Economic downturns, universal health coverage, and cancer mortality in high-income and middle-income countries, 1990–2010: a longitudinal analysis

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Summary

Background **The global economic crisis has been associated with increased unemployment and reduced public-sector expenditure on health care (PEH). We estimated the effects of changes in unemployment and PEH on cancer mortality, and identified how universal health coverage (UHC) affected these relationships.**

Methods **For this longitudinal analysis, we obtained data from the World Bank and WHO (1990–2010). We aggregated mortality data for breast cancer in women, prostate cancer in men, and colorectal cancers in men and women, which are associated with survival rates that exceed 50%, into a treatable cancer class. We likewise aggregated data for lung and pancreatic cancers, which have 5 year survival rates of less than 10%, into an untreatable cancer class. We used multivariable regression analysis, controlling for country-specific demographics and infrastructure, with time-lag analyses and robustness checks to investigate the relationship between unemployment, PEH, and cancer mortality, with and without UHC. We used trend analysis to project mortality rates, on the basis of trends before the sharp unemployment rise that occurred in many countries from 2008 to 2010, and compared them with observed rates.**

Results **Data were available for 75 countries, representing 2·106 billion people, for the unemployment analysis and for 79 countries, representing 2·156 billion people, for the PEH analysis. Unemployment rises were significantly associated with an increase in all-cancer mortality and all specific cancers except lung cancer in women. By contrast, untreatable cancer mortality was not significantly linked with changes in unemployment. Lag analyses showed significant associations remained 5 years after unemployment increases for the treatable cancer class. Rerunning analyses, while accounting for UHC status, removed the significant associations. All-cancer, treatable cancer, and specific cancer mortalities significantly decreased as PEH increased. Time-series analysis provided an estimate of more than 40 000 excess deaths due to a subset of treatable cancers from 2008 to 2010, on the basis of 2000–07 trends. Most of these deaths were in non-UHC countries.**

Interpretation **Unemployment increases are associated with rises in cancer mortality; UHC seems to protect against this effect. PEH increases are associated with reduced cancer mortality. Access to health care could underlie these associations. We estimate that the 2008–10 economic crisis was associated with about 260 000 excess cancer-related deaths in the Organisation for Economic Co-operation and Development alone.**

Funding **None.**

Introduction

The economic crisis beginning in 2008 saw substantial rises in unemployment, and caused many countries to cut public-sector expenditure on health care (PEH).[1,2,3] Several studies[4–14] have shown the impact of such macroeconomic changes on outcome indicators such as suicide rates, cardiovascular disease incidence, and all-cause mortality, with economic downturns leading to increases in respective mortality rates, likely due to increased behavioural, mental, and physiological stress—so-called healthconomic crises.[15]

Cancer is a leading cause of death worldwide, accounting for 8·2 million deaths in 2012, with estimates suggesting a rise in annual cancer cases from 14 million in 2012, to 22 million by 2030.[16] As such, an understanding of the effects of macroeconomic changes on cancer outcomes worldwide is important. However, few studies have analysed the relation between economic downturns and cancer outcomes, especially in countries with underdeveloped social security and health-care systems, which can be particularly susceptible to economic shocks.

Establishment of a causal relation between an economic change, such as aggregate unemployment, and cancer mortality has been challenging because downstream effects of unemployment-induced behavioural changes on lifestyle-related cancers manifest much later (after 20–30 years) than, for example, suicide or acute stress-related cardiovascular events. However, access to health care and PEH might act as mediating factors with more immediate effects on health outcomes.

We examined the association between changes in aggregate unemployment and PEH with deaths due to specific cancers, groups of cancers, and all cancers for countries with available data for 1990–2010 deemed to be of sufficient quality. Mortality was regarded as a more reliable measure of health outcomes than incidence

Research in context

Evidence before this study

We searched the scientific literature to identify articles that quantitatively estimated either the effect of both unemployment and health-care spending (public or otherwise) on cancer mortality, or the effect of universal health coverage on cancer mortality. We searched PubMed for manuscripts published in any language before and including May 31, 2015, using the following combinations of search terms: (A) unemployment AND cancer AND mortalit* AND (spending OR expenditure); and (B) cancer AND mortalit* AND ("universal health coverage" OR "universal healthcare coverage").

Search combination (A) yielded seven publications, and combination (B) yielded one publication. With respect to search combination (A), one study used a time-trend analysis to investigate the association between unemployment and mortality in Scotland, and included specific causes of death such as lung cancer. A second study used Pearson's correlation to find an association between all-cancer mortality, and health-care expenditure (negative) and unemployment (positive) in European countries; the authors of the study were unable to control for potential confounding variables. The study periods for both these publications ended before the 2008 economic recession. Three further studies investigated a substantially narrower geographical region and outcome than the present study. The first study examined the relation between spending, unemployment, and breast cancer mortality in the European Union only, the second examined the relation between unemployment and stomach cancer mortality again in the European Union only, and the third examined prostate cancer mortality in countries belonging to the Organisation for Economic Co-operation and Development. The study extracted from search combination (B) did not seek to quantify the effect of coverage on mortality.

Added value of this study

To our knowledge, our study is the first global analysis of the effect of unemployment and public health-care spending on mortality due to all cancers and to those cancers regarded as treatable, untreatable, or specific. By using a conservative, fixed-effects regression analysis model to ascertain the existence of an association and quantify any associations combined with robustness checks, this study accounts for criticisms made of other studies investigating the relation between health outcomes and unemployment—namely, the omission of potential confounding variables likely to be associated with both unemployment rates (or public health-care spending) and cancer mortality rates. We controlled for time-invariant heterogeneity between countries by using a panel-data approach for the multivariable regression analysis to compare unemployment rates (or public health-care spending) at intervals of 1 year for each year after the increase in unemployment (or public health-care spending) with the mortality rates in each country. Finally, we combined these analyses with a time-trend analysis, to provide a rigorous characterisation of the associations between unemployment, public health-care spending, universal health coverage, income, and cancer mortality. The major findings from these complementary approaches are that unemployment increases are associated with increases in cancer mortality, with universal health coverage protecting against this effect. Consideration of specific types of cancer as either treatable or untreatable revealed that significantly higher than expected numbers of deaths were only seen for treatable cancers, reinforcing the role that access to care has in explaining these relationships. By contrast with unemployment, public health-care spending increases are associated with reductions in cancer mortality, with a recapitulation of the divergent findings between treatable and untreatable cancers. Implementation of universal health coverage did not significantly affect the strength of this association.

