Economic burden of cancer across the European Union: a population-based cost analysis

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Summary

Background In 2008, 2·45 million people were diagnosed with cancer and 1·23 million died because of cancer in the 27 countries of the European Union (EU). We aimed to estimate the economic burden of cancer in the EU.

Methods In a population-based cost analysis, we evaluated the cost of all cancers and also those associated with breast, colorectal, lung, and prostate cancers. We obtained country-specific aggregate data for morbidity, mortality, and health-care resource use from international and national sources. We estimated health-care costs from expenditure on care in the primary, outpatient, emergency, and inpatient settings, and also drugs. Additionally, we estimated the costs of unpaid care provided by relatives or friends of patients (ie, informal care), lost earnings after premature death, and costs associated with individuals who temporarily or permanently left employment because of illness.

Findings Cancer cost the EU €126 billion in 2009, with health care accounting for €51·0 billion (40%). Across the EU, the health-care costs of cancer were equivalent to €102 per citizen, but varied substantially from €16 per person in Bulgaria to €184 per person in Luxembourg. Productivity losses because of early death cost €42·6 billion and lost working days €9·43 billion. Informal care cost €23·2 billion. Lung cancer had the highest economic cost (€18·8 billion, 15% of overall cancer costs), followed by breast cancer (€15·0 billion, 12%), colorectal cancer (€13·1 billion, 10%), and prostate cancer (€8·43 billion, 7%).

Interpretation Our results show wide differences between countries, the reasons for which need further investigation. These data contribute to public health and policy intelligence, which is required to deliver affordable cancer care systems and inform effective public research funds allocation.

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See Online for a podcast interview with Ramon Luengo-Fernandez

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For more on **cancer in the European Union in 2008** see http://globocan.iarc.fr

Introduction

Cancer is a major public health issue. In 2008 alone, 2·45 million people were diagnosed with cancer in the 27 countries of the European Union (EU). Cancer incidence and mortality has been reduced in developed countries due to several factors including advances in early detection, diagnostic approaches, and cancer treatment, and lifestyle changes and the development of prevention vaccines for some cancers.[1,2] Nonetheless, more than 1·23 million people still died because of cancer in the EU in 2008. About half of all new cancer diagnoses and deaths in this region in 2008 were attributable to just breast, colorectal, lung, and prostate cancers.

Cancer imposes a substantial economic burden on society. Substantial health-care costs are associated with its prevention and management.[3] Moreover, some patients are unable to continue working, and many rely on friends and family for support during treatment or in the last phases of the disease. Therefore, quantification of the economic burden of cancer in the EU needs not only an estimation of the costs of cancer to health-care systems, but also an estimation of the lost earnings associated with the inability to work (due to illness or premature death) and the costs of unpaid care provided by patients' friends and relatives.

The costs of cancer have been assessed in individual countries—eg, Germany,[4] the Netherlands,[5] and England[6]—and across different European countries.[7] However, the whole economic burden of cancer—including direct health care, informal costs, and economic losses to countries because of premature mortality and morbidity—has not been analysed across the EU in a comparative study. The delivery of affordable cancer care systems requires public health and policy intelligence to incorporate a comprehensive estimation of the costs of cancer care.[8] A systematic cost-of-illness study can provide valuable data for the relative socioeconomic burden of different diseases, which can inform an objective public policy framework for the allocation of governmental research funds.[9,10] We aimed to estimate the economic burden of cancer across the 27 countries that made up the EU in 2009, as well as the specific proportions of total cost attributable to breast, colorectal, lung, and prostate cancers.

Methods

Analysis framework and data sources

We evaluated the costs of all cancers in a population-based cost analysis. Cancer is defined here by the WHO International Classification of Diseases, 10th revision, codes C00–97. We estimated costs associated with breast (C50), colorectal (C18–21), lung (C33–34), and prostate (C61) cancers separately.

We used one methodological framework to obtain data for, and value cancer-related resource use in, each of the

27 EU countries. We used the same framework as applied previously to estimate the costs of cardiovascular disease,[11] and to estimate the costs of dementia in the EU.[12] The use of the same framework enables comparisons between countries and across other non-communicable diseases, allowing the total estimates to be used for public health policy.

We adopted a societal perspective for our analysis, including health-care costs, informal care costs, and productivity losses. We used an annual timeframe, including all costs for 2009 (the most recent year for which data were available in most cases) or from the most recent year if 2009 data were not available, irrespective of the time of disease onset. We obtained country-specific aggregate data from international and national sources, including WHO, the Organisation for Economic Co-operation and Development, the Statistical Office of the European Communities (EUROSTAT), national ministries of health, and statistical institutes (appendix p 10). When we could not obtain relevant data from these sources, we consulted relevant reports from peer-reviewed journals or national reports by governmental agencies or professional bodies. If no country-specific data were available, we extrapolated from similar countries. We judged a country to be similar to another if it had similar health-care expenditure per person, life expectancy, and geographical location.

