugal	0.04	0.07	0.11	0.09	0.17	0.26	0.39	1.18	1.56	0.10	0.30	0.39
Romania	0.04	0.13	0.18	0.12	0.36	0.48	0.50	2.50	3.00	0.11	0.53	0.64
Slovakia	0.02	0.06	0.07	0.05	0.16	0.21	0.08	0.41	0.49	0.02	0.10	0.12
Slovenia	0.04	0.12	0.16	0.08	0.22	0.30	0.13	0.61	0.73	0.03	0.13	0.16
Spain	1.74	3.07	4.82	4.26	7.50	11.76	6.07	17.57	23.63	1.31	3.79	5.10
Sweden	0.01	0.03	0.05	0.04	0.10	0.14	0.03	0.13	0.16	0.01	0.05	0.06
UK	0.23	0.74	0.97	0.45	1.47	1.92	0.65	3.52	4.17	0.20	1.11	1.31
Total	0.06	0.15	0.21	0.14	0.33	0.47	0.20	0.79	0.99	0.05	0.21	0.26

[a]Adjusted for employment and labor force participation rates (see Table 2).
GDP-PPP, purchasing power parity-adjusted gross domestic product.

intervals of vision loss prevalence estimates from the high income group of countries in the global burden of disease study[10] (Table 6 and Figure 2).

Discussion

The present study estimated the economic losses due to blindness and MSVI in the EU based on three simple macroeconomic models. These findings support the view that VI results in a significant cost burden for the EU, despite the relatively low prevalence of blindness and MSVI.

In our analysis, the most conservative estimates were produced by the MW method. The GNI method produced higher estimates, by around a factor of two when compared with the MW method. The estimates from the GDP-PPP model, when adjusted by employment rates and LFPRs, became very close to those estimated by the MW model. This contrasts with the findings of Eckert and colleagues,[8] who reported that adjusted GDP-PPP figures were consistently similar to those estimated by the GNI model, and were much higher than those from the MW model. This discrepancy in findings may be due to two reasons. First, we had access to age-specific employment rates and LFPRs from Eurostat, which enabled us to refine our estimates. Eckert and colleagues[8] used the LFPRs for the 15–64-year age band in their GDP-PPP model, which may have overestimated the productivity losses for those over 65 years of age. For example, in our dataset, LFPR was as low as 1.72% (Spain) for the older than 65-year age group. Therefore, we have effectively applied higher adjustment rates than those applied by Eckert and colleagues, which resulted in the GDP-PPP estimates approaching the MW model. Second, although EU countries differ significantly from each other in terms of economic strength and purchase power, they still form a more homogenous set than the countries included in the paper by Eckert and colleagues. Furthermore, wealth in the EU is probably more evenly distributed than in some developing countries, which may make MW a better proxy for economic losses in this case.

Our analysis also has significant limitations, most of which are inherent to macroeconomic approaches. In the MW and GNI models, we assumed no productivity for blind people, and 70% productivity for MSVI, and for the GDP-PPP model 30% productivity for blind people and 66.5% for MSVI. We followed the assumptions made in published models, in order to render comparisons possible.[8,9] Few attempts have been made to estimate the productivity loss due to blindness and VI in Europe[11] and the US.[12] However, estimates are substantially weighted to those with partial sight/MSVI, rather than those who are blind, so we feel that our use of complete loss of