Implications of all the available evidence

Policies that maintain spending, and therefore access to and quality of health care, in the face of economic downturns, especially among cancers that are regarded as treatable, could offset some of the negative effects of such periods on health outcomes. Furthermore, the findings of our study add to the existing body of evidence in favour of universal health coverage.

because of the susceptibility of incidence values to artificial rises after the adoption of improved means of diagnosis. We chose unemployment because of its ability to capture changes in individuals' circumstances, especially in the low-income strata of societies. In view of the drive in many countries in the past to implement universal health coverage (UHC),[17] we investigated whether UHC conferred a protective effect. We also used the recent economic crisis as a natural experiment, estimating the difference between the actual numbers of cancer-related deaths during the crisis, and the expected numbers based on previous trends. Using this combination of analyses, we attempted to lend clarity to the complex interplay between socioeconomics, health system investment and reform, and cancer outcomes, to better appreciate the impact of different policy approaches on cancer mortality at the population level.

Methods

Data sources

For this longitudinal analysis, we obtained economic data from the World Bank's Development Indicators & Global Development Finance 2013 edition datasets.[18] We defined unemployment (World Bank data code: SL.UEM.TOTL.ZS) as the share of the labour force without work but available and seeking employment.[18]

	Particular controls*	Controls in the unemployment dataset (75 countries)	Controls in the PEH dataset (79 countries)
Economic	Inflation; GDP per person changes; base interest rates	80	84
Resource availability	Number of physicians per 100 000 population; number of hospital beds per 100 000 population	79	83
Infrastructure	Urbanisation; access to water; calorie intake	80	84
Out-of-pocket spending	Out-of-pocket expenditure	78	82
WHO data quality check	NA†	77	81
Income	2 categories coded into 1 dummy variable	78	82
Human development index	3 categories coded into 2 dummy variables	79	83

Data were obtained from the World Bank.[18] PEH=public-sector expenditure on health care. GDP=gross domestic product. NA=not applicable. *Controls that are common across all datasets were population size, proportion of population younger than 15 years, and proportion of population older than 65 years. †Rerun analysis with data classified as level 1 or level 2 in quality by the WHO.

***Table 1:* Controls used in multiple regression and sensitivity analyses**

	Population (2009)
High income	1 066 391 720
Middle income	188 342 304
UHC	641 437 562
Non-UHC	613 296 462
Very high human development index	849 195 806
High human development index	405 538 218

Population estimates were obtained from the World Bank (data code: SP.POP.TOTL).[18] For country groupings, populations are calculated only for those countries included in the time-series analysis as per figure 1. UHC=universal health coverage.

***Table 2:* Population estimates of countries included in multiple regression and time-series analyses, 2009**

We measured PEH (World Bank data code: SH.XPD.PUBL.ZS) as a percentage of gross domestic product at purchasing power parity; it was defined by the World Bank as including all rent and capital spending from government budgets (central and local), external borrowings and grants (including donations from international agencies and non-governmental organisations), and social (or compulsory) health insurance funds. We classified countries into high-income and middle-income countries according to the World Bank's Atlas Method on the basis of 2015 data.[19] In brief, middle-income countries are those with a gross national income per person of more than US$1045 but less than $12 736, whereas high-income countries are those with a gross national income per person of $12 736 or more. Countries were classified into those with very high or high human development indices according to the UN's Human Development Programme.[20]

We obtained 1990–2010 cancer mortality data (deaths per 100 000 people) for the countries in the unemployment and PEH datasets from the WHO mortality database.[21] These data are based on death certification and updated annually from civil registration systems of WHO member states. We extracted mortality data for prostate cancer (International Classification of Diseases [ICD]-10 C61), breast cancer in women (ICD-10 C50), lung cancer (men and women; ICD-10 C33–C34), colorectal cancer (men and women; ICD-10 C18–C21), and all cancers. Breast cancer in women and prostate and colorectal cancers are associated with survival rates that exceed 50%.[22] We therefore aggregated the mortality data for these tumour types into a treatable cancer class. Lung and pancreatic cancers (men and women; ICD-10 C25), which are associated with 5 year survival rates of less than 10%, were likewise aggregated into an untreatable cancer class.[22] We extracted age-standardised death rates (ASDRs), accounting for age distribution differences in populations, for all ages and ages 0–84 years for both sexes and each sex separately. For age-specific cancer mortality rates, we aggregated crude rates (per 100 000 people) for each sex and country by 10 year age groups, except for the youngest age group (0–34 years), which we combined to reduce the effect of age groups with few observations. We defined these crude rates as the number of deaths during a calendar year for a particular age group divided by the age group's mid-year population. Notably, at the time data were collected, complete cancer mortality data were unavailable for China, India, and countries from sub-Saharan Africa.

Multivariable regression analysis

We used a multivariable regression analysis to assess the relation between mortality rates for each cancer subtype, treatable cancers, untreatable cancers, and all cancers (response variable), and unemployment or PEH (predictor variable). We excluded observations for the year 2010 from the analysis because of incomplete cancer mortality data for many of the 75 countries in the unemployment dataset. To ensure that results were not driven by uncontrollable intercountry variations, we used fixed effects in the regression models, including a dummy variable for each country in each dataset excluding a reference group (ie, 74 dummy variables for the unemployment dataset and 78 for the PEH dataset; table 1). This approach meant that the regression models evaluated mortality changes within individual countries while holding constant time-invariant differences between countries, including enhanced predispositions to cancer and political, health-care, cultural, and structural differences. We used a multivariable regression with fixed effects because this method has been widely used in similar studies and is regarded as statistically robust and conservative.[23] We also controlled for the population structure of each country by incorporating total population size and demographic structure (the percentage of the population older than 65 years and younger than 15 years) into the model (table 1). Further details of the model are provided in the appendix (p 1).

We did 1, 2, 3, 4, and 5 year time-lag analyses. For both datasets, we then classified countries into those with UHC and those without, and reran the analyses using UHC status as a robustness check. We deemed countries to have UHC if all of the following criteria were met: legislation mandating UHC; more than 90% of the population have access to some form of health-care insurance; and more than 90% of the population have access to skilled birth attendance. The skilled birth attendance criterion was used to ensure the implementation of UHC met minimum performance standards expected of a functioning health-care system. To test the sensitivity of our results to this definition, we reran the analysis using an alternative performance criterion (appendix p 2). Robustness checks are detailed in table 1 and the appendix (p 1). Multivariable regression analyses were done with Stata SE version 12.

Trend analysis

For the all-cancer mortality trend projection analysis, we set strict country inclusion criteria to ensure that only high quality data were included. We therefore excluded countries with less than 90% civil registration coverage of cause of death for the study period.[21] To limit the effect of miscoding and comorbidity (frequent for older population groups), we excluded the 85 years and older age group, and to further ensure robustness in cross-country comparisons, we excluded age groups with fewer than 20 deaths in any calendar year. For convenience, we have used the term "excess deaths" to denote those estimated differences for which the number of deaths was higher than expected. Details of the models used are provided in appendix (p 3). Time-series analyses were done in R version 2.14.1.

Role of the funding source

There was no funding source for this study. The corresponding author had full access to all the data in the study and had final responsibility for submitting the manuscript for publication.

