Mortality among Immigrants in England and Wales by Major Causes of Death, 1971-2012: a Longitudinal Analysis of Register-Based Data

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Recent research has observed a migrant mortality advantage among immigrants relative to the UK-born population living in England and Wales. However, while all-cause mortality is useful to show differences in mortality between immigrants and the host population, it can mask variation in mortality patterns from specific causes of death. This study analyses differences in the causes of death among immigrants living in England and Wales. We extend previous research by applying competing-risks survival analysis to study a large-scale longitudinal dataset from 1971-2012 to directly compare causes of death. We confirm low all-cause mortality among nearly all immigrants, except immigrants from Scotland, Northern Ireland and the Republic of Ireland (who have high mortality). In most cases, low all-cause mortality among immigrants is driven by lower mortality from chronic diseases (in nearly all cases by lower cancer mortality and in some cases by lower mortality from cardiovascular diseases (CVD)). This low all-cause mortality often coexists with low respiratory disease mortality and among non-western immigrants, coexists with high relative mortality from infectious diseases; however, these two causes of death contribute little to mortality among immigrants. For men, CVD is the leading cause of death (particularly among South Asians). For women, cancer is the leading cause of death (except among South Asians, for whom CVD is also the leading cause). Differences in CVD mortality over time remain constant between immigrants relative to UK-born, but immigrant cancer patterns shows signs of some convergence to the cancer mortality among the UK-born (though cancer mortality is still low among immigrants by age 80). The study provides the most up-to-date, reliable UK and Europe based analysis of migrant mortality.

3.1. Introduction

Recent research has found a migrant mortality advantage among immigrants relative to the White England and Wales-born population which persists after the adjustment for demographic and socioeconomic (SES) characteristics and uncertainty surrounding the registration of migration events (Scott and Timaeus, 2013; Wallace and Kulu, 2014b). However, while the analysis of all-cause mortality is useful to show differences between immigrants and the host population, it can mask substantial variation in high/low mortality from specific causes of death. For example, low all-cause mortality among Caribbeans in the UK is driven by low mortality from ischaemic heart disease but coexists with high stroke mortality (Wild and McKeigue, 1997). Analysis of cause-specific mortality will contribute important information on mortality among immigrants in England and Wales and improve our overall understanding of the mechanisms which influence mortality patterns among immigrants. This study will provide the most up-to-date and reliable UK-based analysis of cause-specific mortality patterns among immigrants, analysing a long time-series from large-scale, representative longitudinal data.

This study investigates major causes of death (cardiovascular (CVD) diseases, respiratory diseases, cancer, infectious diseases and other causes of death) among immigrants in England and Wales, drawing upon the notion of the immigrant health transition (Spallek et al., 2011), to determine if low all-cause mortality is driven by low mortality, or coexists with high mortality, from specific causes of death. We extend previous research by using large-scale longitudinal data to analyse cause-specific mortality among immigrants. Previous research in the UK has used cross-sectional data (Wild et al., 2006; Wild et al., 2007) and studied certain groups and causes only e.g. South Asians (Balajaran, 1984; Harding et al., 2008). We conduct simultaneous analysis of the causes. Conventional cause-specific analysis facilitates the study of relative mortality by population subgroups separately for each cause, but the direct comparison of mortality from different causes is possible only when the causes are analysed together.

3.2. Background

Low mortality among immigrants has previously been found in western countries (Powles, 1990; Khlat and Courbage, 1996; Razum et al., 1998; Abraído-Lanza et al., 1999; McDonald and Kennedy, 2004; Anson, 2004; Hajat et al., 2010), often despite low socioeconomic status relative to the host population (Deboosere and Gadeyne, 2005). Immigrants often have low

cancer mortality with site-specific diversity. Non-western immigrants are prone to cancers linked to early life infections (e.g. stomach and liver) and resilient to lifestyle-related cancers (e.g. breast and prostate) (Arnold et al., 2010). Cancer mortality among Moroccans, Turks and Surinamese is low relative to the Dutch (Stirbu et al., 2006). Turks also have low cancer mortality relative to the Belgians, French and Danish and similar cancer mortality to Turkish non-migrants (Spallek et al., 2012). Moroccans living in France have low cancer mortality relative to the French population, men from most cancers and women from breast and intestinal (Khlat and Courbage, 1996). Hispanics have low cancer mortality relative to the US host population (Singh and Siahpush, 2001). A Swedish study observes that immigrant cancer rates are closer to the rates of people in the country of origin than the host country (Hemminki et al., 2002).

CVD mortality varies by country of origin. Finnish, central European and Turkish immigrants in Sweden have high CVD mortality but Baltics and South Europeans have low mortality (Sundquist and Li, 2006). In the Netherlands, CVD mortality is low among Moroccans, high among Surinamese and similar to the Dutch for Turks (Bos et al., 2004). Among Moroccans in France, men have low CVD mortality but women have high CVD and diabetes mortality (a CVD risk factor) (Khlat and Courbage, 1996). High diabetes mortality is also observed in a study of immigrants in several European countries (Vandenheede, 2012). For respiratory diseases, Turks, Moroccans and the Surinamese have low mortality relative to the Dutch (Bos et al., 2004). In the U.S., Black and Hispanic migrants have low COPD mortality, but not low pneumonia or influenza mortality (Singh and Siahpush, 2001); Asian immigrants have higher mortality (Singh and Miller, 2004). Studies show high infectious disease mortality among non-western immigrants in Europe (Singh and Siahpush, 2001; Bos et al., 2004; Boulogne et al., 2012).

3.2.1. Immigrant health transition

Relative to western host countries, many immigrants arrive from a country in an earlier phase of health transition (Razum, 2006). Upon arrival, immigrants immediately benefit from health care for the treatment of infectious diseases and develop a lower risk due to better hygiene and environmental conditions. Immigrants have also been exposed to fewer chronic disease risk factors, but new ones emerge in smoking, diet and a sedentary lifestyle (Spallek et al., 2011). However, even with the emergence of these new factors, it takes time to acculturate to a western lifestyle (POST, 2007) and behavioural changes, such as increase in smoking prevalence, can

predate their effects on mortality levels by decades (Zaman and Mangtani, 2007). Immigrants therefore experience a mortality advantage due to the immediate decrease in risk of death from infectious diseases, combined with only the gradual, growing influence that chronic diseases exert in their mortality (Spallek et al., 2011). Chronic diseases will become the major cause of death and mortality will converge to that of the host population, but only after a lag period (Spallek et al., 2011). Further, immigrants can have high mortality from specific causes of death (but low overall mortality) due to early life exposures in the country of origin or genetic susceptibility and gene-environment interactions (Spallek et al., 2011). Immigrants will move through three different phases of this health transition during the lifecourse; these are outlined below.

3.2.1.1. Phase I: Pre-migration

The first phase, pre-migration, suggests that immigrants are exposed to factors not faced by the majority population in the host country such as deprived and insanitary living conditions (Boulogne et al., 2012) and certain infections (e.g. Helicobacter pylori and hepatitis, which increase risk for stomach and liver cancer) (Spallek et al., 2011). Genetic susceptibility passed down from a parent born in the country of origin influences disease risk through direct causation and gene-environment interactions (Spallek et al., 2011)). South Asians, for example, may be genetically susceptible to cardiovascular diseases (Wild and McKeigue, 1997; Gupta et al., 2006); their risk may be enhanced by interaction with the environment (Spallek et al., 2011). Cultural factors such as healthy behaviours may also operate to produce lower mortality (Abraído-Lanza et al., 1999). For example, a Mediterranean-style diet among Southern Europeans (Powles, 1990; Khlat and Darmon, 2003; Sofi et al., 2008) has been linked with lower all-cause, CVD and cancer mortality (Knoops et al., 2004) and may offset health-damaging effects of other behavioural risk factors e.g. smoking (Powles, 1990). In the U.S., Latinos have been shown, after adjusting for sociodemographic factors, to drink and smoke less than non-Latino Whites (though they were also less likely to exercise) (Abraído-Lanza et al., 2005).

3.2.1.2. Phase II: The migration process

During the migration phase, immigrants usually select on the basis of good health (Franzini et al., 2001). The selective effect can be so strong that mortality remains lower than the host population irrespective of SES (Deboosere and Gadeyne, 2005) but can vary depending on the motives for migration e.g. education, work or family. Gender differences can exist if men

migrate for employment and women for family reunification (Boulogne et al., 2012). Some question the selective effects lasting long enough to explain low mortality among immigrants decades later (Khlat and Darmon, 2003) and the ability of young people to select based on future disease susceptibility (Uitenbroek and Verhoeff, 2002). The only direct study of selection (which compared Mexican immigrants in the U.S. to Mexican non-migrants from the region of origin) could not detect selection effects (Rubalcava et al., 2008). Migration can also be stressful and this might increase the risk for psychiatric diseases or CVD (Spallek et al., 2011).