See Online for appendix

All costs were expressed in 2009 prices[13] and converted to euros for the ten countries not using this currency with converters from The Economist[14] (service no longer available). In view of the price differentials across European countries, we made adjustments with the purchasing power parity method.[13] This method measures the price of the same bundle of goods in different countries where euros are used as common currency, thus allowing comparison of costs adjusted for cost of living between countries.

For more on **SHARE** see http://www.share-project.org

Procedures and statistical analysis

We included five categories of cancer health-care services: primary care, emergency care, outpatient care, hospital inpatient care, and drugs. We did not include other categories of health care, such as health promotion and prevention activities, because of difficulties in consistent identification and quantification across countries. To account for private expenditure in countries where only public expenditures were available, we inflated cancer-related public expenditure to account for all expenditure using information about the proportion of private expenditure making up all health expenditure.[15,16]

Primary care consisted of visits to or from family doctors and practice nurses. Accident and emergency care consisted of all cancer-related hospital emergency visits. Outpatient care consisted of specialist consultations and treatments (eg, radiotherapy) in outpatient wards, clinics, or patients' homes. We obtained information about the total number of contacts with each type of service, and then the proportion of those that were attributable to cancer (appendix pp 3–5). Information about inpatient care was obtained from EUROSTAT.[13] We calculated costs by applying country-specific unit costs (appendix p 6) to the total number of cancer-related contacts or hospital days.

Drug expenditure consisted of total retail and hospital sales of antineoplastic agents and endocrine treatment (Anatomical Therapeutic Chemical codes L1 and L2). Drug expenditure data were obtained from IMS Health and a report from the Netherlands.[5] Only Germany[4] and the Netherlands[5] provided information about the proportion of cancer-related drug expenditure attributable to the different types of cancer. We therefore calculated the mean proportion of cancer-specific drug expenditure of these two countries and applied it to the total L1 and L2 sales in the remaining countries (giving proportions of 4% for colorectal cancer, 4% for lung cancer, 21% for breast cancer, and 22% for prostate cancer).

We defined informal care costs as the opportunity cost of unpaid care—ie, the working time or leisure time, or both, that carers forgo to provide unpaid care for relatives or friends with cancer, valued in monetary terms. Conservatively, we assumed that only patients severely limited in daily activities or who were terminally ill would receive informal care. To estimate the number of hours of informal care by country, we undertook a series of logistic and ordered logistic regression analyses adjusted for several covariates (eg, age, sex, other health conditions, and country of residence; appendix p 7) using wave 2 (for severely limited patients with cancer) and wave 3 (for terminally ill patients) from the Survey of Health, Ageing and Retirement in Europe (SHARE), which covers 13 EU countries (appendix p 7).[17] We used data from SHARE release 2.5.0 as of May 24, 2011. Number of hours of informal care by country were calculated by summing the age-specific and sex-specific SHARE data products for the following four values: prevalence of all cancers and of colorectal, lung, breast, and prostate cancers; probability of a patient with cancer being severely limited in daily activities; probability of patient receiving informal care; and the hours of informal care received.[17] Hours of informal care for terminally ill patients were estimated by summing the age-specific and sex-specific products of three values: number of cancer deaths,[13] probability of receiving informal care in the year before death due to cancer, and hours of informal care received (all values, except number of patient deaths, were again obtained from SHARE[17]).

For the 14 countries not in SHARE, we pooled data from the survey by region (northern, central, southern, and eastern Europe), undertook regression analyses, and applied the resulting values to these countries. Therefore, for Bulgaria, Estonia, Hungary, Latvia, Lithuania, Romania, Slovakia, and Slovenia, we used pooled data from the Czech Republic and Poland for the regression analyses. For Finland, we used pooled data from Denmark

and Sweden. For Cyprus, Malta, and Portugal, we used pooled data from Greece, Italy, and Spain. Finally, for Luxembourg and the UK, we used pooled data from Austria, Belgium, France, Germany, Ireland, and the Netherlands (appendix pp 7–8).

We then estimated the total hours of informal care provided to patients with cancer by carers of working age who were employed and applied the mean hourly wage.[13] For carers in retirement or who do not work, we applied hourly minimum wages (or mean wage in worst paid economic sector).[13]

We estimated productivity costs attributable to mortality as the lost earnings after premature death. We estimated these costs using age-specific and sex-specific number of cancer deaths to predict the working years lost at the time of death, and then adjusted the estimates for the age-specific and sex-specific probability of employment.[13,17] We calculated the costs of cancer-related deaths by using mean annual earnings (stratified by sex) and the number of working years of employment lost.[13] Because these costs would be incurred in the future, we discounted all future lost earnings to present values with a 3·5% annual discount rate (ie, the value society attaches to present as opposed to future costs).