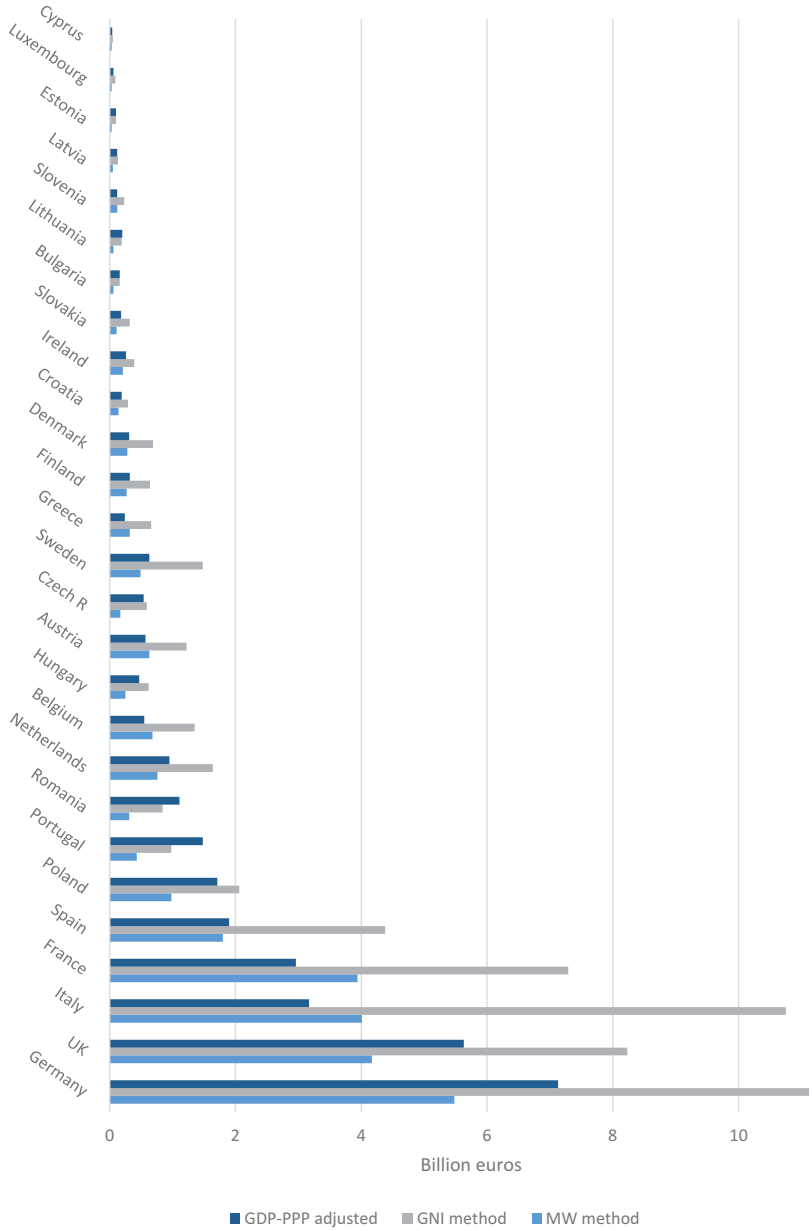

Figure 1. Cost of blindness and moderate to severe visual impairment by country, using three different models (in billion euros), European Union. GDP-PPP, purchasing power parity-adjusted gross domestic product; GNI, gross national income; MW, minimum wage.

productivity is fair for the blindness category. Assumptions also include an additional 10% productivity loss in the GDP-PPP model due to carers' involvement for blind people (and 5% for those with MSVI), derived from a study outside of Europe due to the lack of European literature on the subject of carer involvement.[12]

We have used the country- and age-specific prevalence rates estimated by the Vision Loss Expert Group of the GBD study.[15] We believe that this meta-analysis represents the most comprehensive database (The Global Vision Database) of all population-based blindness/VI prevalence studies and includes all those that were performed between 1980 and 2012 and thus is the most accurate data to date for both blindness and MSVI prevalence. Although new country-specific prevalence estimates will be available in late 2016, our analysis was based on the currently available estimates of prevalence for 2010. We considered using 2010 as an index year, and matching all cost and economic input with actual 2010 data, or alternatively adjusting them to 2010 by using inflation/deflation factors where appropriate. However, considering the rapid changes in the economic environment in the EU over the last decade, we felt that the 2010 economic estimates would already be out of date.

Table 6. Visual impairment prevalence variation by country for sensitivity analysis of economic impact, European Union.