Results

Unemployment and cancer mortality data for 1990 to 2010 were available for 75 countries (with a population of 2·106 billion in 2009) and data on PEH and cancer mortality for 1990 to 2009 were available for four additional countries (total population of 2·156 billion in

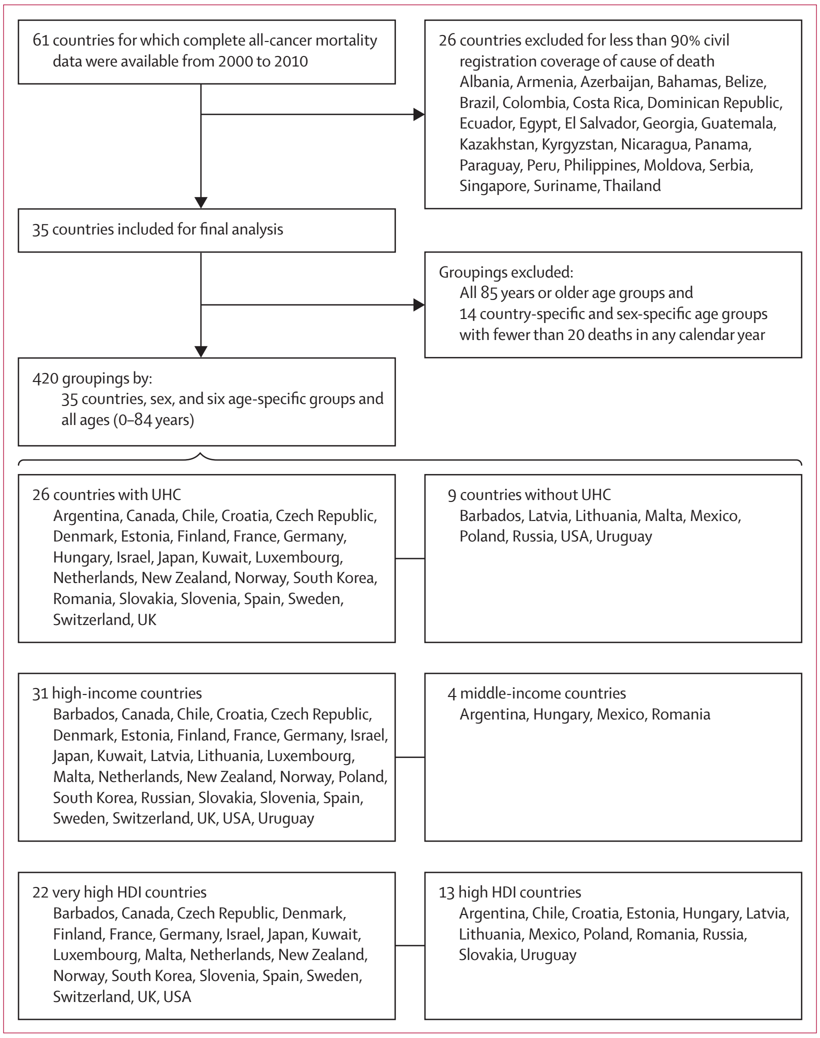

***Figure 1:* Cohort selection for the trend prediction analysis**
Cohort selection with final aggregation by universal health coverage (UHC) country status. The first step is the selection of countries with complete consecutive mortality data from 2000 to 2010. The second filters out countries with less than 90% civil registration coverage of cause of death. Next, the older than 85 years age group and age groups with fewer than 20 deaths in any calendar year were excluded. The first row of boxes at the end of the workflow shows the categorisation of countries by UHC status (as determined by skilled birth attendance). The second row of boxes at the end of the workflow shows the categorisation of countries by income status. The third row shows the categorisation of countries by human development indices (HDI). We obtained cancer mortality data (deaths per 100 000 people) from the WHO Mortality Database 2013.[21] We obtained human development index categories from the UN Development Programme website.[20]

2009; table 2).[18] We excluded 26 countries from the 61 for which all-cancer mortality data were complete for 2000 to 2010 because they had less than 90% civil registration coverage of cause of death during the study period (figure 1).

For **R Project for Statistical Computing** see http://www.r-project.org

See Online for appendix

A 1% unemployment rise was associated with an increase in mortality for all but one of the six cancer subtypes studied: prostate cancer (regression coefficient [R] 0·0981 [95% CI 0·0353–0·1609]; p=0·0022), breast cancer in women (R 0·1583 [0·1110–0·2056]; p<0·0001), lung cancer in men (R 0·2260 [0·1216–0·3304]; p<0·0001), colorectal cancer in men (R 0·0596