Costs of lost productivity due to cancer-related morbidity comprised both the costs associated with individuals taking sickness leave for a defined period of time (temporary absence), and the costs of individuals being declared incapacitated or disabled because of cancer (permanent absence). We assessed cancer-related temporary absence from work by obtaining country-specific overall annual days of sickness leave and then applying the proportion of sickness leave that was attributable to cancer (appendix p 8). For cancer-

	Cancer-related health-care costs							Productivity losses		Informal care costs	Total costs	
	Primary care	Outpatient care	Accident and emergency	Inpatient care	Drugs	Total	Percentage of total health-care expenditure	Mortality	Morbidity		Total	Percentage of gross domestic product
Austria	33	53	22	750	343	1202	4%	750	136	550	2638	0·95%
Belgium	34	70	9	550	346	1010	3%	1047	604	553	3214	0·94%
Bulgaria	10	12	2	56	44	124	5%	119	26	31	300	0·86%
Cyprus	<1	1	1	12	22	36	4%	53	5	15	109	0·65%
Czech Republic	29	77	14	284	194	598	5%	446	166	122	1331	0·94%
Denmark	4	55	11	299	205	574	2%	1010	380	277	2241	1·00%
Estonia	8	10	7	27	10	61	6%	61	34	17	172	1·25%
Finland	21	145	20	460	157	804	5%	464	77	166	1511	0·88%
France	114	176	19	3716	3025	7051	3%	4990	2299	2543	16 883	0·90%
Germany	710	1689	29	9760	2705	14 893	5%	11 607	2213	6414	35 126	1·48%
Greece	57	126	25	584	453	1244	5%	917	86	348	2596	1·12%
Hungary	26	19	5	121	221	393	5%	416	48	122	980	1·07%
Ireland	32	30	13	417	127	619	4%	603	63	162	1447	0·89%
Italy	487	452	115	4136	1664	6854	5%	3966	143	5491	16 454	1·08%
Latvia	5	7	2	34	11	60	5%	88	20	23	191	1·03%
Lithuania	8	8	4	30	9	59	3%	100	40	29	228	0·85%
Luxembourg	4	7	1	53	26	91	3%	57	18	26	191	0·53%
Malta	1	1	<1	6	7	16	4%	12	1	9	38	0·63%
Netherlands	172	250	13	1351	356	2143	3%	2519	706	983	6350	1·11%
Poland	129	368	15	619	267	1399	6%	1306	386	550	3641	1·17%
Portugal	43	65	28	182	247	564	3%	1118	98	268	2048	1·22%
Romania	19	62	2	133	205	421	6%	643	81	112	1257	1·06%
Slovakia	28	71	3	92	112	306	5%	180	88	53	627	1·00%
Slovenia	3	7	5	82	47	145	4%	147	72	42	406	1·14%
Spain	776	340	208	1275	1515	4114	4%	2838	482	1581	9016	0·86%
Sweden	47	244	40	408	233	971	3%	923	478	397	2769	0·95%
UK	153	1072	44	2916	1054	5241	3%	6186	682	2334	14 442	0·91%
Total for European Union	2954	5419	659	28 357	13 604	50 994	4%	42 565	9431	23 216	126 205	1·07%

Data are millions of euros, unless otherwise stated. No adjustment for price differentials. Totals do not match sum of costs because of rounding.

Table 1: **Costs of cancer in the European Union in 2009, by country**

related permanent absence from work, we obtained country-specific information about the numbers of individuals of working age receiving incapacity benefits, disability benefits, and those unable to work for all medical conditions. We then applied the proportion that was attributable to cancer (appendix p 8). We multiplied the total number of working days lost by temporary or permanent absences because of cancer by mean daily earnings.[13] However, because absent workers are likely to be replaced after some time, we used the so-called friction period approach, whereby costs are counted only during the time taken to replace a worker, and estimated that an employee would be replaced after 90 days of absence.[18] Therefore, for all new permanent cases of disability or incapacity, or when the average length of temporary sickness leave was more than 90 days, or both, we included only the first 90 days of work absence.

To investigate variations in cancer-related health-care expenditure between countries, we undertook a series of ordinary least-squares univariate regression analyses, using national income, crude cancer incidence, crude cancer mortality, case fatality (mortality divided by incidence), 5-year cancer relative survival, and cancer-specific disability-adjusted life-years as explanatory variables. We did diagnostic tests for omitted variables (RESET test and link test) and heteroskedasticity (Breusch-Pagan test). We deemed an explanatory variable to be significant if its p value was less than 0·05. All regression analyses were done in Stata (version 12.1).