Country	Blind, % (95%Ci)	MSVI, % (95%Ci)
Austria	0.6 (0.3–1.0)	4.5 (2.3–9.6)
Belgium	0.5 (0.3–0.9)	4.2 (1.9–9.0)
Bulgaria	0.6 (0.5–1.9)	4.5 (2.1–16.4)
Croatia	0.9 (0.6–2.2)	8.7 (3.6–18.4)
Cyprus	0.4 (0.2–0.8)	3.8 (1.8–7.5)
Czech Republic	0.5 (0.3–1.3)	5.5 (2.3–13.6)
Denmark	0.4 (0.3–0.6)	3.3 (2.1–6.6)
Estonia	0.8 (0.6–2.0)	6.6 (4.3–15.0)
Finland	0.4 (0.3–0.8)	3.9 (1.7–8.8)
France	0.6 (0.4–1.3)	4.1 (2.7–9.1)
Germany	0.5 (0.2–0.8)	4.2 (2.0–9.9)
Greece	0.5 (0.3–1.2)	4.2 (2.8–8.9)
Hungary	0.9 (0.6–2.2)	8.1 (3.3–15.5)
Ireland	0.5 (0.3–0.8)	4.0 (1.8–9.2)
Italy	0.9 (0.5–1.2)	4.9 (3.7–7.3)
Latvia	0.8 (0.4–1.7)	7.1 (3.1–15.1)
Lithuania	0.8 (0.4–1.7)	6.8 (2.7–14.7)
Luxembourg	0.5 (0.3–1.0)	3.7 (1.6–8.6)
Malta	0.4 (0.2–0.7)	3.8 (1.8–8.3)
Netherlands	0.4 (0.3–0.8)	2.9 (2.1–6.8)
Poland	0.7 (0.4–1.5)	7.1 (2.8–14.6)
Portugal	1.0 (0.6–2.3)	6.2 (2.6–15.5)
Romania	0.8 (0.4–1.9)	8.1 (3.4–15.3)
Slovakia	0.6 (0.4–1.4)	6.6 (2.7–14.0)
Slovenia	0.8 (0.4–1.9)	7.7 (3.1–15.0)
Spain	0.8 (0.5–1.4)	4.7 (3.2–8.1)
Sweden	0.5 (0.3–0.9)	4.1 (1.8–8.9)
UK	0.5 (0.3–0.6)	5.5 (2.9–11.5)

CI, confidence interval; MSVI, moderate to severe visual impairment.

Therefore, we have applied these 2010-derived blind/MSVI prevalence rates to the more recent estimates of population and economic data from 2014/2015. It is possible that if a decrease in the prevalence of VI and blindness has occurred in the EU after 2010 (as occurred in terms of age-standardized prevalence and absolute numbers of individuals affected between 1990 and 2010[13]) from improved treatment strategies, our data could represent an over-estimation of the economic burden as this could have been expected to proportionally decrease.

Last, we applied the disability weights for blindness and MSVI used by Eckert and colleagues[8] to produce comparable estimates. We do acknowledge that these weights are higher than those reported in the GBD 2013 study[14] (blindness, 0.187; severe VI 0.184; moderate VI, 0.031). For example, had the GBD 2013 disability weight for blindness been used in our analysis, the GDP-PPP unadjusted cost of blindness would be halved. The GBD study decided in its 2010[17] and 2013 calculations of disability weight, to use "health" as a unidimensional construct to weigh multidimensional non-fatal health conditions against each other and death. Consequently, conditions such as vision loss which are not perceived by the public as states of illness, have seen a dramatic reduction in disability weight.[15] This has led to considerable dispute over their credibility for vision loss,[16] hence our decision to use those used by Eckert and colleagues.[8]

With these limitations in mind, we feel that the MW method overall offers a simple way of estimating the cost burden of VI due to productivity losses in European settings. We believe our findings should be treated as