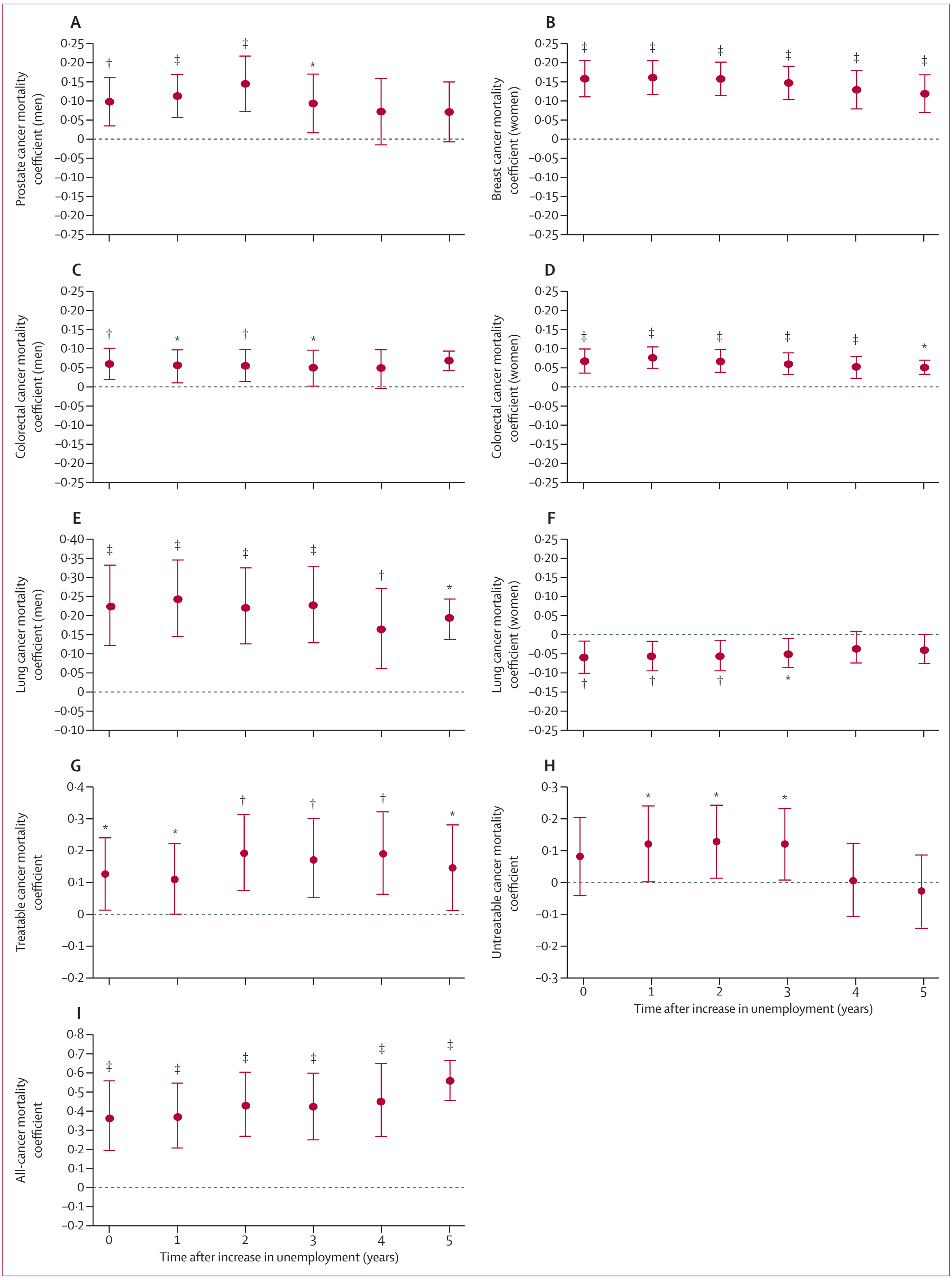

Figure 2: **Time-lag analyses of changes in unemployment on cancer mortality**
We did a multivariable regression analysis using data from 75 countries from 1990 to 2009 to assess the relation between unemployment, and (A) prostate cancer mortality, (B) breast cancer mortality, (C) colorectal cancer in men mortality, (D) colorectal cancer in women mortality, (E) lung cancer in men mortality, (F) lung cancer in women mortality, (G) treatable cancer mortality, (H) untreatable cancer mortality, and (I) all-cancer mortality. We did the analyses with controls for population size, population structure (proportion of population younger than 14 years and older than 65 years), and country-specific differences in health-care infrastructure. Data are also shown for 1, 2, 3, 4, and 5 year time-lag analyses. We obtained economic data from the World Bank.[23] We obtained cancer mortality data (deaths per 100 000 people) from the WHO Mortality Database 2013.[21] *p<0·05. †p<0·01. ‡p<0·001.

[0·0188–0·1003]; p=0·0042), and colorectal cancer in women (R 0·0676 [0·0362–0·099]; p<0·0001; figure 2, appendix p 9). The association for mortality in women with lung cancer and unemployment was negative (R –0·0593 [–0·1013 to –0·0172]; p=0·0058; figure 2, appendix p 9). Although treatable cancer mortality was significantly linked with unemployment (R 0·1256 [0·0148 to 0·2364]; p=0·0265), no such significance was found for untreatable cancers (R 0·0820 [–0·041 to 0·205]; p=0·1919; figure 2, appendix p 9). The strongest associations were found in the all-cancer data (R 0·3745 [0·1939 to 0·5551]; p=0·0001; figure 2, appendix p 9). Lag analysis showed that these results remained through to 5 years after unemployment increases for breast cancer in women, colorectal cancer in women, lung cancer in men, and overall cancer mortality (figure 2). These associations held and remained significant in the robustness checks performed (appendix pp 11–21).

After controlling for the UHC status of countries, we found no significant association between unemployment and cancer mortality within the first year of an increase in unemployment (table 3). The results were unaffected by country classifications according to an alternative definition for UHC (appendix p 2).

For the trend analysis, population-weighted mean values of the projected age-specific rates and ASDRs for each year and sex were obtained. Globally (for the 35 countries selected), we found significant deviations in the projected ASDR from the observed ASDR for all-cancer mortality in both men and women, with the 2010 predicted ASDR—3 years after the increase in unemployment in 2007—deviating the most from the observed ASDR (men: rate ratio [RR] 1·0362 [95% CI 1·0209–1·0520]; p<0·0001; women: RR 1·0428 [1·0254–1·0607]; p<0·0001; figure 3, table 4). This RR corresponded to 55 434 (95% CI 32 439–78 428) excess deaths among men and 53 573 (32 386–74 759) excess deaths among women in 2010 alone. A summation of the point estimates for men and women from 2008 to 2010 yielded 252 199 excess deaths (figure 3). Extrapolation of these results by applying the rate ratios (table 4) to the 75 country dataset yielded a point estimate of 312 847 additional deaths. Restriction of this extrapolation to countries belonging to the Organisation for Economic Co-operation and Development (OECD), some of which were not included in the time-series analysis, returned a point estimate of 263 221 additional deaths. Likewise, restriction to member countries of the European Union (excluding Croatia, which acceded in 2013) produced a point estimate of 169 129 additional deaths. This finding was recapitulated after confinement of our analysis to treatable cancers (RR 1·0362 [1·0225–1·0502]; p<0·0001), resulting in 22 977 (14 482–31 472) excess deaths in 2010 (figure 3, table 4). By contrast, for untreatable cancers, the deviation between predicted and observed ASDR was not significant in 2008, 2009, or 2010 (figure 3, table 4).

	Coefficient* (robust standard error)	95% CI	p value
Prostate cancer (men)	0·0975 (0·1025)	–0·1042 to 0·2992	0·3422
Breast cancer (women)	0·0802 (0·0763)	–0·0699 to 0·2302	0·2939
Colorectal cancer (men)	–0·0679 (0·0589)	–0·1838 to 0·0479	0·2495
Colorectal cancer (women)	–0·0306 (0·0384)	–0·1062 to 0·0450	0·4263
Lung cancer (men)	–0·0126 (0·1753)	–0·3575 to 0·3324	0·9428
Lung cancer (women)	–0·0143 (0·0454)	–0·1035 to 0·0750	0·7534
Treatable cancers	0·0319 (0·0692)	–0·1037 to 0·1675	0·6449
Untreatable cancers	0·0758 (0·061)	–0·0437 to 0·1952	0·2142
All cancers	0·0525 (0·1778)	–0·2970 to 0·4019	0·7679

Countries were classified as UHC countries according to whether they were assessed to have met all of the following previously described conditions: legislation mandating UHC, more than 90% health-care coverage, and more than 90% skilled birth attendance. *Deaths per 100 000 people.