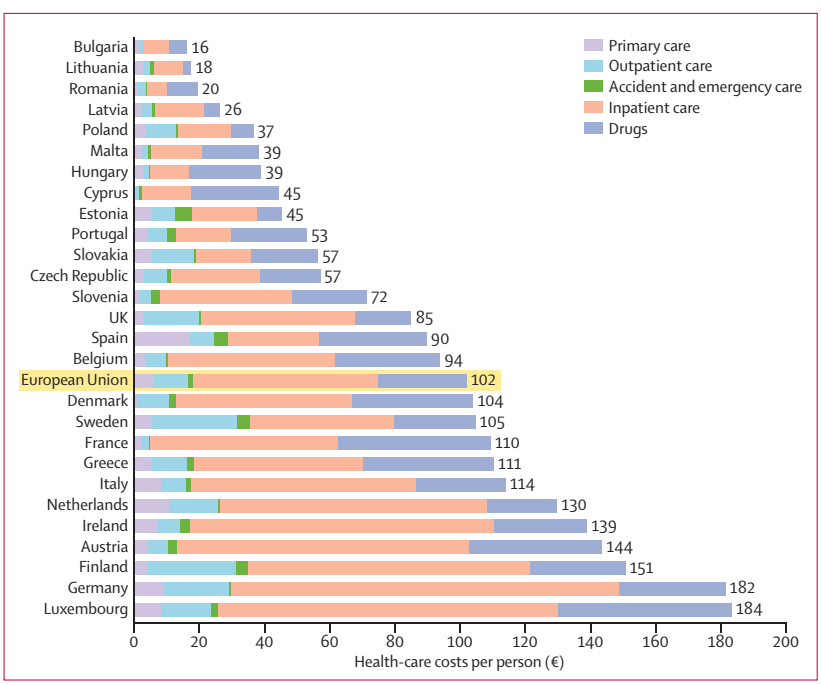

Figure 1: **Health-care costs of cancer per person in European Union countries in 2009, by health-care service category**
Data not adjusted for price differentials.

We also did a sensitivity analysis to measure what effect changes in different categories of resource use would have in terms of total costs of cancer. The aim was to identify which categories were most sensitive. Therefore, we examined the effects of a 20% increase or decrease in health-care costs and earnings for men and women. Additionally, we tested the effect of a 50% increase or decrease in countries without direct information about family doctor, outpatient, or accident and emergency visits attributable to cancer (appendix p 5). We also assessed the effect of discounting productivity costs using rates of 0% and 10%.

Role of the funding source

The sponsor of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. RL-F and JL had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Results

We estimated the total economic cost of cancer in the EU as more than €126 billion in 2009 (table 1). The four countries with the highest populations in the EU—Germany, France, Italy, and the UK—accounted for €82·9 billion (66% of all costs). The lowest overall costs were recorded for Bulgaria, Cyprus, Estonia, Latvia, Lithuania, Luxembourg, and Malta; the combined costs in these countries accounted for only €1·23 billion (1%). Results of the sensitivity analyses showed that a 20% variation in earnings—which were used to value informal care, morbidity, and mortality losses—had the biggest effect on total costs, followed by variations in the discount rate (appendix p 29). We also estimated that the total costs of cancer increased from €126 billion (with friction-adjusted costs) to €133 billion when we used the human capital approach.

The health-care cost of cancer care to EU health-care systems was €51·0 billion, and accounted for 4% of total EU health-care expenditure (table 1). Inpatient care costs were estimated at €28·4 billion—accounting for 56% of cancer-related health-care costs (table 1). This proportion varied substantially between countries, from 30% in Slovakia to 67% in Ireland. Drug expenditure accounted for more than €13·5 billion—ie, 27% of cancer-related health-care costs (table 1). Drug expenditure as a proportion of overall cancer-related health-care costs was lowest in Lithuania (15%) and highest in Cyprus (61%). Primary, outpatient, and emergency care together accounted for less than 20% of cancer-related health-care costs (table 1). Mean unit costs varied substantially by country—eg, daily earnings varied from €17 in Bulgaria to €231 in Luxembourg (appendix p 21). We also recorded substantial variation in the number of years and days lost because of premature death and morbidity, and in the number of contacts with health-care services across the countries—eg, cancer-related inpatient days varied from

48 per 1000 individuals in Malta to 218 per 1000 in Germany (appendix p 22).

Across the EU population, the health-care costs of cancer were equivalent to €102 per citizen (figure 1, table 2, appendix p 23). Health-care costs per person varied widely between countries (figure 1, table 2, appendix p 23). Although cost differences between countries narrowed after adjustment for price differentials, they were still substantial (table 2, appendix p 30). The results of the ordinary least-squares regression showed a strong positive relation between cancer-related health-care expenditure and national income ($p<0·0001$) and cancer incidence ($p=0·003$; appendix p 31). We identified no other significant relations, so, as an example, the results from our regression analyses suggested that a €1 billion increase in EU cancer-related health-care costs would be associated with a non-significant reduction of 640 cancer-related deaths.

Friends and relatives provided 3 billion hours (5·2 h per EU citizen) of unpaid care in 2009 to patients with cancer across the EU, which we valued at about €23·2 billion (table 1). Additionally, cancer accounted for 1·24 million deaths in the EU in 2009, representing 2 million lost working years. After adjusting for employment rates, and discounting to present values, we valued these lost working years at €42·6 billion (table 1). Finally, cancer-related morbidity accounted for about 83 million lost working days, which, when adjusted using the friction period (ie, accounting for time for employee replacement), we valued at €9·43 billion (table 1).

The cost of lung, breast, colorectal, and prostate cancers in the EU in 2009 was €55·3 billion (appendix pp 24–27)—ie, 44% of the total economic cost of cancer in the EU. Lung cancer had the highest economic cost (€18·8 billion, 15% of overall cancer costs), followed by breast cancer (€15·0 billion, 12%), colorectal cancer (€13·1 billion, 10%), and prostate cancer (€8·43 billion, 7%; appendix pp 24–27).