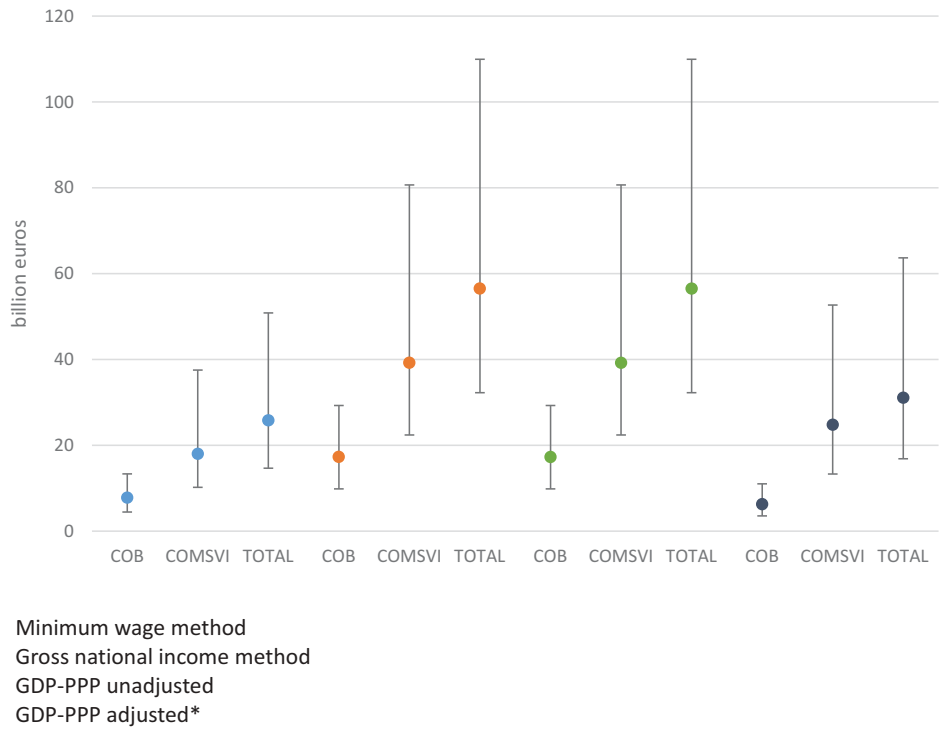

Figure 2. Cost of blindness and moderate to severe visual impairment with 95% confidence intervals by model, European Union. GDP-PPP, purchasing power parity-adjusted gross domestic product; COB, cost of blindness; COMSVI, cost of moderate to severe visual impairment. [a]Adjusted for employment and labor force participation rates (see Table 2).

