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An age-period-cohort analysis and projection of cancer mortality in Hong Kong, 1998–2030

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24 **Abstract**

25 **Objectives:** Explore age, period, birth cohort effects and effects across different genders and
26 immigration groups on mortality rates of lung, pancreatic, colon, liver, prostate and stomach
27 cancers and their projections.

28
29 **Design, Setting, and Participants:** Death registry data in Hong Kong between 1998 and 2021.
30 The population data were stratified by age, sex, immigration status, and length of stay in Hong
31 Kong. Immigration status was classified into three groups: locals born in Hong Kong, long-stay
32 immigrants and short-stay immigrants.

33
34 **Main Outcomes and Measures:** Age-period-cohort analysis was used to examine age, period,
35 and birth cohort effects for genders and immigration groups from 1998 to 2021. Bayesian age-
36 period-cohort models were applied to predict the mortality rates from 2022 to 2030.

37
38 **Results:** Short-stay immigrants indicated relatively pronounced fluctuations in age, cohort and
39 period effects for six types of cancers, as increasing trends of age effect occurred for both
40 genders and all immigration groups. Monotone decreasing trends or plateau of forecasting
41 occur for both genders and all immigration groups in cancers except for increasing trends for
42 short-stay male immigrants with colon cancer and long-stay male immigrants with pancreatic
43 cancer. Long-stay male immigrants with lung cancer would perform the most significant
44 decline in predictive mean from 100.18 to 79.55 deaths/100,000 population, while the same
45 immigration group with pancreatic cancer would indicate the most significant uptrend in each
46 year of 17.87 deaths and 23.49 deaths/100,000 population in 2022 and 2030, respectively.

47
48 **Conclusions** Immigrants had more pronounced fluctuations and sharper slopes of age, cohort,
49 and period effects than locals. Men will be at a higher risk of mortality from cancers than
50 women in the future, except for prostate cancer. Long-stay immigrants for each type of cancer
51 and gender will be at a higher mortality risk than locals.

52
53 **Keywords:** Age-period-cohort analysis, immigration, mortality, lung cancer, pancreatic cancer,
54 colon cancer, liver cancer, prostate cancer, stomach cancer

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56 **Strengths and limitations of this study**

- 58 • Complicated population distribution has resulted in intricate causes of cancers, while few
59 studies have assessed the relationship between immigration status and cancer mortality.
60 This study provides new evidence regarding the relationship between immigration status
61 and cancer mortality.
- 63 • We could only depict trends and variations among different immigration and sex groups
64 and insufficiently perform the estimates of the contributions of three effects or subgroups
65 to mortality rates.

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67 **Introduction**

68 Several migration waves from mainland China to Hong Kong have occurred over the past
69 century. These migration waves included a large-scale migration inflow from 1945 to 1950 (the
70 Chinese Civil War) and a few small-scale inflows in the 1950s, 1970s, and 1990s [1-3]. In 2016,
71 immigrants from mainland China formed approximately 38% of the population of Hong Kong.
72 These inflows have led to a growing interest in research on the disparity of health conditions
73 between the locals and immigrants.

74
75 Cancer has been one of most common causes of death, as an estimated 19.3 million new cancer
76 cases and 9.9 million new cancer-associated deaths occurred worldwide in 2020 [4]. In Hong
77 Kong, lung cancer is one of the most common causes of cancer deaths [5, 6]. Previous studies
78 suggested that the primary cause of lung cancer is cigarette smoking [7-11]. Genetic factors,
79 asbestos, radon gas, second-hand smoke, and other forms of air pollution have been proven to
80 influence the risk of lung cancer [12-18]. The overall daily smoking rate in mainland China was
81 approximately 23.2% in 2018 [21], whereas the daily smoking rate in Hong Kong was only
82 10.2% in 2019 [22]. The leading causes of liver cancer include viral infection, drinking of
83 alcohol and polluted water and food supplies which are also culprits for colon, stomach and
84 pancreatic cancer [19]. Alcohol consumption per capita in Hong Kong has reached to 2.37 liters
85 in 2021 [23], compared to 7.0 liters of per capita consumption of alcohol in mainland China in
86 2018 [24]. As approximately 99% of prostate cancer cases occur after age 50, factors of prostate
87 cancer have been regarded as old age, race, family history and the diet of red meat consumption
88 [20]. In addition to these risk factors, studies have suggested that cancer mortality rates vary
89 depending on migrant status [25-28]. According to data from the Census and Statistics
90 Department of Hong Kong, approximately 81% of immigrants in Hong Kong immigrated from
91 China mainland, Macau, and Taiwan. Immigrants from mainland China account for a bulk of
92 this population. Previous studies have shown that child immigrants in Hong Kong tend to suffer
93 from a higher risk of wheezing disorders and cardiovascular diseases, and immigrant women
94 have higher age-specific mortality rates of breast cancer than locally-born women in Hong
95 Kong [29, 30]. However, to date, few studies have investigated the effect of length of stay in
96 Hong Kong and birthplace on the risk of other types of cancer.