Breast cancer accounted for the highest health-care costs (€6·73 billion; 13% of all cancer-related health-care

	All cancers		Colorectal cancer		Lung cancer		Breast cancer		Prostate cancer	
	Cost per person (€)	Adjusted cost per person (€)*	Cost per person (€)	Adjusted cost per person (€)*	Cost per person (€)	Adjusted cost per person (€)*	Cost per person (€)	Adjusted cost per person (€)*	Cost per person (€)	Adjusted cost per person (€)*
Austria	144	119	16	13	13	11	19	16	14	12
Belgium	94	71	12	9	8	6	12	9	11	8
Bulgaria	16	54	1	5	1	2	2	8	1	5
Cyprus	45	47	4	4	2	2	7	7	4	4
Czech Republic	57	104	7	13	5	9	7	13	6	11
Denmark	104	69	12	8	10	6	13	8	12	8
Estonia	45	82	6	11	4	7	7	13	4	7
Finland	151	127	15	13	12	10	20	16	16	14
France	110	97	10	9	7	6	15	13	15	13
Germany	182	171	21	20	16	15	29	27	21	20
Greece	111	128	8	10	10	11	17	20	14	16
Hungary	39	80	4	8	4	8	6	12	5	11
Ireland	139	88	15	10	13	8	15	9	11	7
Italy	114	96	13	11	9	8	11	9	10	8
Latvia	26	53	3	6	2	4	4	8	2	4
Lithuania	18	33	2	4	1	3	2	4	2	4
Luxembourg	184	141	22	17	21	16	26	20	18	14
Malta	39	59	4	7	2	3	6	9	4	6
Netherlands	130	123	17	16	13	12	19	18	9	8
Poland	37	78	4	9	5	11	4	9	2	5
Portugal	53	61	5	6	3	4	7	8	6	7
Romania	20	52	2	5	1	4	3	8	2	6
Slovakia	57	103	6	11	5	9	7	14	6	10
Slovenia	72	90	7	9	6	7	8	10	8	10
Spain	90	96	9	10	5	5	11	12	10	11
Sweden	105	92	7	6	8	7	11	10	13	11
UK	85	92	10	10	7	8	9	10	7	7
Total for European Union	102	102	11	11	8	8	13	13	11	11

*Adjusted for price differentials with the purchasing power parity method.

Table 2: **Health-care costs of all cancers and of colorectal, lung, breast, and prostate cancers in the European Union in 2009, by country**