***Table 3:* Cancer mortality rates in year of unemployment controlling for universal health coverage (UHC)**

We then assessed whether these trends held among different groups of countries. We extracted ASDRs for: 26 countries with UHC implemented and nine countries without UHC as of 2008; 31 high-income countries and four middle-income countries as classified by the World Bank using the Atlas Method;[19] and 22 very high human development index and 13 high human development index countries.[20]

For the UHC country group, we found no significant difference for treatable cancer ASDR (figure 3, table 4). By contrast, for the non-UHC country group the predicted ASDRs for treatable cancers were significantly lower than the observed ASDRs for all 3 projected years (in 2010: RR 1·0746 [95% CI 1·0417–1·1096]; p<0·0001), which equated to 21 241 (95% CI 12 244–30 238) excess deaths due to treatable cancers in 2010 (figure 3, table 4). Differences between the actual and projected ASDR of untreatable cancer were non-significant for both UHC and non-UHC country groups in 2008, with a significantly lower than expected number of deaths in 2009 and 2010 for the UHC country group, and a non-significantly higher than expected number of deaths in 2009 and a significantly higher than expected number of deaths in 2010 for the non-UHC country group (table 4).

Stratification of countries by income using the World Bank's classification[19] yielded higher RRs (indicating higher than expected numbers of deaths) for male, female, and treatable cancer groups in middle-income countries than in high-income countries (table 4). For untreatable cancers, high-income countries had significantly lower than expected numbers of deaths whereas middle-income countries had significantly higher than expected numbers of deaths (table 4). After dividing countries according to human development index, the very high and high human development index groupings did not have higher than expected numbers of untreatable cancer deaths, although significantly lower than expected numbers of deaths across all years were only observed for the very high human development index group (table 4).

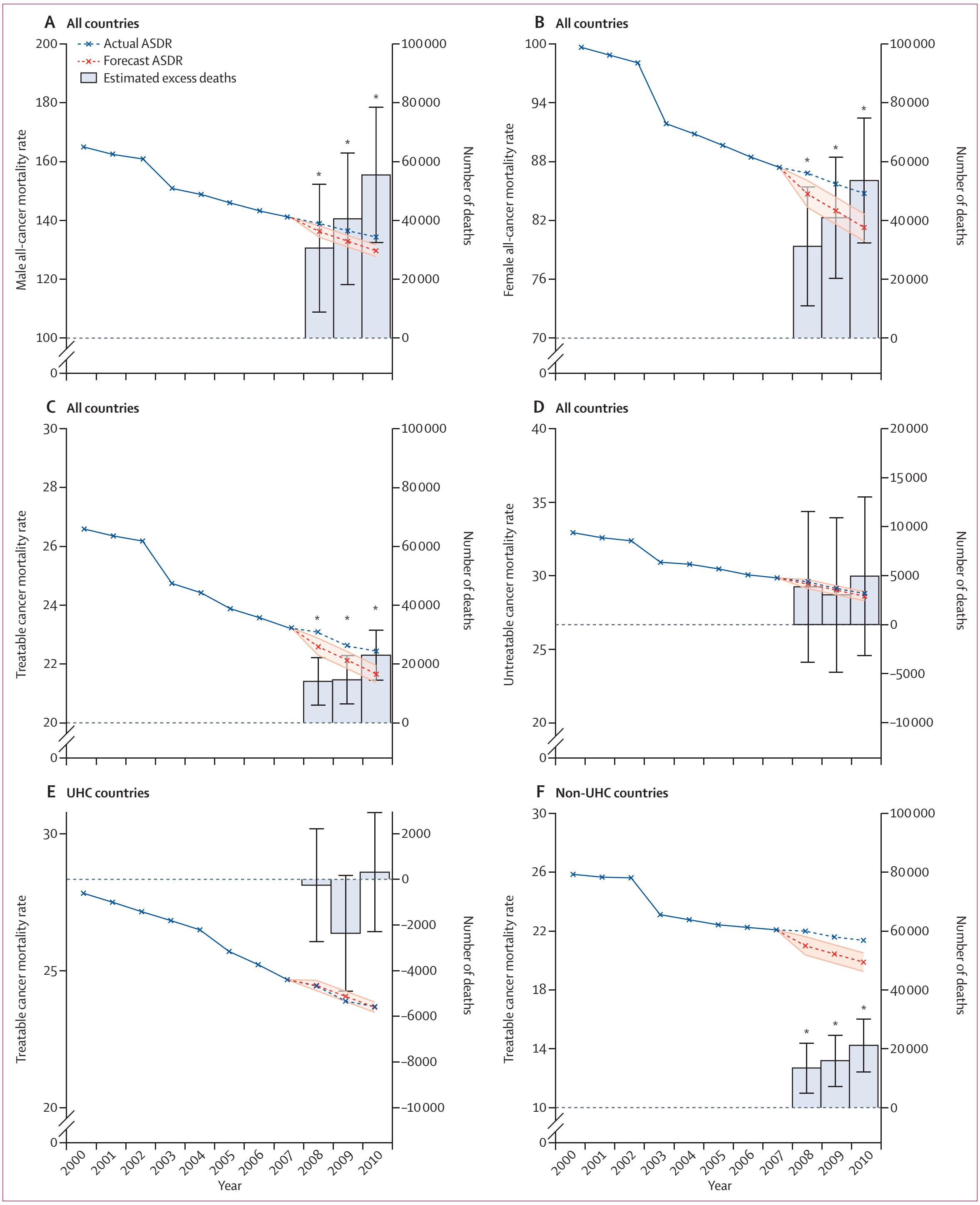

Figure 3: **Predicted cancer-related mortality rate and number of deaths, 2008–10**

Projections of age-standardised cancer-related mortality rates per 100 000 (ASDR) for 35 countries from 2008 to 2010 were made based on ASDRs observed from 2000 to 2007, and compared with those observed from 2008 to 2010. The number of excess deaths due to (A) cancers in men, (B) cancers in women, (C) treatable cancers (breast cancer in women, prostate cancer, and colorectal cancer), and (D) untreatable cancers (lung and pancreatic) were estimated by comparing 2008–10 projected rates with 2008–10 observed rates. The projections of ASDRs for treatable cancers are also shown for (E) universal health coverage (UHC) and (F) non-UHC countries. ASDRs were extracted from the WHO Mortality Database 2013.[21] *p<0·001.