3.2.1.3. Phase III: The period after migration

After migration, non-western immigrants can experience a mortality advantage due to the immediate decrease in the risk of mortality from infectious diseases (previously their major cause of death), combined with only a gradual, growing influence of chronic diseases in their mortality (Spallek et al., 2011). Western immigrants can also experience lower mortality if mechanisms such as selection effects, genetics and cultural factors combine to produce low mortality. However, immigrants are then exposed to new risk factors in smoking, diet and a sedentary lifestyle, behaviours largely responsible for chronic diseases (WHO, 2006). While cultural factors may initially dissuade the practice of these behaviours, as the immigrants acculturate and gradually adopt these behaviours (Abraído-Lanza et al., 2005) they amass risk for chronic diseases at a similar rate to the host population. In a large-scale review of the U.S. acculturation literature, Lara et al. (2005), find that in areas such as substance abuse, diet and birth outcomes, acculturation has a negative affect and is associated with poorer health outcomes and health behaviours. In other areas, such as health care use and self-perceptions of health, acculturation can have a positive effect. Franzini et al. (2001) posit that low mortality among immigrants will only persist if immigrants remain culturally distinct from their host population.

Immigrants can also experience poverty after migration (Bhopal et al., 2002) and time spent in poor conditions increases disease risk by a process of accumulation (Spallek et al., 2011). However, evidence of an socioeconomic mortality paradox has been found among Hispanics and Mediterraneans (Khlat and Courbage, 1996; Abraído-Lanza et al., 1999). This may be explained by the rapid health transition, which precedes the gradual, cumulative effect of low socioeconomic status (Spallek et al., 2011). A psychosocial interpretation in the migrant hope effect, suggests that immigrant's view poor conditions as hardship to be endured and are more

sanguine (relative to the host population) in their hope for improvement (Anson, 2004). This outlook may reduce the production of negative emotions that translate into poor health via psycho-neuro-endocrine mechanisms and stress-induced behaviours in smoking (Lynch et al., 2000).

Return migration mechanisms in salmon bias and unhealthy re-migration effect posit that immigrants return home at old ages to die through a cultural desire to die in ones birthplace (Turra and Elo, 2008), or at younger ages based on poorer general health and social factors which may predict a future high mortality risk (Razum et al, 1998). However, the motivation and ability of the ill to undertake a trip home is questioned (Khlat and Darmon, 2003) especially given the high quality of healthcare available to immigrants in the host society (Razum et al., 1998) and that family has often settled (possibly negating the desire to return) (Arnold et al., 2010). Studies find little evidence of a salmon bias effect (Abraído-Lanza et al., 1999; Rosenberg et al., 1999; Razum et al., 2006). Indeed, recent studies find a decreasing tendency among immigrants with illnesses to return home (Norredam et al., 2014; Wallace and Kulu, 2014a).

In sum, immigrant mortality is determined by factors which operate at different phases of the life course (Spallek et al., 2011). Cause-specific mortality provides us with valuable insight into these factors (Deboosere and Gadeyne, 2005). Before migration, disease patterns reflect patterns in the country of origin, but after migration, patterns will change for diseases where risk is influenced by exposures in both the country of origin and the host country (Marmot et al., 1984). Based on previous findings and, recalling the aim of the study, we expect that low mortality among immigrants (relative to the English and Welsh host population) will coexist with:

(**1**) low mortality from cancer and respiratory diseases;

(**2**) high mortality from infectious diseases;

(**3**) marked variation by country of birth in CVD mortality.

Data & Methods

We use the Office for National Statistics Longitudinal Study (ONS LS), a nationally representative dataset which links census and life event information for a 1% sample of the population living in England and Wales. We define immigrants by country of birth. Country of birth is asked at each census from 1971 to 2011. For people present at one census we take the country of birth selected at that census; for individuals present at multiple censuses we take

the country selected most often. The analysis controls for socio-demographic characteristics age, sex, period, marital status, occupation type, education level and the area of residence type. The categorisation of covariates, along with risk-time and death events, is presented in Table 1.

In the ONS LS, immigrant entry dates are obtained through their registration with the National Health Service (NHS). People do not have to register immediately and the date of entry specified on the form is not cross-checked and can be inaccurate (Hattersley, 1999). Immigrants can also be picked up at census year if they have not yet registered with the NHS. Immigrant exit dates are recorded through de-registration from the NHS. The NHS advises all patients to cancel their registration if they emigrate. However not all patients do this. If an individual does not notify the NHS of their emigration they will have no exit date and they become 'lost to follow-up' (LTFU). This registration uncertainty could lead to a downward bias in mortality rates (Kibele et al., 2008) if the time-at-risk in the country is overestimated for immigrants. The study therefore implements a framework for controlling registration errors devised by Wallace and Kulu (2014b). They fitted several sensitivity models, allowing immigrants to enter on the date specified with the NHS or limiting entry to first census appearance and projected exit dates for those LTFU of 2-, 4- and 7-years after final census (values based on the empirical distribution of known de-registrations from the NHS). Immigrant mortality was robust to the testing. Wallace and Kulu (2014b) allowed immigrants to enter on the date specified with a doctor and projected a 4-year exit for individuals LTFU, the median value of recorded exit dates.

Mortality from CVD, respiratory, cancers, infectious diseases and other causes of death are studied. The first three groups accounted for seven of ten deaths in the UK in 2014 (cancer 29%, CVD 28%, respiratory 15%) (ONS, 2014). Categorisation of causes is available from the authors. Risk-time and number of death events by all-cause mortality and each cause of death is provided in Table 2. We use the underlying cause of death, defined as the disease which initiated the train of morbid events leading directly to death or to the accident which produced the injury (WHO, 2015). Wallace and Kulu (2014b) tested the representativeness of mortality in the ONS LS by comparing mortality rates with the Human Mortality Database. Mortality at most ages fell within 95% confidence intervals and for all ages fell within 90% confidence intervals.

Table 1. Person-years at risk and number of events by covariates.

Covariate	Risk Time	%	Event	%	Covariate	Risk Time	%	Event	%
Age					**Occupation type**				
20-24	1,575,564	11.8	880	1.4	Professional/Managerial	3,239,946	24.2	11,473	18.6
25-29	1,622,355	12.1	965	1.6	Skilled	4,947,606	37.0	20,699	33.6
30-34	1,625,654	12.2	1,260	2.0	Unskilled	2,442,758	18.3	13,426	21.8
35-39	1,598,852	12.0	1,696	2.8	Missing	2,743,820	20.5	15,955	25.9
40-44	1,545,443	11.6	2,655	4.3	**Education Level**				
45-49	1,409,373	10.5	3876	6.3	Degee Level +	1,577,947	11.8	4,460	7.2
50-54	1,177,953	8.8	5165	8.4	A-level	1,015,308	7.6	2,283	3.7
55-59	957,057	7.2	6,769	11.0	No 18+ Qualifications	10,716,667	80.1	53,834	87.5
60-64	743,603	5.6	8,208	13.3	Missing	64,208	0.5	976	1.6
65-69	524,897	3.9	8,926	14.5	**Marital Status**				
70-74	338,520	2.5	8,723	14.2	Single	4,174,905	31.2	9,309	15.1
75-79	183,898	1.4	7,586	12.3	Married	7,856,936	58.7	38,020	61.8
80-84	66,524	0.5	4417	7.2	Divorced	964,974	7.2	6,533	10.6
85+	4,439	0.0	427	0.7	Widowed	315,330	2.4	6,715	10.9
Period					Missing	61,985	0.5	976	1.6
1971-1980	2,013,172	15.1	3,064	5.0	**Area Type**				
1981-1990	2,930,028	21.9	7,403	12.0	London	1,941,442	14.5	7,375	12.0
1991-2000	3,643,701	27.2	16120	26.2	Other Metropolitan	2,919,884	21.8	14,422	23.4
2001-2012	4,787,229	35.8	34966	56.8	Non-Metropolitan	8,450,000	63.2	38,780	63.0
Gender					Missing	62,804	0.5	976	1.6
Male	6,630,431	49.6	36,266	58.9					
Female	6,743,699	50.4	25,287	41.1	**Total**	**13,374,130**	**100**	**61,553**	**100**

Source: authors calculations based on ONS LS

Table 2. Person years at risk and number of events by cause of death.