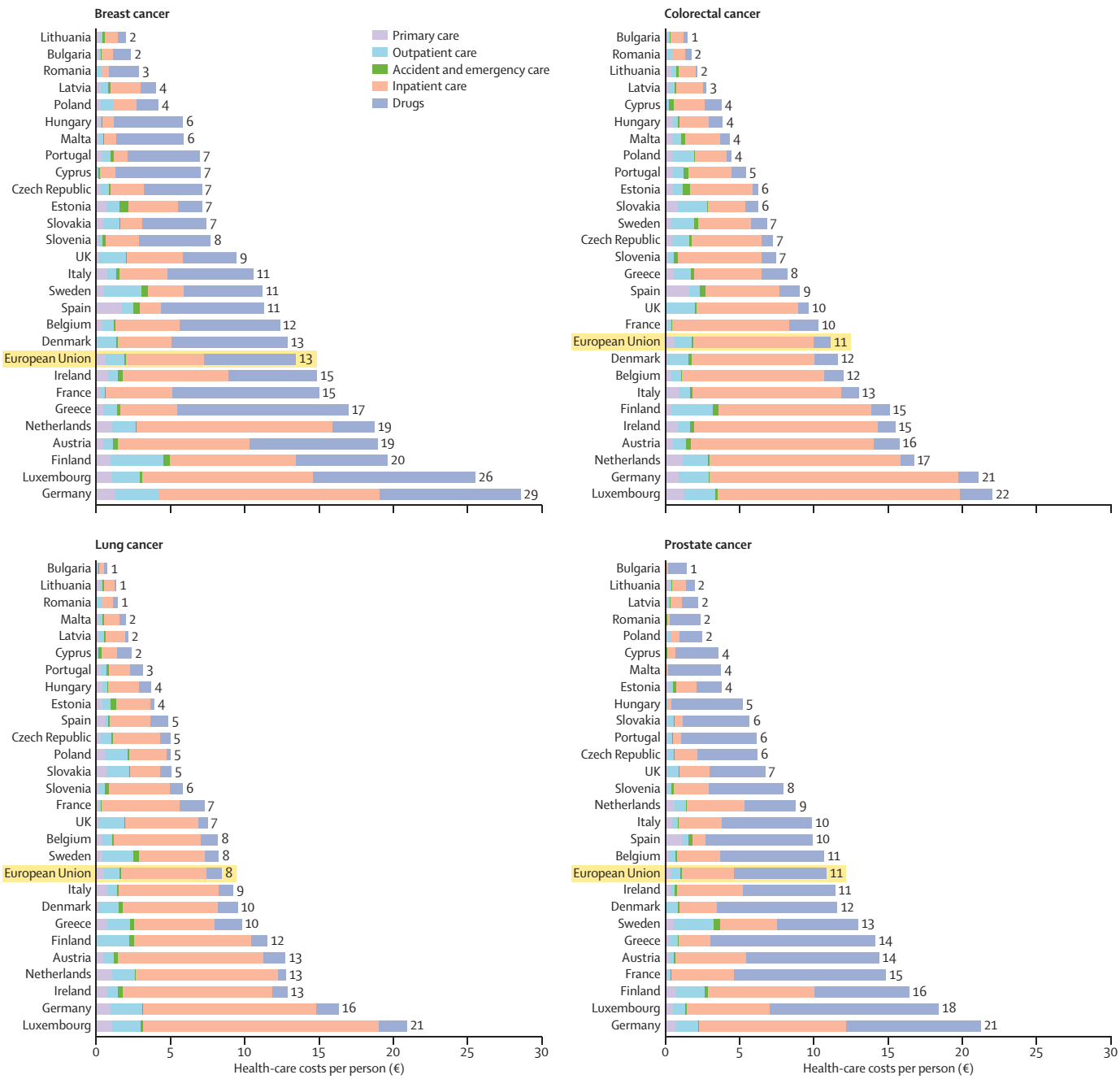

Figure 2: **Health-care costs of breast, colorectal, lung, and prostate cancers per person in European Union countries in 2009, by health-care service category**
Data not adjusted for price differentials.

costs), followed by colorectal cancer (€5·57 billion; 11%), prostate cancer (€5·43 billion; 11%), and lung cancer (€4·23 billion; 8%; appendix p 32). The proportion of health-care costs accounted for by each of these four cancers varied substantially between countries—eg, in Poland, lung cancer accounted for €191 million (14%) of €1·40 billion in health-care costs, whereas in Cyprus, it accounted for €1·90 million (5%) of €36 million (appendix p 24). Inpatient care was the major component of health-care costs in lung cancer (€2·87 billion, 68%) and colorectal cancer (€4·04 billion, 73%; appendix p 32). By contrast, drugs were the major component for breast cancer (€3·07 billion, 46%) and prostate cancer (€3·12 billion, 57%; appendix p 32).

We recorded substantial variation in health-care costs per person between countries and types of health-care services (table 2, figure 2). Health-care costs per person were between €2 and €29 for breast cancer, between €1 and €22 for colorectal cancer, and between €1 and €21 for lung and prostate cancers (figure 2). After adjustment for price differentials, these differences were slightly smaller, but were still substantial (appendix p 33). Although some countries were consistently the highest (Germany and Luxembourg) and lowest (Cyprus and Lithuania) spenders, others varied in expenditure by cancer type—eg, Poland had the fifth highest costs per head for lung cancer but was among the lowest spenders for prostate cancer (appendix p 28).

The highest productivity losses attributable to mortality were identified for lung cancer (€9·92 billion; 23% of the €42·6 billion in productivity losses because of all cancers; appendix pp 32). Colorectal cancer had the second highest productivity losses (€3·77 billion; 9%), followed by breast cancer (€3·25 billion; 8%), and prostate cancer (€0·73 billion; 2%). The costs of informal care were also highest for patients with lung cancer (€3·82 billion; 16% of the €23·2 billion total informal care provided), followed by breast cancer (€3·20 billion; 14%), colorectal cancer (€2·84 billion; 12%), and prostate cancer (€1·88 billion; 8%; appendix p 32). The highest morbidity losses were identified for breast cancer (€1·79 billion; 19% of the €9·43 billion losses due to cancer-related morbidity; appendix p 32).

Discussion

We estimated the total cost of cancer in the EU at €126 billion in 2009, of which €51·0 billion (or €102 per citizen) were incurred by EU health-care systems. However, 60% of the economic burden of cancer was incurred in non-health-care areas, with almost €43 billion in lost productivity attributable to early death. Although the economic cost by cancer type varied between EU countries, lung cancer had the greatest overall economic burden of the four cancers we studied. To our knowledge, ours is the first study to provide cost estimates for cancer in the EU and the proportion specifically attributable to lung, colorectal, breast, and prostate cancers (panel).

Hospital inpatient care accounted for more than half of cancer-related health-care costs, followed by drug expenditure, outpatient care, primary care, and emergency care. Although a cost of €659 million for cancer-specific emergency visits across Europe might seem high in absolute terms, these costs represented only slightly more than 1% of total cancer-related health-care costs. The emergency visits could be necessary because of the effects of some cancers (eg, internal bleeding, haemorrhages, or bowel perforations) or the side-effects of treatment (eg severe vomiting due to chemotherapy).