	2008		2009		2010	
	Rate ratio (95% CI)	p value	Rate ratio (95% CI)	p value	Rate ratio (95% CI)	p value
Global						
Men	1·0201 (1·0057–1·0349)	0·0064	1·0266 (1·0118–1·0418)	0·0005	1·0362 (1·0209–1·0520)	<0·0001
Women	1·0251 (1·0087–1·042)	0·0028	1·0329 (1·016–1·0503)	0·0001	1·0428 (1·0254–1·0607)	<0·0001
Treatable	1·0224 (1·0095–1·0357)	0·0007	1·0232 (1·01–1·0368)	0·0006	1·0362 (1·0225–1·0502)	<0·0001
Untreatable	1·0052 (0·9936–1·0157)	0·3328	1·004 (0·9936–1·0147)	0·4607	1·0065 (0·9959–1·0174)	0·2361
UHC countries						
Men	1·0009 (0·9976–1·0043)	0·5889	0·9964 (0·9931–0·9998)	0·0383	0·9974 (0·9939–1·0008)	0·1324
Women	1·0074 (1·005–1·0099)	<0·0001	1·0037 (1·0012–1·0062)	0·0035	1·0065 (1·004–1·009)	<0·0001
Treatable	0·999 (0·992–1·0065)	0·8462	0·9932 (0·986–1·0005)	0·0655	1·0009 (0·9935–1·0084)	0·8285
Untreatable	0·9972 (0·994–1·0005)	0·0967	0·9886 (0·9853–0·9918)	<0·0001	0·9864 (0·9831–0·9897)	<0·0001
Non-UHC countries						
Men	1·0419 (1·0097–1·0762)	0·0116	1·0611 (1·0272–1·0972)	0·0005	1·0813 (1·0457–1·1195)	<0·0001
Women	1·04 (1·0092–1·0727)	0·0118	1·0576 (1·0255–1·0919)	0·0005	1·0737 (1·0402–1·1096)	<0·0001
Treatable	1·0474 (1·017–1·0797)	0·0024	1·0563 (1·0248–1·0898)	0·0005	1·0746 (1·0417–1·1096)	<0·0001
Untreatable	1·0126 (0·9934–1·0325)	0·2051	1·0194 (0·9996–1·0399)	0·057	1·0269 (1·0065–1·0482)	0·0104
High-income countries						
Men	1·0006 (0·9975–1·0038)	0·722	1·0008 (1–1·0018)	0·0742	1·0009 (1·0001–1·0018)	0·0353
Women	1·0029 (1·0008–1·0051)	0·0078	1·0006 (0·9984–1·0028)	0·6068	1·0007 (0·9985–1·0029)	0·5483
Treatable	1·0028 (1·0008–1·0048)	0·006	1·002 (1·0008–1·0032)	0·001	1·002 (1·0001–1·0031)	0·0319
Untreatable	0·9921 (0·9899–0·9944)	<0·0001	0·9857 (0·9835–0·9879)	<0·0001	0·9833 (0·9811–0·9856)	<0·0001
Middle-income countries						
Men	1·1333 (1·0292–1·2607)	0·0156	1·1939 (1·0776–1·3384)	0·0014	1·2747 (1·1424–1·4417)	0·0001
Women	1·1306 (1·0315–1·2509)	0·0125	1·198 (1·0866–1·3349)	0·0006	1·2729 (1·1469–1·4299)	<0·0001
Treatable	1·1324 (1·0395–1·2436)	0·0066	1·1779 (1·0764–1·3005)	0·0007	1·2549 (1·1411–1·3939)	<0·0001
Untreatable	1·1071 (1·022–1·2077)	0·0168	1·1558 (1·0623–1·2674)	0·0014	1·2088 (1·1055–1·3333)	<0·0001
High HDI countries						
Men	0·9999 (0·9861–1·0139)	0·9763	1·0034 (0·9956–1·0113)	0·4036	1·0138 (1·0060–1·0217)	0·0006
Women	1·0176 (1·0147–1·0204)	<0·0001	1·0169 (1·0140–1·0197)	<0·0001	1·0079 (1·0051–1·0108)	<0·0001
Treatable	1·0089 (0·9997–1·0183)	0·0589	1·0154 (1·0062–1·0248)	0·0012	1·0304 (1·0211–1·0400)	<0·0001
Untreatable	1·0030 (0·9953–1·0108)	0·4582	0·9931 (0·9855–1·0008)	0·0792	0·9850 (0·9775–0·9928)	0·0002
Very high HDI countries						
Men	1·0129 (0·9910–1·0357)	0·2585	1·0045 (0·9985–1·0106)	0·1411	1·0134 (1·0039–1·0231)	0·0058
Women	1·0088 (0·9997–1·0181)	0·0600	1·025 (1·005–1·046)	0·0152	1·0139 (1·0023–1·0257)	0·0190
Treatable	1·0142 (1·0057–1·0228)	0·0012	1·0204 (1·0117–1·0293)	<0·0001	1·0210 (1·0121–1·0300)	<0·0001
Untreatable	0·9824 (0·9784–0·9865)	<0·0001	0·9736 (0·9697–0·9777)	<0·0001	0·9817 (0·9776–0·9857)	<0·0001

We obtained cancer mortality data (deaths per 100 000) from the WHO Mortality Database 2013.[21] We classified countries as universal health coverage (UHC) countries according to whether they were assessed to have met all of the following previously described conditions: legislation mandating UHC, more than 90% health-care coverage, and more than 90% skilled birth attendance.[24] We classified countries into high income or middle income using World Bank data.[19] We classified countries into very high or high human development index (HDI) countries according to the UN's Human Development Programme.[20]

Table 4: **Rate ratios between projected mortality rates based on 2000–07 observation base and observed mortality rates in 2008, 2009, and 2010 for all cancers and all age groups (0–84 years) in different country categories**

Increases in PEH, as a proportion of gross domestic product, were significantly associated with mortality reductions in seven of the nine cancer categories studied: prostate cancer (R –0·0013 [95% CI –0·0019 to –0·0008]; p<0·0001), breast cancer in women (R –0·0023 [–0·0029 to –0·0017]; p<0·0001), lung cancer in men (R –0·0037 [–0·0045 to –0·0028]; p<0·0001), colorectal cancer in men (R –0·0011 [–0·0016 to –0·0007]; p<0·0001), colorectal cancer in women (R –0·0011 [–0·0014 to –0·0008]; p<0·0001), treatable cancers (R –0·0023 [–0·0032 to –0·0013]; p<0·0001), and all cancers (R –0·0053 [–0·0070 to –0·0036]; p<0·0001; figure 4, appendix p 22). Lung cancer in women mortality (R 0·0007 [0·0004 to 0·0011]; p=0·0001) was significantly positively associated with PEH and mortality from untreatable cancers had no significant association with PEH (R 0·0006 [–0·0002 to 0·0014]; p=0·1492; figures 4, appendix p 22).