Country of Birth	Risk Time	%	**All-cause**		**Cardiovascular**		**Cancers**		**Respiratory**		**Infectious**		**Other causes**	
			Events	%	Events	%	Events	%	Events	%	Events	%	Events	%
England and Wales	11,411,341	85.3	52,793	85.8	16,728	27.2	19,984	32.5	5,049	8.2	468	0.8	10,564	17.2
Scotland	230,839	1.7	1,587	2.6	489	0.8	573	0.9	172	0.3	25	0.0	328	0.5
Northern Ireland	68,736	0.5	477	0.8	148	0.2	174	0.3	54	0.1	<10	0.0	97	0.2
Republic of Ireland	175,186	1.3	1,498	2.4	494	0.8	572	0.9	172	0.3	11	0.0	249	0.4
India	265,944	2.0	1,199	1.9	560	0.9	245	0.4					257	0.4
Pakistan	160,716	1.2	452	0.7	213	0.3	119	0.2	152	0.2	53	0.1	71	0.1
Bangladesh	71,210	0.5	183	0.3	96	0.2	41	0.1					27	0.0
Jamaica	65,835	0.5	475	0.8	186	0.3	175	0.3	48	0.1	13	0.0	76	0.1
Other Caribbean	51,368	0.4	249	0.4	96	0.2	85	0.1					45	0.1
East and Southern Africa	129,077	1.0	295	0.5	93	0.2	86	0.1	28	0.0	22	0.0	78	0.1
West and Central Africa	59,306	0.4	150	0.2	66	0.1	42	0.1					30	0.0
Western Europe	211,792	1.6	785	1.3	272	0.4	301	0.5	77	0.1	16	0.0	147	0.2
Eastern Europe	88,319	0.7	426	0.7	181	0.3	146	0.2					71	0.1
China	40,268	0.3	117	0.2	42	0.1	43	0.1	21	0.0	<10	0.0	20	0.0
Other Asia	94,910	0.7	170	0.3	55	0.1	68	0.1					36	0.1
Rest of the World	249,283	1.9	697	1.1	193	0.3	236	0.4	69	0.1	11	0.0	188	0.3
Total	**13,374,130**	**100**	**61,553**	**100**	**19,912**	**32.3**	**22,890**	**37.2**	**5,842**	**9.5**	**625**	**1.0**	**12,284**	**20.0**

Notes: For respiratory and infectious diseases, some countries of birth are combined due to low event numbers: South Asian (India, Pakistan and Bangladesh), Caribbean (Jamaica and Caribbean), African (East and South and West and Central Africa), European (West and East) and China (China and Other Asia).

Source: authors calculations based on ONS LS

The study spans three revisions of the International Classifications of Diseases (ICD). Deaths from 1971-1981 relate to ICD-8, 1981-1999 to ICD-9 and deaths from 2000-2012 to ICD-10 (Rooney and Smith, 2000). The change from ICD-8 to ICD-9 is considered a minor revision (Moriyama et al., 2011) but the move to ICD-10 saw changes to the number and structure of chapters and rules for selection of underlying cause of death (Rooney et al., 2002). While bridge coding studies have been conducted to highlight disruptions in the reporting of causes, trying to apply corrections rates would be problematic due to the large number of small population subgroups. To account for this we use the broad disease groups defined above. We also plotted the total number of yearly deaths for each disease group for the sample as a whole to check for disruptions in reporting in the years immediately after revisions to the ICD classification (see Appendix D Table 11 and Figure 1). We observed little disruption in reporting for our disease groups.

Study sample

The study period spans 41 years from April 1971 to Dec 2012. At the start of observation in 1971, people aged 20-45 years are studied (or are 'at risk'). As each year passes, the lower age limit remains stationary but the upper age limit increases by one year, each year, up to 86 years in 2012. While age is controlled for (by month) this design (given how critical age structures are for mortality analyses) ensures that age structures of the host population and immigrants remain as comparable as possible. Previous research also suggests that significant numbers of people aged 45-years and older born in India, Pakistan and Bangladesh in 1971 are children born to British expatriates (Marmot et al., 1984). Using the above age design removes these individuals from analysis. People were dropped if it was not possible to match their census and event data (these people are "untraced") (18,020; <3%), if we could not assign country of birth (1,142; <0.2%), and if dates recorded for peoples' exits and returns to England and Wales were not chronological and we could not determine risk-time (892; <0.2%). Final sample is 591,724 people.

Statistical Methods

We implement competing-risks survival analysis. The cause-specific hazard function, $\boldsymbol{\mu_k(t)}$, is defined as:

$$\mu_k(t) = \lim_{\Delta t \to 0} \frac{\Pr(t \le T < t + \Delta t, D = k \mid T \ge t}{\Delta t}, k = 1,2...,K, \quad \textbf{(1)}$$

where **T** represents the duration of an episode (or age) and **D** denotes cause of death with **k** causes. To study mortality among immigrants and the UK-born population living in England and Wales by cause of death, we first define a cause-specific proportional hazards regression model:

$$\ln \mu_k(t) = \ln \mu_{k,0}(t) + \sum_l \beta_{kl} x_l(t) + \gamma_k z, \qquad \textbf{(2)}$$

where $\boldsymbol{\mu_k(t)}$ denotes the hazard (or force) of mortality at age **t** and $\boldsymbol{\mu_{k,0}(t)}$ denotes the baseline hazard, i.e. the mortality risk from cause **k** by age, which we assume to follow a Gompertz distribution where mortality by age increases exponentially. **x(t)** represents the values of a variable measuring individual socioeconomic characteristics; $\boldsymbol{\beta_k}$ is the parameter estimate for **x(t)**, with **l** variables; $\boldsymbol{\gamma_k}$ denotes the effect of variable **z**, migrant status, on mortality from cause **k**.

We extend this cause-specific proportional hazards regression model **(2)** to model all causes jointly. This way, we can identify which causes are most important to the overall mortality of the sample:

$$\ln \mu_k(t) = \ln \mu_0(t) + \alpha k + \sum_l \beta_l x_l(t) + \gamma z, \qquad \textbf{(3)}$$

where **α** denotes the effect of the **k**th cause on mortality. The model assumes one baseline for all causes; mortality levels can vary by cause but the effect of socioeconomic characteristics and migrant status remains the same.

We then develop a final model where the effect of migration status **z** can vary by cause of death:

$$\ln \mu_k(t) = \ln \mu_0(t) + \sum_l \beta_l x_l(t) + \gamma_k z, \quad \textbf{(4)}$$

where $\boldsymbol{\gamma_k}$ is a cause-specific parameter for variable **z** (migrant status). The model is very similar to **(2)**, except that it assumes a common baseline for all causes of death and the same effect of socioeconomic characteristics.

The models defined in **(3)** and **(4)** are fitted using extended data, where each person has **k** records and **k** is the cause of death. We create five datasets (one per cause) as if we were modelling each cause separately (thus in each dataset mortality from the four other causes is treated as censored i.e. death=0), but we define a variable cause which is common to all

datasets. In the CVD dataset, cause=1, in the cancer dataset, cause=2 … up to the other cause dataset where cause=5. We append these datasets to create the extended data. For model 1, we model all-cause mortality and specify cause as an explanatory variable like in equation **(3).** For model 2, we interact variable cause with country of birth like in equation **(4)** to simultaneously model cause-specific mortality among immigrants. This approach has become common in mortality research (Putter et al. 2007) but has not been used to study immigrant mortality until now.

Results

To determine whether immigrants in England and Wales benefit from a migrant mortality advantage, model 1a analyses all-cause mortality and controls for age, period and cause of death. Men and women from India, Bangladesh, Western Europe, Other Asia and Rest of the World have low mortality relative to UK-born (model 1a, Table 3). Men from Pakistan and East and South Africa and women from Other Caribbean, West and Central Africa, Eastern Europe and China have low mortality. Women from Jamaica and men and women from Scotland, Northern Ireland and Republic of Ireland have high mortality. All other countries have similar mortality to White England and Wales-born. To determine whether patterns persist beyond differences in socioeconomic status, model 1b (Table 3) further controls for occupation type, education level, marital status and the area of residence type (covariates are time-varying and the change takes place at census years 1971, 1981, 1991 and 2001). Nearly all immigrants, except for Chinese men and Jamaican women (who have similar mortality to UK-born), have low mortality. High mortality among men and women from Scotland, Northern Ireland and Republic of Ireland largely persists. For men, CVD and cancer are the leading causes of death, followed by other causes of death, respiratory and infectious diseases. For women, cancer is the leading cause of death, followed by CVD, other causes of death, respiratory and infectious diseases.