In the USA, the cost of cancer, excluding informal care and morbidity losses, was estimated at US$202 (€157) billion in 2008,[19] of which $77 (€60) billion were direct medical costs and $124 (€97) billion were mortality costs. The USA devoted $255 per person (€196 [adjusted for price differentials]) to cancer-related health-care in 2008—ie, more than any country in the EU and about €100 more per citizen than the EU as a whole after adjustment for price differentials. The reasons for, and results of, greater cancer care expenditure by the USA compared with the EU are not the subject of our analysis, but competing arguments to explain these differences have been made. Some claim that more patients survive as a result of the amount of spending in the USA compared with Europe,[20] but others suggest that the higher spending in the USA is mainly a manifestation of unnecessary testing and unproven medical procedures.[21]

Our regression analyses suggest that a €1 billion increase in cancer-related health-care spending in the EU would be associated with a reduction of 640 cancer-related deaths. However, the relation was weak and non-significant. The relation also seems to be confounded by a nation's income or wealth (as measured by gross domestic product per head), with income affecting both cancer health-care costs (positive association) and mortality (negative association). Furthermore, after adjusting for income, cancer mortality became positively correlated with cancer-related health-care costs, albeit non-significantly. It is important to note that survival and mortality are complex outcomes of various input factors, of which funding is only one: sociocultural, structural, and organisational determinants of cancer care matter equally when considering how to better deliver outcomes.

The most important univariate predictor of increased health expenditure on cancer was per-person national income (as measured by gross domestic product).

Panel: Research in context

Systematic review

We reviewed all reports about the economic burden of cancer in Europe. We searched Medline, Embase, and the UK National Health Service Economic Evaluation Database for studies published in English between Jan 1, 2000, and Dec 31, 2012. We used the search terms "cost*", "economic burden", "cost of illness", or "burden of illness", and "cancer" or "neoplasm". We identified no study in which the cost of cancer and lung, colorectal, breast, and prostate cancers was systematically evaluated for the whole of the European Union (EU). Previous studies have relied on ad-hoc estimates and extrapolations without use of comparative and accurate sources of financial information.

Interpretation

We have shown that cancer cost the 27 countries in the EU in 2009 about €126 billion annually, representing an annual cancer care spend of €102 per person. 60% of the economic burden of cancer was in non-health-care areas, with almost €43 billion in lost productivity due to early death. Of the four cancers we studied, lung cancer had the highest economic burden. Our study draws attention to the need for cost-effective public health and screening measures to prevent cancer and improve early detection. Our results show wide differences between countries, the reasons for which are unclear and require further investigation. These data contribute to public health and policy intelligence, which is required to deliver affordable cancer care systems and inform effective public research funds allocation.

However, even for countries with the same levels of national income, health expenditure on cancer varied widely—eg, the gross domestic product per head of Germany and the UK were similar in 2009, but Germany's expenditure on cancer-specific health care was twice that for the UK on a per-person basis (€171 *vs* €92, adjusted for price differentials).

Although cost differences between European countries can be partly explained by differences in gross domestic product and health system configuration (eg, the number of inpatient days attributable to cancer was much higher in Germany than in the UK), understanding of variations in health expenditures needs to improve. Presentation of data showing differences in costs across countries should provide a solid foundation for further research and discussion, but we cannot explain all the patterns identified. The substantial variations in drug costs across countries that we recorded could be explained by differences in the prices paid for the same drugs, increased drug consumption, or differences in the types of drugs consumed. In turn, such differences could be related to price setting and reimbursement mechanisms, variations in clinical practice, or other factors. Future research should clarify these possible explanations. Generally, careful assessment of expenditure decisions within a clear cost-effectiveness framework, similar to that done by the UK's National Institute for Health and Care Excellence, might improve value for money and strengthen moves towards evidence-based cancer care across the EU.[22] Such assessment is particularly pressing in southeast Europe, which is experiencing an increasing incidence of and mortality from tobacco-related cancers, and of screen-detectable cancers, compared with northwest Europe.[23]

As the same framework was used to estimate the economic burden of cardiovascular disease and dementia across the EU, we can reliably compare these data to cancer costs.[11,12] By these evaluations, cancer imposes a lower economic burden on the EU than cardiovascular disease does (€126 billion *vs* €195 billion). However, cancer caused higher productivity losses as a result of premature mortality (€43 billion *vs* €27 billion), reflecting the higher number of deaths in people of working age.[11] Costs of dementia were estimated for 2007 and only for the 15 countries who were members of the EU before 2004. For these 15 countries, the economic burden of dementia was €189 billion compared with €117 billion for cancer in 2009. Although health-care costs for cancer are substantially higher than are those for dementia (€47 billion *vs* €10 billion), the costs for the informal care of individuals with dementia far outweigh those for cancer (€129 billion *vs* €22 billion).[12]

Such comparisons of the economic burden of different diseases are important and useful to decision makers and health-policy planners, because they can inform decisions about the allocation of resources to service provision, prevention strategies, and research funding.[8] Our analysis also provides evidence that could be used to assess whether cancer prevention measures such as public awareness campaigns and screening programmes to improve early detection are cost effective.

It is important to note that our study had several limitations. First, the precision of our results depended on the quality and availability of comparable cancer-related data across the EU. We consulted and used more than 150 sources for this study, all of which varied in terms of quality and reliability. Despite calls to improve and standardise cancer data across the EU,[3] we encountered deficiencies in epidemiological data for cancer, and in information about related resource use and unit costs. Similar deficiencies were encountered during previous work on the burden of cardiovascular disease and dementia.[12,24] National data for the number of primary-care, outpatient-care, and emergency visits attributable to cancer were largely absent. Therefore, we had to make assumptions and extrapolations to estimate these numbers. As a result, differences in data adequacy and quality across countries might explain some of the substantial cost differences reported between countries.