Lag analysis showed that these results carried through to 5 years after increases in PEH for all associations apart from treatable cancer (figure 4). Spending increases were associated with a slight increase in lung cancer mortality

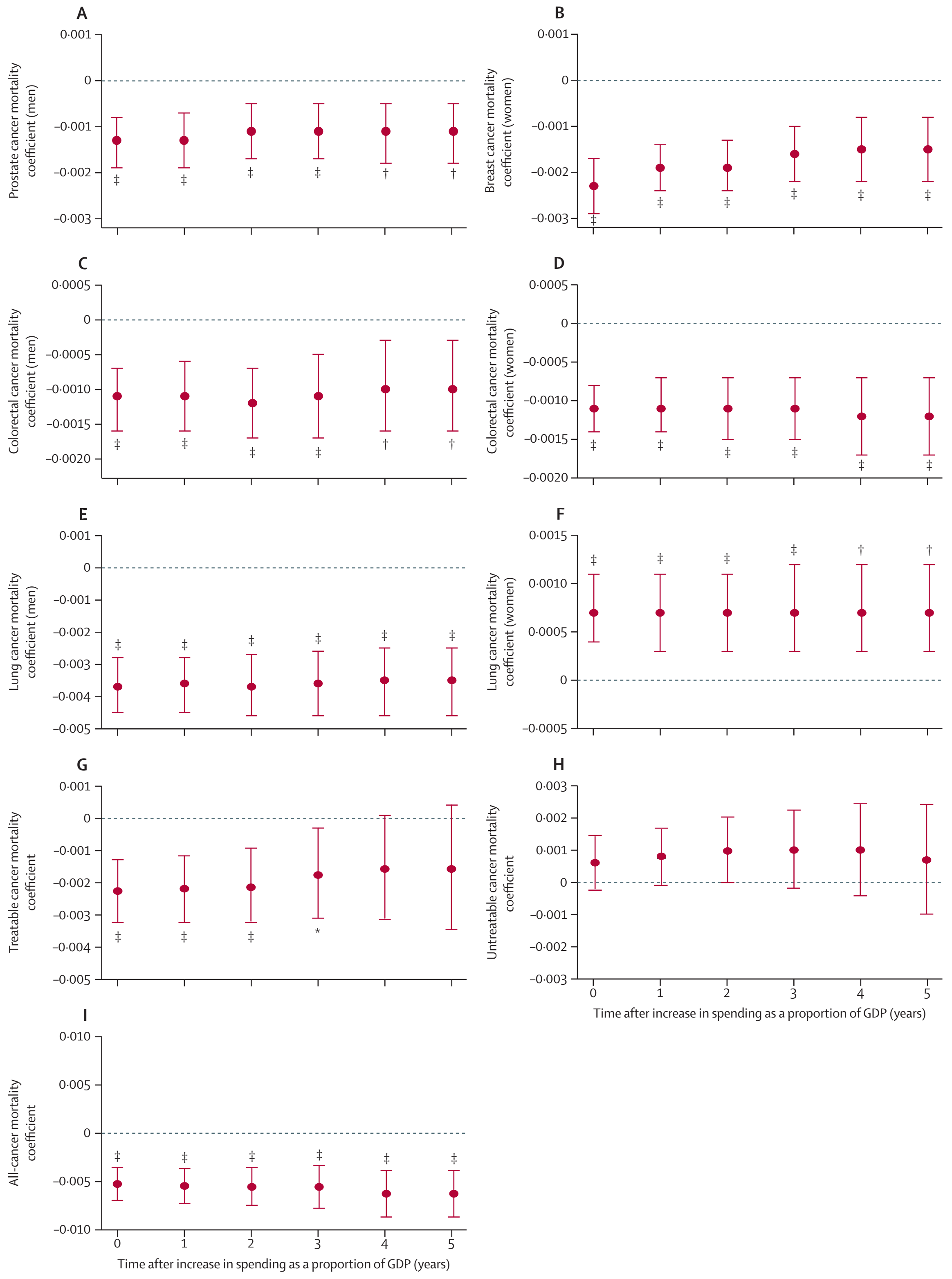

***Figure 4:* Time-lag analyses of changes in public-sector health-care expenditure on cancer mortality**
We did a multivariable regression analysis on data for 79 countries from 1990 to 2009 to assess the association between public-sector health-care expenditure, and (A) prostate cancer mortality, (B) breast cancer mortality, (C) colorectal cancer in men mortality, (D) colorectal cancer in women mortality, (E) lung cancer in men mortality, (F) lung cancer in women mortality, (G) treatable cancer mortality, (H) untreatable cancer mortality, and (I) all-cancer mortality. We did the analyses with controls for population size, population structure (proportion of population younger than 14 years and older than 65 years), and country-specific differences in health-care infrastructure. Data are also shown for 1, 2, 3, 4, and 5 year time-lag analyses. We obtained economic data from the World Bank.[23] We obtained cancer mortality data (deaths per 100 000) from the WHO Mortality Database 2013.[21] GDP=gross domestic product. *p<0·05. †p<0·01. ‡p<0·001.

in women but not with deaths from untreatable cancers (figure 4). The same trends were found irrespective of UHC status (table 5). For the most part, these significant associations held after we did robustness checks (appendix pp 23–29).

	Coefficient* (robust standard error)	95% CI	p value
Prostate cancer (men)	−0·0009 (0·0001)	−0·0011 to −0·0006	p<0·0001
Breast cancer (women)	−0·0009 (0·0001)	−0·0012 to −0·0007	p<0·0001
Colorectal cancer (men)	-3×10^{-5} (0·0003)	−0·0006 to 0·0006	0·9126
Colorectal cancer (women)	−0·0004 (0·0001)	−0·0011 to −0·0002	p<0·0001
Lung cancer (men)	−0·0007 (0·0003)	−0·0012 to −0·0002	0·0087
Lung cancer (women)	0·0005 (0·0001)	0·0003 to 0·0007	p<0·0001
Treatable cancers	−0·0022 (0·0005)	−0·0032 to −0·0012	p<0·0001
Untreatable cancers	0·0008 (0·0004)	0·0001 to 0·0016	0·0341
All cancers	−0·0016 (0·0005)	−0·0026 to −0·0006	p<0·0001

Countries were classified as universal health coverage (UHC) countries according to whether they were deemed to have met all of the following previously described conditions: legislation mandating UHC, more than 90% health-care coverage, and more than 90% skilled birth attendance. *Deaths per 100 000 people.

Table 5: **Cancer mortality in year of rise in public-sector expenditure on health care controlling for universal health coverage**

Discussion

Our results suggest that increases in unemployment from 1990 to 2009 were associated with increased mortality from prostate, breast, lung (men), and colorectal cancers in a range of countries. Unemployment rises were also associated with increased mortality due to all cancers and a subset of treatable cancers. Time-lag analyses suggested that these adverse effects persisted after initial rises in unemployment. Most of these associations remained significant after controlling for economic, resource availability, infrastructure, and out-of-pocket spending indicators. However, UHC implementation removed the association between changes in unemployment and cancer mortality, implying that UHC could have had a protective effect against the possible impact of unemployment. Our findings also suggest that increased PEH (as a proportion of gross domestic product) is associated with improved cancer mortality. This trend continued irrespective of UHC status. We also found that the recent global economic crisis was associated with more than 260 000 excess cancer deaths between 2008 and 2010

In all analyses, we did not find an association between unemployment rises and lung cancer in women, unlike other cancers (figure 2). Our treatable versus untreatable cancer analysis showed that this discrepancy might have been the consequence of the survival rate for lung cancer in women being less than that in men; however, this hypothesis is not supported by evidence.[25]