Model 2 investigates mortality from specific causes (CVD, cancers, respiratory, infectious, and other causes of death) simultaneously to determine whether all-cause mortality patterns are driven by low mortality, or coexists with high mortality, from specific causes of death among immigrants. Model 2a controls for age and period and model 2b (male: Table 4 and Fig. 1; female Table 5 and Fig. 2) additionally controls for occupation type, education level, marital status and the area of residence type. The simultaneous model imposes one common baseline for all-causes (CVD mortality among UK-born men/women) and assumes the same effect of

covariates across causes. Estimates for covariates are not shown in model 2b, but are identical to those in model 1b. Further, we discuss, but do not present, the results from Model 2a to avoid overloading the study with too much information. Model 2a is available in Appendix D (Table 3).

For CVD mortality (2a) marked variation exists by country of origin. Men and women from India have high CVD mortality. Further, men from Bangladesh, West and Central Africa and Eastern Europe, and women from Pakistan and Jamaica, have high CVD mortality. However, men and women from Other Asia and Rest of the World have low CVD mortality. Additionally, men from East and South Africa and Western Europe have low mortality. After adjusting for socioeconomic status (2b) (Table 4 and 5, Fig. 1 and 2), high CVD mortality persists among Indian men but attenuates among women. A polarised pattern emerges among Bangladeshis and Jamaicans. Bangladeshi men have high CVD mortality (CIs overlap with UK-born) and women have low CVD mortality; Jamaican men have low CVD mortality and women high CVD mortality. Among Pakistani women and Eastern European men, initial high CVD mortality attenuates to the CVD mortality level of the White England and Wales-born population. Immigrants from Scotland, Northern Ireland and Republic of Ireland have high initial CVD mortality relative to White England and Wales-born population which persists among women from Republic of Ireland and Scottish men after adjusting for socioeconomic status.

For cancer (2a), mortality among immigrants is generally low relative to cancer mortality among White England and Wales-born and there is little (if any) variation by gender. Men and women from India, Pakistan, Bangladesh, East and South Africa, Western Europe, Other Asia, and the Rest of the World have low cancer mortality. Additionally, women from West and Central Africa and Eastern Europe have low cancer mortality. Men and women from Jamaica have similar cancer mortality to White England and Wales-born. After adjusting for their socioeconomic status (2b) (Tables 4 and 5, Fig. 1 and 2), all women have low cancer mortality except for Jamaican (the estimate is indicative of low mortality but CIs overlap with White England and Wales-born). Similarly, all men, except Chinese (the estimate is low relative to White England and Wales-born but CIs overlap), have low cancer mortality. High cancer mortality persists among immigrants from Scotland and Northern Ireland (except women from Northern Ireland). High cancer mortality attenuates among men and women from Republic of Ireland.

For respiratory diseases, due to low event numbers we combine several countries of birth: South Asian (India, Pakistan and Bangladesh), Caribbean (Jamaican and Other Caribbean), African (East and South and West and Central African), European (Eastern and Western Europe) and Chinese (Chinese and Other Asian). In Model 2a mortality is low among men from South Asia, Caribbean, Africa and Europe and women from Europe and China. All other groups (male and female) have estimates indicative of low mortality but CIs overlap with White England and Wales-born. After adjusting socioeconomic status (2b) (Tables 4 and 5, Figures 1 and 2) the same patterns persist among males. Among females, low mortality becomes apparent among Caribbeans and Africans. Immigrants from Scotland, Northern Ireland and Republic of Ireland have high respiratory mortality which persists after adjusting for their socioeconomic status.

Similarly, for infectious diseases death numbers are low and we combine groups in the same way as for respiratory diseases (South Asian, Caribbean, European/Other and Chinese). Men from Scotland, India, Caribbean and Africa have high mortality, while men from Northern Ireland, Republic of Ireland, Europe and China have similar estimates to White England and Wales-born. All other males have estimates indicative of high infectious disease mortality but CIs overlap. Women from South Asia and Africa have high mortality; women from Caribbean, China and Rest of the World have similar levels to White England and Wales-born. All other women have estimates indicative of high infectious disease mortality but CIs overlap. After adjusting for socioeconomic status (2b) (Tables 4 and 5, Fig. 1 and 2), high infectious disease mortality persists among men and women from Scotland, South Asia and Africa. Estimates for men from Caribbean and the Rest of the World remain high but CIs overlap with England and Wales-born.

For other causes of death (2a), men and women from Western Europe have low mortality relative to the White England and Wales-born. Additionally, men from Pakistan, Bangladesh, Other Caribbean and Other Asia have low mortality. Estimates are low for men and women from Eastern Europe and China, men from Jamaica, and women from Pakistan and West and Central Africa but CIs overlap with the White England and Wales-born. Estimates are also high among men from Rest of the World and women from Northern Ireland, Republic of Ireland, East and South Africa and Rest of the World but CIs also overlap with the White England and Wales-born. After adjusting for socioeconomic characteristics (2b) (Tables 4 and 5, Fig. 1 and 2), low mortality from other causes of death also becomes apparent among men from the Republic of Ireland, Jamaica and Eastern Europe and women from Pakistan, China and Other

Asia. High mortality persists among men and women from Scotland and men from Northern Ireland.

Table 3. Hazard ratios: all-cause mortality among immigrants relative to England and Wales-born.

Model 1	**Male**						**Female**					
	[a]			[b]			[a]			[b]		
	Haz Ratio	Sig	95% CI	Haz Ratio	Sig	95% CI	Haz Ratio	Sig	95% CI	Haz Ratio	Sig	95% CI
Period												
1971-1981	**1**			**1**			**1**			**1**		
1981-1991	0.93	***	0.88 - 0.98	0.92	***	0.87 - 0.97	0.84	***	0.79 - 0.90	0.90	***	0.84 - 0.96
1991-2001	0.86	***	0.82 - 0.91	0.78	***	0.74 - 0.83	0.76	***	0.71 - 0.81	0.83	***	0.77 - 0.88
2001-2012	0.72	***	0.68 - 0.76	0.66	***	0.63 - 0.70	0.66	***	0.62 - 0.71	0.82	***	0.77 - 0.88
Country of birth												
England and Wales	**1**			**1**			**1**			**1**		
Scotland	1.28	***	1.20 - 1.36	1.28	***	1.20 - 1.36	1.36	***	1.26 - 1.48	1.35	***	1.24 - 1.46
Northern Ireland	1.35	***	1.20 - 1.51	1.21	***	1.08 - 1.36	1.15	*	0.99 - 1.33	1.08		0.93 - 1.25
Republic of Ireland	1.29	***	1.20 - 1.38	0.99		0.92 - 1.06	1.25	***	1.15 - 1.35	1.09	**	1.01 - 1.18
India	0.89	***	0.83 - 0.95	0.83	***	0.78 - 0.90	0.91	**	0.82 - 1.00	0.74	***	0.68 - 0.82
Pakistan	0.73	***	0.65 - 0.82	0.63	***	0.56 - 0.71	0.93		0.80 - 1.09	0.62	***	0.53 - 0.73
Bangladesh	0.89	***	0.75 - 1.05	0.72	***	0.61 - 0.85	0.66	***	0.50 - 0.89	0.41	***	0.30 - 0.54
Jamaica	0.97		0.86 - 1.10	0.66	***	0.58 - 0.74	1.18	**	1.03 - 1.34	0.90		0.78 - 1.03
Other Caribbean	0.88		0.75 - 1.03	0.69	***	0.59 - 0.81	0.82	*	0.67 - 1.01	0.69	***	0.56 - 0.84
East and Southern Africa	0.70	***	0.60 - 0.82	0.67	***	0.57 - 0.78	0.88		0.74 - 1.04	0.74	***	0.62 - 0.87
West and Central Africa	1.00		0.83 - 1.21	0.81	**	0.67 - 0.97	0.64	***	0.46 - 0.88	0.52	***	0.38 - 0.71
Western Europe	0.77	***	0.70 - 0.86	0.72	***	0.65 - 0.80	0.77	***	0.70 - 0.85	0.70	***	0.63 - 0.77
Eastern Europe	0.98		0.86 - 1.10	0.79	**	0.70 - 0.90	0.82	**	0.70 - 0.96	0.74	***	0.63 - 0.86
China	0.87		0.71 - 1.08	0.85		0.69 - 1.05	0.61	***	0.42 - 0.88	0.51	***	0.36 - 0.74
Other Asia	0.57	***	0.47 - 0.71	0.56	***	0.45 - 0.69	0.60	***	0.48 - 0.75	0.54	***	0.43 - 0.67
Rest of the World	0.84	***	0.76 - 0.93	0.80	***	0.73 - 0.89	0.82	***	0.73 - 0.92	0.76	***	0.68 - 0.86
Cause												
Cardiovascular	**1**			**1**			**1**			**1**		
Cancers	0.93	***	0.90 - 0.95	0.92	***	0.90 - 0.95	1.58	***	1.53 - 1.63	1.58	***	1.54 - 1.63
Respiratory	0.25	***	0.24 - 0.26	0.25	***	0.24 - 0.26	0.37	***	0.36 - 0.39	0.37	***	0.36 - 0.39
Infectious	0.03	***	0.02 - 0.03	0.03	***	0.02 - 0.03	0.04	***	0.04 - 0.05	0.04	***	0.04 - 0.05
Other cause	0.57	***	0.55 - 0.58	0.56	***	0.54 - 0.58	0.71	***	0.69 - 0.74	0.71	***	0.69 - 0.74
Occupation Type												
Professional/Managerial				**1**						**1**		
Skilled				1.19	***	1.15 - 1.22				1.03		0.98 - 1.08
Unskilled				1.42	***	1.38 - 1.47				1.35	***	1.29 - 1.41
Missing				2.31	***	2.22 - 2.39				1.90	***	1.82 - 1.98
Education Level												
Degree level				0.67	***	0.64 - 0.70				0.69	***	0.66 - 0.73
A-level				0.81	***	0.76 - 0.85				0.79	***	0.73 - 0.84
No 18+ qualificatons	*(Socioeconomic characteristics not adjusted for)*			**1**			*(Socioeconomic characteristics not adjusted for)*			**1**		
Missing				4.07	***	3.82 4.33				5.11	***	4.74 5.51
Marital Status												
Married				**1**						**1**		
Single				1.74	***	1.69 - 1.79				1.69	***	1.62 - 1.77
Divorced				1.44	***	1.39 - 1.49				1.35	***	1.30 - 1.41
Widowed				1.29	***	1.23 - 1.36				1.18	***	1.14 - 1.23
Area of residence type												
Rural				**1**						**1**		
London				1.08	***	1.04 - 1.12				1.05	**	1.01 - 1.09
Other Urban				1.15	***	1.12 - 1.17				1.15	***	1.12 - 1.19