Second, because overall health-care costs were obtained from the System of Health Accounts (ie, as part of the data that countries submit both to EUROSTAT and the Organisation for Economic Co-operation and Development), overall costs are likely to be more complete than are cancer-specific costs. However, as data for cancer-specific inpatient care were available from EUROSTAT, and inpatient costs accounted for most of the total cancer health-care costs, we believe that our total cost estimates are valid.

Third, only antineoplastic drugs and endocrine therapy for the treatment of cancer were included in the analysis. We did not include other drugs typically prescribed to patients with cancer—eg, immunosuppressants, opioids, and antiemetic drugs—because information about the proportion of these drugs prescribed to patients with cancer was insufficient. Furthermore, data for drug expenditure by type of cancer were scarce. This area is another in which detailed prospective studies and close analysis of national databases will provide valuable additional data.

Fourth, we obtained estimates of the informal care needs of patients with cancer from SHARE, a cross-national panel database of microdata for health, socioeconomic status, and social and family networks. For this study, we used information from the 32 000 individuals in waves 2 and 3 of the survey, which included only residents of 13 EU countries, albeit in diverse geographic distribution. As a result, as outlined previously, for the 14 remaining countries not in SHARE, we had to combine data from similar countries that were included in order to obtain informal care estimates.

Fifth, our results are for 2009, which was the start of the global financial crisis affecting most countries in the EU. We believe that wider economic trends will affect our

estimates of productivity costs, because we accounted for age-specific and sex-specific economic activity and unemployment in our analysis. In 2009, 18% of the active Spanish population (ie, those in work and looking for work) were unemployed, compared with 25% in 2012, and just 8% in 2007,[13] which would result in decreased or increased productivity losses respectively.

Sixth, the costs for sick leave and early retirement due to incapacity did not include expenditure for sick leave benefits. One of the reasons was to avoid valuation of the same spell of leave twice. Another was that sick leave benefits are deemed to be so-called transfer payments—ie, they are neither a cost nor a gain to society, because they represent a redistribution of income from the paying government to the individual with cancer without any resource use (no exchange of services). Both UK and US guidelines caution against including these transfer payments in any economic analysis.[24,25] Furthermore, our sick leave and early retirement costs were estimated only during the time taken to replace a worker with another from the pool of unemployed individuals—ie, the friction period. An alternative approach would have been to value worker absence in terms of lost earnings without any adjustment—ie, the human capital approach. Because there is little consensus as to which approach is best,[24,26] we adjusted for the friction period to be consistent with previous work and allow meaningful comparisons with disorders such as cardiovascular disease and dementia.[11,12,27] Nonetheless, in sensitivity analyses, we estimated that the total costs of cancer increased from €126 billion (using friction-adjusted costs) to €133 billion when we used the human capital approach.

Seventh, we adopted a prevalence-based approach to estimating cancer costs: we measured the costs of cancer in 2009 in each EU country, irrespective of when each cancer was diagnosed. By contrast, an incidence-based approach consists of following a cohort of patients with cancer from diagnosis for the duration of cancer to estimate the lifetime costs of the disease. Both approaches will produce similar results in the cases of cancers which shorten life expectancy to about a year—eg, testicular or pancreatic cancers. However, for cancers with costs that can accrue over several years—eg, breast and prostate cancers—the approaches will produce similar results only under strict conditions of constant incidence, survival, and treatment rates over time.[28] Therefore, when annual health-care costs are compared across several cancers, the relative differences in incidence, survival, and treatment should also be considered. Colorectal cancer, the cancer with the highest incidence across the EU, had lower health-care costs than breast cancer (€5·6 *vs* €6·7 billion) and marginally higher costs than prostate cancer (€5·4 billion). These economic differences most likely reflect the differences in survival, management patterns, and costs (eg, surgical *vs* radiation treatment) across these cancers.

Finally, our estimates are likely to be underestimates. Some categories of health-care costs, such as health education, public health activities, supportive treatments (eg, antiemetic drugs, antibiotics, and growth factors), home adaptations, and care provided outside the health-care system (eg, palliative care provided in hospices based outside hospitals), are not recorded in health-care statistics. These categories of cost were not included because of data limitations, and the inability to obtain these data for all countries under study. Additional research is also necessary to assess the costs incurred by working people with cancer returning to their post but whose productivity is diminished because of illness.

Despite these acknowledged and important data limitations, our study is the first to quantify the economic burden of cancer in the EU. We believe that our study will be of particular interest to European policy makers. Evidence-based policy making for delivery of affordable cancer care for all European citizens rests on the breadth, depth, and quality of cancer intelligence that the EU as a whole can deliver, and our study adds reliable cost-of-illness data to this intelligence system.

Contributors

RL-F, JL, and AG designed the study. RL-F and JL did the literature search. RL-F, JL, and RS collected data. RL-F, JL, and AG analysed data. All authors interpreted data and wrote the report.

Conflicts of interest

We declare that we have no conflicts of interest.

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