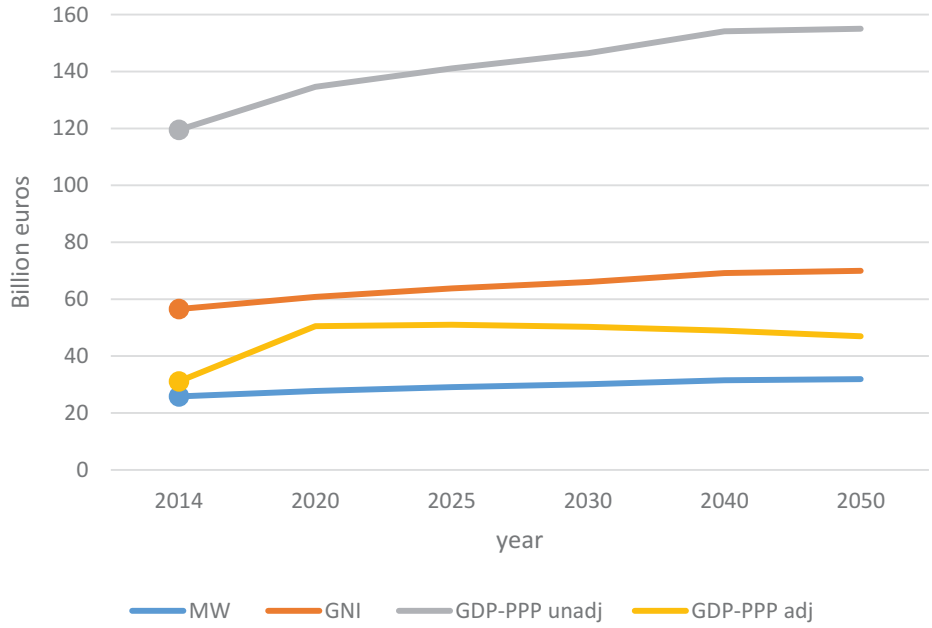

Figure 3. Projections of cost of blindness and moderate to severe visual impairment using different models, European Union. GDP-PPP, purchasing power parity-adjusted gross domestic product; GNI, gross national income; MW, minimum wage; unadj, unadjusted; adj, adjusted for employment and labor force participation rates (see Table 2).

conservative estimates in many ways. For example, by assuming no productivity for those over 65 years of age in the MW and GNI models, we effectively limited our analysis to a narrow population band, aged between 50 and 65. Furthermore, our calculations only considered productivity costs, but the actual cost burden to the health systems will be significantly higher when the direct medical and non-medical costs are included. A recent systematic review suggested that the medical costs for people with VI are almost twice as high as those with no VI, and that the annual direct medical costs for blind patients would be purchasing power parity US$14,882–24,180.[7] In this context it is worth noting that in 2003, Meads and Hyde estimated the direct costs for blind people in UK settings, which ranged between £1375 and £17,100 for the first year, followed by £1325–£16,800 per year for consecutive years.[18]

Unfortunately, recent similar data in EU health systems are scarce in the published literature, and there is a lack of country-specific databases that report VI-related direct health care costs, making it very difficult to reliably estimate all relevant costs around VI across the EU, hence our decision not to include medical costs in our estimates.

Nonetheless the findings of our study are in line with those of similar studies in Japan, Canada, and the US. All studies show how blindness and VI place a heavy burden on individuals and society, however direct comparison of results is difficult because of differing methodologies applied. Roberts and colleagues[19] estimated that in 2007, VI affected more than 1.64 million people in Japan. Indirect financial costs, estimated through a prevalence-based costing method, were €9.9 billion (¥1583.5 billion), including productivity losses, carers' costs, and efficiency losses from welfare payments and taxes. Cruess and co-workers[20] estimated that in 2007 the financial cost of vision loss in Canada was 11.9 billion euros (CAN $15.8 billion) per annum (inclusive of direct healthcare costs). Their study used a prevalence-based approach, based primarily on the costs associated with the five major causes of VI. Rein and co-authors[21] estimated that in 2001 the economic burden of visual disorders in the US was €14.4 billion (US$19.1 billion; direct costs excluded). These aforementioned authors used a mixed set of data sources to calculate the direct and indirect costs of VI.

We estimated how total costs of VI would evolve in the future. We applied the population projections from the Eurostat database[22] to our models, assuming all other parameters were constant. The cost projections until 2050 show that the demographic evolution of the European population alone would increase the economic burden (Figure 3). The estimated costs are likely to experience additional increases in the future when based on the MW, GNI, and GDP-PPP unadjusted methods. On the other hand, from the GDP-PPP adjusted method, there should be an initial sharp increase in costs but in the long term costs would decrease although always remain higher than the current situation. A possible interpretation of this is that the European population will be aging, hence less individuals are

going to be of working age and productive so with the adjustment for productivity the impact of VI is smaller.

In conclusion, the MW (most conservative) model estimated the total cost of VI in the EU to be €25.8 billion and €31.9 billion by 2050, not accounting for direct costs of medical care. In comparison, the cost of Type II diabetes in Europe has been estimated to be €29 billion.[23] The findings of this analysis might spur policy makers to work towards developing and implementing appropriate strategies to help visually impaired people to find and keep employment. In addition, providing access to cost-effective healthcare technologies that have the potential to reduce the incidences of blindness and MSVI should be given priority. For those diseases that are preventable or treatable, early recognition of these conditions and timely management will reduce the numbers of visually impaired people, which in turn can have a beneficial impact on the overall burden to health and social systems.

Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the writing and content of this article.

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