Notes: Missing category in marital status and area of residence type omitted from models; significance levels at 1% (***) 5% (**) and 10% (*).

Source: authors calculations based on ONS LS

Table 4. Hazard ratios: cause-specific mortality among male immigrants relative to England and Wales-born.

Model 2b (male)	Cardiovascular				Cancers				Respiratory				Infectious				Other causes			
	Haz Ratio	Sig	95% CI		Haz Ratio	Sig	95% CI		Haz Ratio	Sig	95% CI		Haz Ratio	Sig	95% CI		Haz Ratio	Sig	95% CI	
Country of birth																				
England and Wales	1				0.96	***	*0.93*	*- 0.98*	0.26	***	*0.25*	*- 0.27*	0.02	***	*0.02*	*- 0.03*	0.58	***	*0.56*	*- 0.60*
Scotland	1.23	***	*1.10*	*- 1.37*	1.21	***	*1.08*	*- 1.35*	0.35	***	*0.29*	*- 0.43*	0.06	***	*0.04*	*- 0.10*	0.77	***	*0.67*	*- 0.88*
Northern Ireland	1.09		*0.89*	*- 1.34*	1.24	**	*1.03*	*- 1.50*	0.37	***	*0.26*	*- 0.52*	0.01	***	*0.00*	*- 0.08*	0.71	**	*0.55*	*- 0.91*
Republic of Ireland	1.02		*0.91*	*- 1.15*	0.99		*0.88*	*- 1.11*	0.32	***	*0.26*	*- 0.39*	0.01	***	*0.00*	*- 0.03*	0.44	***	*0.37*	*- 0.52*
India	1.22	***	*1.10*	*- 1.35*	0.40	***	*0.33*	*- 0.47*									0.50	***	*0.43*	*- 0.58*
Pakistan	0.91		*0.77*	*- 1.07*	0.43	***	*0.34*	*- 0.55*	0.16	***	*0.13*	*- 0.20*	0.06	***	*0.04*	*- 0.08*	0.28	***	*0.21*	*- 0.37*
Bangladesh	1.19		*0.95*	*- 1.48*	0.41	***	*0.29*	*- 0.60*									0.21	***	*0.12*	*- 0.35*
Jamaica	0.76	***	*0.62*	*- 0.92*	0.65	***	*0.53*	*- 0.80*	0.11	***	*0.07*	*- 0.16*	0.05	***	*0.02*	*- 0.08*	0.31	***	*0.23*	*- 0.41*
Other Caribbean	0.84		*0.66*	*- 1.07*	0.63	***	*0.47*	*- 0.83*									0.30	***	*0.20*	*- 0.45*
East and Southern Africa	0.71	***	*0.55*	*- 0.91*	0.50	***	*0.37*	*- 0.67*	0.10	***	*0.06*	*- 0.17*	0.08	***	*0.04*	*- 0.15*	0.48	***	*0.35*	*- 0.65*
West and Central Africa	1.08		*0.82*	*- 1.41*	0.59	***	*0.41*	*- 0.85*									0.45	***	*0.29*	*- 0.68*
Western Europe	0.79	***	*0.67*	*- 0.93*	0.69	***	*0.58*	*- 0.82*	0.11	***	*0.08*	*- 0.15*	0.02	***	*0.01*	*- 0.04*	0.43	***	*0.35*	*- 0.54*
Eastern Europe	1.02		*0.85*	*- 1.22*	0.73	***	*0.59*	*- 0.90*									0.37	***	*0.27*	*- 0.49*
China	0.87		*0.62*	*- 1.23*	0.82		*0.57*	*- 1.17*	0.15	***	*0.09*	*- 0.25*	0.01	***	*0.00*	*- 0.08*	0.46	***	*0.29*	*- 0.75*
Other Asia	0.57	***	*0.40*	*- 0.80*	0.59	***	*0.42*	*- 0.82*									0.32	***	*0.20*	*- 0.51*
Rest of the World	0.68	***	*0.57*	*- 0.82*	0.69	***	*0.58*	*- 0.83*	0.22	***	*0.16*	*- 0.31*	0.05	***	*0.02*	*- 0.09*	0.62	***	*0.51*	*- 0.75*

Notes: Significance levels at 1% (***) 5% (**) and 10% (*); sex, period, occupation type, education level, marital status and area of residence type are adjusted for but not shown, they are identical to Model 1b; For respiratory and infectious diseases, some countries of birth are combined due to low event numbers: South Asian (India, Pakistan and Bangladesh), Caribbean (Jamaica and Caribbean), African (East and South and West and Central Africa), European (West and East) and China (China and Other Asia).