To further characterise these relationships, a trend analysis was applied to a particular set of time periods to obtain counterfactual results for 2008–10 (the projection period), on the basis of models of mortality trends for 2000–07 (the observation period), with the hypothesis that observation period trends would continue for the projection period. These time periods were chosen to correspond with the sharp upturn in unemployment recorded from 2008 onwards (appendix pp 4, 5) during the global economic crisis, while limiting the effects of previous unemployment fluctuations and technical progress in cancer care, which might otherwise have affected rates if the observation period had been extended to earlier than 2000. We found the strongest, most significant deviations between observed and projected rates in the non-UHC country grouping, corroborating our multivariable regression analyses. Moreover, the difference between expected and actual all-cancer mortality rates in middle-income countries exceeded that found between high-income countries, a finding that mirrors the variable effect that the income class of a country has on other causes of death.[26] The chronological correlation between the unemployment rise due to the global economic crisis and the subsequent change in cancer mortality, lends favour to a potentially causal association, rather than reverse causality or endogenity.

The principal means by which increased unemployment is likely to have an adverse effect on cancer mortality is through reduced access to health care (figure 5), which could manifest as late-stage diagnoses[35,36] and poor or delayed treatment.[37] Furthermore, unemployment has been found to be associated with low socioeconomic status.[31,38] Substantial evidence exists linking lower socioeconomic status with decreased cancer survival—with reduced access to treatment being a mediating cause[27,32]—and less health-seeking behaviours.[28] Job loss is also strongly associated with mental health and behavioural problems,[4] and could also have a negative effect on survival in patients with cancer as a result of decreased rates of treatment commencement after diagnosis or higher treatment discontinuation rates.[29]

Our results regarding PEH and cancer mortality are consistent with studies comparing spending levels across countries.[30] Integrated multidisciplinary care pathways for cancer involving screening, radiotherapy, chemotherapy, and surgery, are costly but effective at reducing mortality. Changes in the availability of health-care resources—whether at the diagnosis or treatment stage—due to changes in spending, are likely to have an effect on health outcomes. Additionally, further consequences of changes in PEH include effects on the number of health-care professionals, with fewer health-care professionals likely to result in reduced quality of care if productivity gains are not made,[39] and changes in the number of localised sites providing health care, with longer distances or travel times likely to increase delays in presentation for diagnosis and to have an adverse effect on treatment.[33]

Our study has at least two major policy implications. First, it makes a strong case for UHC and its possible

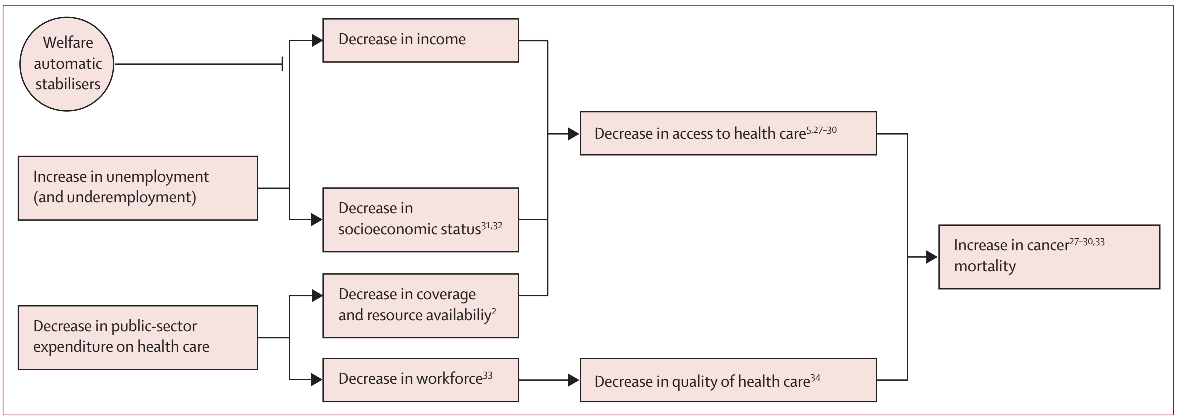

Figure 5: **Possible causal pathways for the observed associations**
The flat arrowhead denotes a mitigating effect on the causal pathway.

moderating effect on unemployed populations during economic downturns. In UHC countries, where health-care provision is meant to be equally accessible irrespective of employment status, access to health care is less problematic than in non-UHC countries, where access is often provided by means of an employment package. Second, amid a background of rising health-care costs, if spending restrictions are not accompanied by proportionate improvements in efficiency, worse quality of care and, in turn, higher mortality levels might follow.

We note several limitations of our study. First, we evaluated population health outcomes and economic trends but did not account for variations at regional and subnational levels. Second, for reasons of data availability and quality, we were unable to analyse the effects of the global economic crisis after 2010. However, in addition to the sizeable economic fluctuations that occurred during the time period studied, our analysis was still able to capture the effects of the earlier stages of the crisis with the trend analysis, during which unemployment levels rose sharply and in some countries peaked. For the PEH dataset, we did not account for changes in efficiency; indeed, a country might spend less on health care but achieve greater outcomes due to the efficiency of its system. Additionally, we acknowledge the reduced global reach of our study due to the scarcity of data from China, India, and low-income countries. An examination of whether our findings in middle-income and high-income countries would be replicated in low-income countries, where mortality rates for some cancer types might have been increasing rather than decreasing, would offer valuable insights. Fourth, our study was retrospective and observational, limiting our ability to draw causal inferences. The possibility of residual confounding from social determinant and region-specific health-care system variables also necessitates a comprehensive, longitudinal approach characterising trends and predictors of health-care access and quality before and after substantial economic changes to strengthen the case for any causative effect and to clarify the expected latency between cancer treatment and mortality. Finally, by using a fixed-effects model, we assumed that any unobserved factors within each country were time invariant and not associated with our variables of interest; the comprehensiveness of our robustness checks will have reduced the probability of this assumption affecting our findings.

Notwithstanding these limitations, our findings suggest that both unemployment and PEH are significantly associated with cancer mortality, with associations lasting up to 5 years. We estimate that the 2008–10 economic crisis was associated with about 260 000 excess cancer-related deaths in the OECD alone. Our analysis also suggests that UHC might mitigate the association between unemployment and cancer mortality, lending evidence in favour of ambitions to adopt and deliver UHC across different countries.

Contributors
MM, JW, AMN, and CW compiled the data. MM conceived and designed the study with input from JW, RAl, RS, TZ, and RAt. MM and JW did the statistical analysis, and wrote the first draft of the manuscript. AMN, CW, RAl, RS, TZ, and RAt helped interpret the findings and provided input to subsequent drafts of the manuscript. All authors have seen and approved the final version of the report. MM and JW contributed equally.

Declaration of interests
We declare no competing interests.

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