Source: authors calculations based on ONS LS

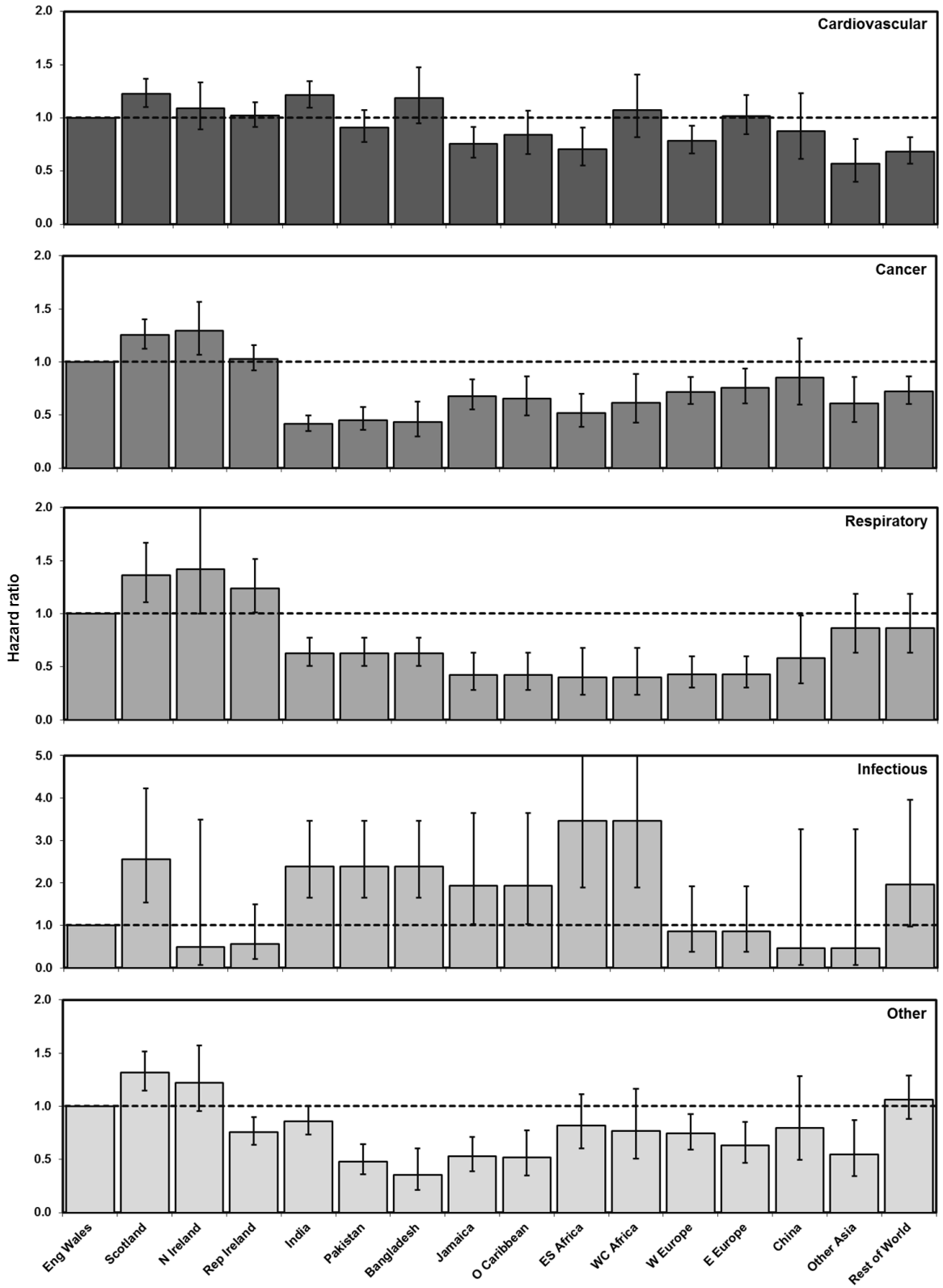

Figure 1. Hazard ratios: cause-specific mortality among male immigrants relative to England and Wales-born.

Source: authors calculations based on ONS LS

Table 5. Hazard ratios: cause-specific mortality among female immigrants relative to England and Wales-born.

Model 2b (female)	Cardiovascular				Cancers				Respiratory				Infectious				Other causes			
	Haz Ratio	Sig	95% CI		Haz Ratio	Sig	95% CI		Haz Ratio	Sig	95% CI		Haz Ratio	Sig	95% CI		Haz Ratio	Sig	95% CI	
Country of birth																				
England and Wales	1				1.65	***	*1.59*	*- 1.70*	0.38	***	*0.37*	*- 0.40*	0.04	***	*0.03*	*- 0.04*	0.73	***	*0.70*	*- 0.76*
Scotland	1.32	***	*1.13*	*- 1.55*	2.06	***	*1.82*	*- 2.34*	0.64	***	*0.51*	*- 0.80*	0.07	***	*0.04*	*- 0.14*	1.01		*0.84*	*- 1.21*
Northern Ireland	1.21		*0.92*	*- 1.59*	1.51	***	*1.18*	*- 1.92*	0.50	***	*0.33*	*- 0.76*	0.07	***	*0.02*	*- 0.21*	0.80		*0.57*	*- 1.12*
Republic of Ireland	1.16	*	*1.00*	*- 1.34*	1.73	***	*1.53*	*- 1.95*	0.47	***	*0.38*	*- 0.60*	0.04	***	*0.02*	*- 0.09*	0.73	***	*0.61*	*- 0.88*
India	1.07		*0.92*	*- 1.25*	0.76	***	*0.63*	*- 0.91*									0.62	***	*0.50*	*- 0.76*
Pakistan	0.96		*0.75*	*- 1.22*	0.71	**	*0.54*	*- 0.94*	0.25	***	*0.19*	*- 0.32*	0.09	***	*0.06*	*- 0.13*	0.38	***	*0.26*	*- 0.55*
Bangladesh	0.54	**	*0.33*	*- 0.88*	0.44	***	*0.25*	*- 0.75*									0.44	***	*0.25*	*- 0.75*
Jamaica	1.26	*	*1.01*	*- 1.57*	1.32	**	*1.07*	*- 1.64*	0.24	***	*0.16*	*- 0.36*	0.03	***	*0.01*	*- 0.09*	0.52	***	*0.37*	*- 0.73*
Other Caribbean	0.81		*0.56*	*- 1.17*	0.98		*0.70*	*- 1.37*									0.59	**	*0.38*	*- 0.90*
East and Southern Africa	0.67	**	*0.48*	*- 0.95*	0.90		*0.67*	*- 1.22*	0.21	***	*0.12*	*- 0.35*	0.16	***	*0.09*	*- 0.30*	0.78		*0.56*	*- 1.08*
West and Central Africa	0.67		*0.39*	*- 1.16*	0.67		*0.39*	*- 1.16*									0.41	**	*0.21*	*- 0.83*
Western Europe	0.82	**	*0.69*	*- 0.98*	1.12		*0.96*	*- 1.30*	0.21	***	*0.15*	*- 0.28*	0.05	***	*0.03*	*- 0.09*	0.44	***	*0.34*	*- 0.55*
Eastern Europe	1.06		*0.83*	*- 1.36*	1.04		*0.81*	*- 1.34*									0.48	***	*0.33*	*- 0.70*
China	0.67		*0.36*	*- 1.25*	0.87		*0.51*	*- 1.50*	0.13	***	*0.06*	*- 0.27*	0.02	***	*0.00*	*- 0.13*	0.20	***	*0.06*	*- 0.62*
Other Asia	0.58	***	*0.38*	*- 0.87*	0.88		*0.63*	*- 1.23*									0.45	***	*0.28*	*- 0.72*
Rest of the World	0.71	***	*0.57*	*- 0.89*	1.10		*0.92*	*- 1.33*	0.29	***	*0.20*	*- 0.41*	0.03	***	*0.01*	*- 0.09*	0.77	**	*0.62*	*- 0.96*

Notes: Significance levels at 1% (***) 5% (**) and 10% (*); sex, period, occupation type, education level, marital status and area of residence type are adjusted for but not shown, they are identical to Model 1b; For respiratory and infectious diseases, some countries of birth are combined due to low event numbers: South Asian (India, Pakistan and Bangladesh), Caribbean (Jamaica and Caribbean), African (East and South and West and Central Africa), European (West and East) and China (China and Other Asia).

Source: authors calculations based on ONS LS

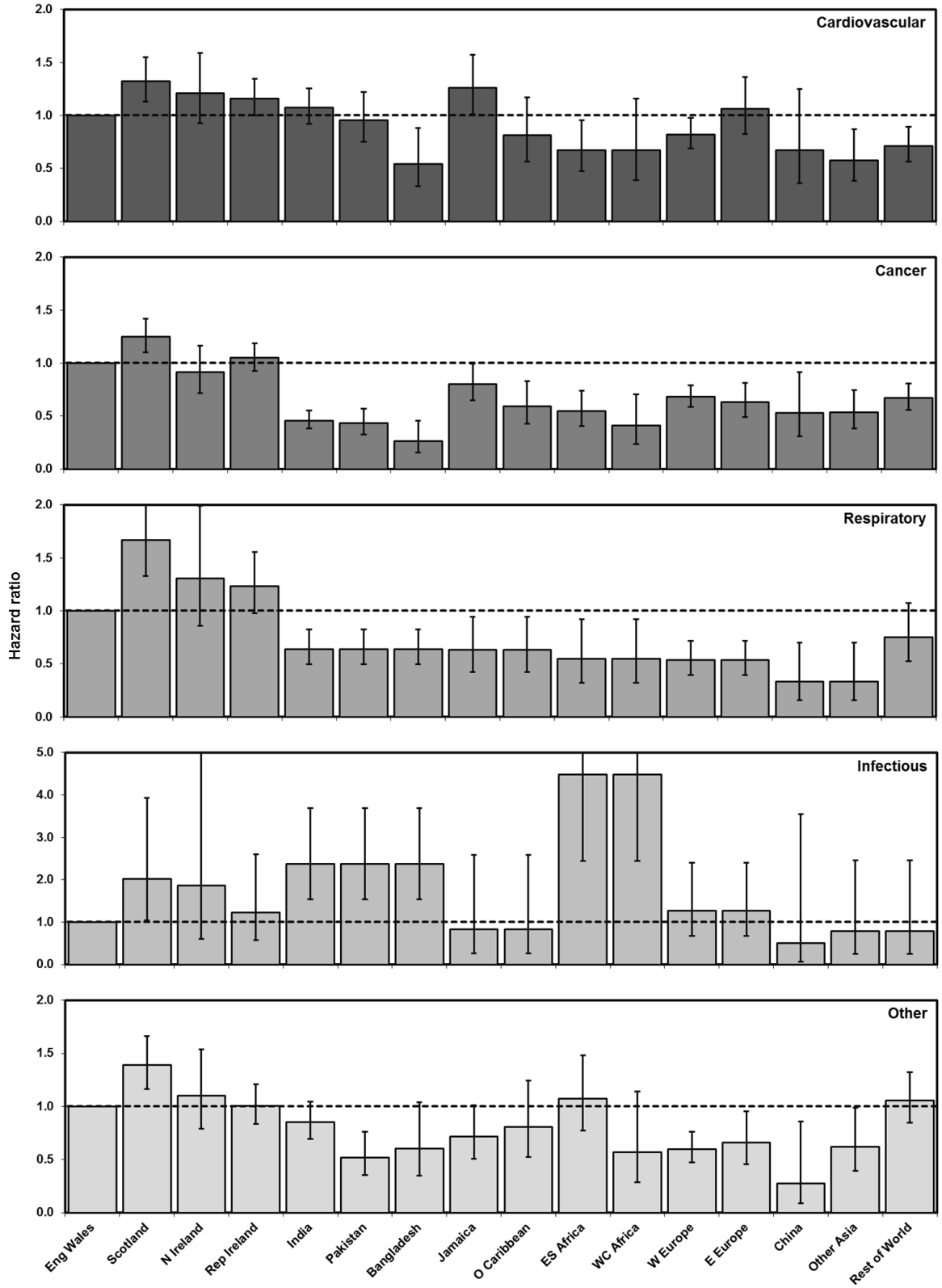

Figure 2. Hazard ratios: cause-specific mortality among female immigrants relative to England and Wales-born.

Source: authors calculations based on ONS LS

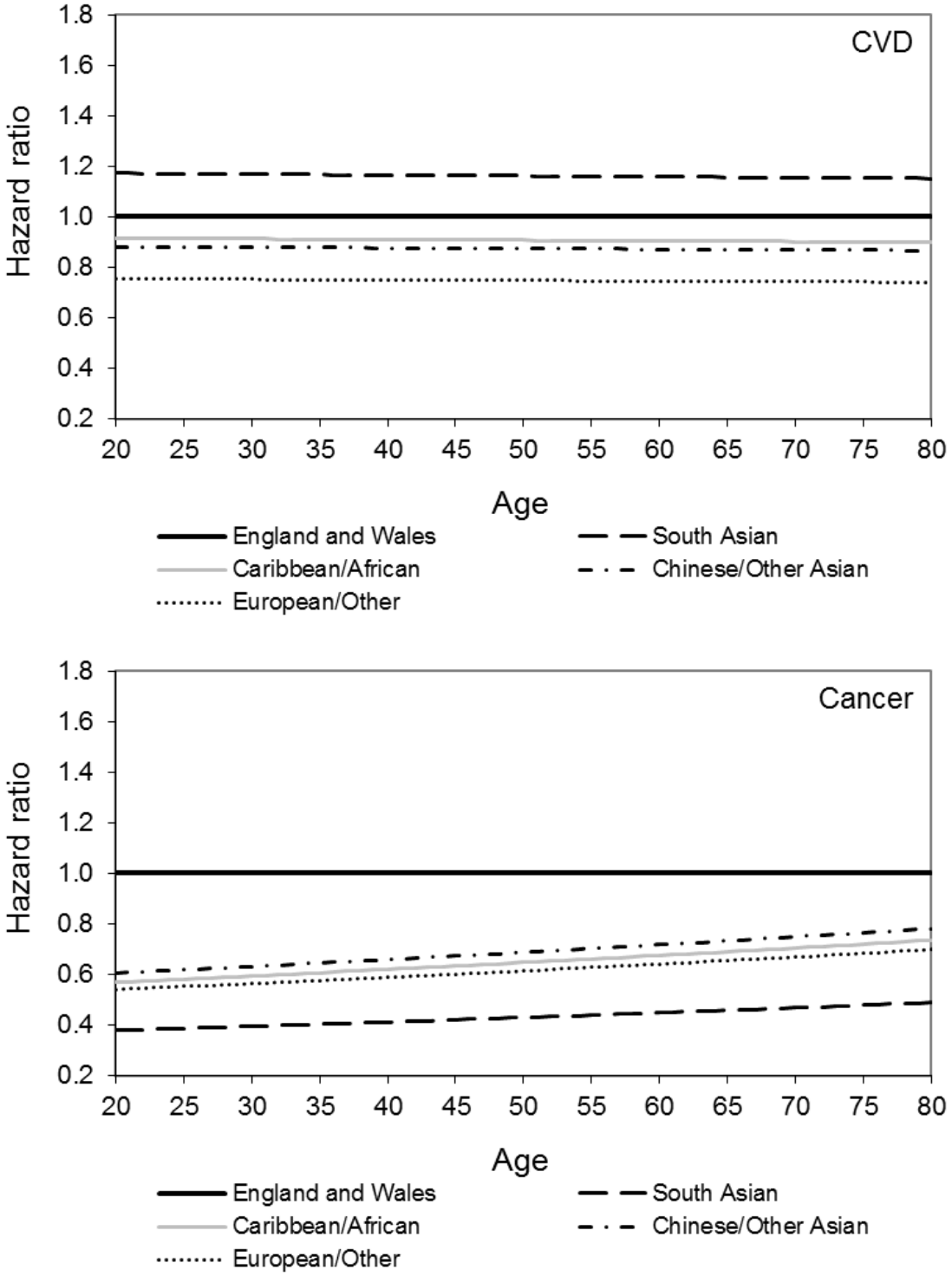

Figure 3. Age interactions (as a proxy for time since entry to England and Wales) for chronic diseases (CVD and cancer)

Source: authors calculations based on ONS LS

To assess the importance of this variation in mortality from specific causes of death among immigrants relative to the White England and Wales-born, patterns need to be placed in context of the proportion of total mortality each cause of death accounts for. Given that all estimates are relative to just one reference, we can extract this information by comparing the value of estimates for each cause of death within each country of birth. For men, CVD tends to be the leading cause of death, followed by cancers (Table 4). For South Asian men in particular, CVD dominates as their leading cause of death. For Indian men, other causes of death are more important than cancers. CVD also accounts for a large proportion of total mortality among men from West and Central Africa and Eastern Europe. Conversley, for women, cancer is the leading cause of death in most groups, followed by CVD. However, for South Asian women, CVD is the leading cause (except for Bangladeshis, for whom the leading cause is other causes of death). Respiratory and infectious diseases contribute little to the overall mortality of either sex.

Model 3 (Fig. 3) specifies age as an interaction term (and proxy for length of residence) for the two main chronic disease groups (CVD and cancers) to see if mortality from these two causes becomes more important over time. To fit the models we must aggregate groups to South Asian, Caribbean/African, Chinese/Asian and European/Other. The interaction term is defined as 0=White England and Wales-born; 1=immigrants (those from Scotland, Northern Ireland and the Republic of Ireland are coded under 0, but account for less than 4% of the group). We use a likelihood ratio test to the fit of these models. The fit of the CVD model did not improve: LR=0.02, with d.f.=1 and $p>0.1$). As Fig. 3 shows, differences in CVD levels by country group relative to White England and Wales-born (whether high/low at age 20) remain consistent over time. The fit of the cancer model improved significantly: LR=4.46, with d.f.=1 and $p<0.05$). All groups have lower cancer mortality at age 20 relative to UK-born. Fig 3. Shows that levels converge towards UK-born over time but even by age 80 cancer mortality is still low among immigrants.

Discussion

The aim of this study was to determine whether low immigrant mortality (relative to the host population) was driven by low mortality, and/or coexisted with high mortality, from specific causes of death. Recalling the hypotheses, we expected low immigrant mortality from cancers and respiratory diseases, high mortality from infectious diseases, and variation by country of origin in CVD mortality. Low all-cause mortality was driven for most immigrants by low

mortality from chronic diseases (in nearly all cases from cancer and in some cases from CVD), often coexisted with low respiratory mortality and among non-western immigrants, high mortality from infectious diseases. However, both respiratory and infectious diseases contributed little to overall mortality among immigrants. For South Asians, low mortality coexisted with high CVD mortality, the leading cause of death among South Asians (except Bangladeshi women). Their low all-cause mortality, despite high CVD mortality, was driven by very low cancer mortality. Immigrants from Scotland, Northern Ireland and the Republic of Ireland had high all-cause mortality which coexisted with high mortality from most causes of death.

These patterns support the notion of the immigrant health transition, which proposes an immediate decrease in the risk of infectious diseases and a gradual transition to increased risk for CVD and cancers (Spallek et al., 2011). For infectious diseases, we have shown that non-western immigrants have high mortality when compared to the White England and Wales-born population. This is due to early life exposures in the country of origin where infectious (not chronic) diseases dominate the epidemiologic regime and people face exposures in deprived and insanitary living conditions (Boulogne et al., 2012). High infectious disease mortality is thus expected. However, this high infectious disease mortality is able to coexist with low overall mortality among immigrants because they immediately benefit from access to better quality health care and fewer die because of infectious diseases (Spallek et al., 2011). The proportion of total mortality accounted for by infectious diseases becomes, as observed, very low.

The immigrant health transition also posits that, on arrival, immigrants have low chronic disease mortality, but this advantage decreases over time (Spallek et al., 2011). We could not control directly for length of residence, but conducted age interactions for CVD and cancer to see if mortality from these chronic diseases exerted more influence over time relative to White England and Wales-born. There was some convergence in cancer but mortality remained lower even at older ages. For CVD, differences remained consistent by age. Convergence in cancer provides some support for an immigrant health transition in that immigrants may accumulate risk for cancers over time and this chronic disease becomes more important for their mortality (Spallek et al., 2011). But while cancer showed some convergence it never reached the level of White England and Wales-born. Given that immigrants have accumulated few risk factors on arrival, and it takes time to acquire a western lifestyle (POST, 2007), it may be that immigrants never accumulate the same level of risk as White England and Wales-born. However, it should

also be noted cancer and CVD share common risks. If acculturation is largely responsible for convergence in cancer mortality, we should have seen some degree of convergence in CVD mortality.

For western immigrants who arrive from countries at a similar stage of health transition, chronic diseases are already the major cause of death in the country of origin. However, if mechanisms such as selection effects do indeed operate to produce low mortality, western immigrants can also benefit from a mortality advantage. Given that we expect gender differences in mortality, our consistent findings across a diverse range of countries, especially for all-cause mortality may indicate selection (Wallace and Kulu, 2014b). Moreover, low mortality from chronic diseases among western immigrants in this study may indicate that individuals with more favourable health behaviours are more likely to migrate. For example, while many Western and Eastern European countries have similar smoking rates to the UK-born (Zatoński et al., 2012), immigrants may select on the basis of having favourable health behaviours (i.e. they do not smoke). For Europeans, a Mediterranean diet, which has been strongly linked with lower all-cause, CVD and cancer mortality, may be quite crucial to low mortality (Knoops et al., 2004) and may offset the health-damaging effects of other risk factors such as smoking (Powles, 1990). Given the lack of evidence for a salmon bias effect in previous studies (Abraído-Lanza et al., 1999; Rosenberg et al., 1999; Razum et al., 2006; Norredam et al., 2014), biases in unrecorded return migrations are unlikely to have an effect on mortality patterns.

Cancer mortality was low among nearly all immigrants. Non-western immigrants are more prone to cancers related to early life infections (e.g. liver, cervical and stomach) and less likely to suffer from cancers related to a western lifestyle (e.g. colorectal, breast and prostate) (Arnold et al., 2010). Immigrant cancer patterns have been shown to remain similar to those in the country of origin (Hemminki and Li, 2002; Spallek et al., 2012) and it has been posited that by moving as adults immigrants have had their cancer incidence environmentally imprinted during the pre-migration phase (Hemminki and Li, 2002). That said, some signs of convergence in the interaction model somewhat challenge this. Breast, prostate, lung and bowel (lifestyle-related cancers) are the leading cancer sites in the UK (Griffiths et al., 2005) and accounted for over half of new cases in 2012 (CRUK, 2015). If the cancer site risk profiles of non-western migrants remain unchanged, continued low mortality from lifestyle-related cancers, which dominate among White England and Wales-born, could play a key role in low cancer and all-cause mortality.

High CVD mortality among men from India and Bangladesh, women from Pakistan and India and Jamaican women could be interpreted as the effect of acculturation, reinforced by a gene-environment interaction, which enhances the effect of the health transition (Spallek et al., 2011). Ethnicity (being South Asian/African Caribbean) is an independent risk factor for CVD (NHS, 2012). For South Asians, the thrifty gene and adipose tissue hypotheses posit a gene-environment interaction where individuals develop obesity and CVD risk when exposed to a western lifestyle (Gupta et al., 2006; Sniderman et al., 2006). For South Asians, mortality from CVD could also be so prevalent because there are fewer competing causes of death, especially as cancer rates are so low (Bhopal et al., 2002). Our results show that South Asians have very low rates of cancer mortality, particularly women. Jamaican women (unlike Jamaican men who had low CVD mortality after adjusting for socioeconomic status) had persistent high CVD mortality. Jamaican women, relative to White England and Wales-born women and Jamaican men, are more likely to be obese (Higgins and Dale, 2009; NOO, 2011), have high waist-to-hip ratios and bigger waists (NOO, 2011). Sex-specific acculturation, reinforced by a gene-environment interaction could speed up the health transition among Jamaican women relative to men.

In some cases, high mortality attenuated after adjusting for socioeconomic characteristics. The immigrant health transition posits the effect of socioeconomic characteristics is gradual and cumulative over time. It was not possible to directly adjust for length of residence, but it may be that these immigrants have lived in the UK for longer and accumulated more of the health-degrading effects of socioeconomic status relative to other groups. Moreover, it is generally accepted that chronic disease prevalence and the incidence of risk behaviours is high in more disadvantaged socioeconomic groups (Emmons, 2007). But immigrants do not always conform to the pattern of inequality in the host country and culture-specific attitudes may transcend socioeconomic behaviour patterns e.g. while a strong socioeconomic gradient in smoking incidence is observed in the Chinese, it is weak in Black groups and absent in South Asians (Aspinall and Mitton, 2014). Instances where high mortality attenuated on adjusting for socioeconomic status may also represent acculturation to the adverse behavioural patterns associated with the low socioeconomic circumstances immigrants can experience upon arrival (Bhopal, 2002), intensified by culture-specific attitudes. For example, alcohol intake among Eastern Europeans has been linked to CVD (Britton and McKee, 2000) and is higher among men (Popova et al., 2007). The high CVD mortality observed among Eastern European men (but not women) may reflect culture- and sex-specific health behaviours, which is intensified

if Eastern Europeans suffer low socioeconomic circumstances after arrival in England and Wales.

Immigrants from Scotland, Northern Ireland and Republic of Ireland had high mortality from each cause of death. Similar to Western and Eastern Europeans, they arrive from countries at a similar stage of health transition to England and Wales, where chronic diseases are the major cause of death. Unlike other western immigrants, other factors such as established migration history, geographical proximity, extensive support networks and a shared language may diminish the scale of the physical and psychological challenges associated with migration and place less emphasis on good health as a perquisite for migration. Recent research corroborates this, showing that Scottish migrants, though they have better health that Scottish non-migrants, are not healthier than the White non-migrants in England and Wales (Wallace and Kulu, 2014a).

Our study does have limitations. First, the number of causes we could analyse was restricted by low risk-time and deaths for some causes (e.g. stroke, diabetes) and the number of ICD changes over the study period. Second, analysis of major disease groups may have masked intra-group variation from e.g. specific cancer sites. Diseases of the respiratory system are heterogeneous, comprising acute conditions in pneumonia and chronic conditions such as bronchitis which link to very different exposures and risk factors. Third, we were unable to directly control for length of residence (though we did analyse mortality patterns by age). This would have provided further insight into the immigrant health transition, in terms of low initial mortality which diminishes over time due to the growing importance of chronic diseases. Lastly, we were unable to compare mortality among immigrants to mortality among non-migrants in the country of origin who are arguably a more suitable reference (Rubalcava et al., 2008).

This study has provided the most up-to-date UK-based analysis of immigrant mortality. It is a reliable analysis which has used a long time-series from a large longitudinal sample. We have studied cause-specific mortality among immigrants relative to White England and Wales-born and placed patterns in the context of importance of each cause of death for mortality among immigrants. Their low mortality was driven by low chronic disease mortality (particularly cancer but in some cases CVD), coexisted with low respiratory mortality and among non-western immigrants, high infectious disease mortality. Low mortality among South Asians was driven by low cancer mortality, but coexisted with high CVD mortality (which was also their

leading cause of death). For South Asians, whose CVD mortality may be a result of genetic susceptibility enhanced by gene-environment interactions, interventions to reduce obesity, by promoting good diet and exercise, combined with the adoption of ethnic-specific measures of obesity should be implemented (Gupta et al., 2006). Further research into the mechanisms which underlie low immigrant mortality may provide insight into lifestyle and dietary practices which could help address chronic disease prevalence among the White England and Wales-born.

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Acknowledgments

Project 030157: "The permission of the Office for National Statistics to use the Longitudinal Study is gratefully acknowledged, as is the help provided by staff of the Centre for Longitudinal Study Information & User Support (CeLSIUS). CeLSIUS is supported by the ESRC Census of Population Programme (Award Ref: ES/K000365/1). The authors alone are responsible for the interpretation of the data."

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