97
98 In this study, we compared the mortality rates of lung, pancreatic, colon, liver, prostate and
99 stomach cancers between locally born residents in Hong Kong and immigrants from mainland
100 China. Both populations are widely considered as ethnically homogeneous with similar cultures.
101 Nevertheless, due to different early life experiences, immigrants are exposed to more various
102 social economy and lifestyle than locals. Therefore, it's constructive to ascertain whether
103 immigrants from mainland China have a different mortality pattern of cancers with locals to

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4 104 verify the significance of migration status for this health outcome. As Age-period-cohort (APC)
5 105 analysis plays a vital role in studying time-specific phenomena in epidemiology, in this study,
6 106 we developed APC models specified by sex and migrant status to assess the effects of age,
7 107 period, birth cohort, and of the length of stay in Hong Kong on the mortality risks of cancers.
8 108 Additionally, we predicted the mortality rates for the locally born population and immigrants
9 109 in Hong Kong for the next 9 years using a predictive model, taking into account age, period,
10 110 and birth cohort effects as well.
11 111

112 **Materials and methods**

113 *Data*

114 We obtained the death registry data in Hong Kong between 1998 and 2021 from the Census
115 and Statistics Department of Hong Kong, as the data in 2022 has not been available up to now.
116 The population data were stratified by age, sex, immigration status, and length of stay in Hong
117 Kong. We retrieved six types of cancer cases from the death registry data using ICD codes,
118 such as ICD-9 code 162 and ICD-10 codes C34.0–C34.3, C348, and C349 for lung cancer. To
119 assure comparability among registries, deaths from the age group of 35–85 years were selected,
120 since cases younger than 35 and older than 85 were relatively trivial for lack of statistical
121 interpretability [31]. Immigration status was classified into three groups: locals born in Hong
122 Kong, immigrants who have lived in Hong Kong for >10 years before death defined as long-
123 stay immigrants, and immigrants who have lived in Hong Kong for ≤10 years before death
124 defined as short-stay immigrants. Notably, much focus was placed on immigrants from
125 mainland China, because approximately 81% of immigrants in Hong Kong came from
126 mainland China, Macau, and Taiwan based on the data from the Census and Statistics
127 Department of Hong Kong. Moreover, few cases recorded from Macau and Taiwan are
128 statistically insignificant in the analysis. Demographics and population projections from 2022
129 to 2030 were retrieved from the Census and Statistics Department of Hong Kong and estimated
130 with cubic smoothing spline as the prerequisite of the predictive model. Codes for APC and
131 BAPC analysis are available in the GitHub repository ([https://github.com/kshz2164313/APC-
132 population-projections-for-immigration-HK](https://github.com/kshz2164313/APC-population-projections-for-immigration-HK)).
133

134 *Patient and Public Involvement*

135 No patient involved. Death registry data was obtained from Census and Statistics Department
136 of Hong Kong.
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138 *Statistical analysis*

139 We modeled cancer mortality rates in Hong Kong using APC analysis based on log-linear
140 Poisson regression models. The model aimed to disentangle age, period, and cohort effects of

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4 141 time-varying phenomena simultaneously [32, 33], given that

5 142
$$\log(E_{ij}) = \alpha_i + \beta_j + \gamma_k + \mu + \log(\theta_{ij}) \quad (1)$$

7 143 where E_{ij} denotes expected mortality; α_i , β_j , and γ_k denote age, period, and cohort
8
9 144 effect, respectively, for $i = 1, \dots, I$, $j = 1, \dots, J$, $k = 1, \dots, K$ with $k = I - i + j$.

10
11 145 $\log(\theta_{ij})$ is the offset. We mainly focused on the contributions of sex and immigration status
12
13 146 due to the non-identifiability problem that the effects of these three components are collinear
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15 147 with each other (denoted as period – age = cohort) [34]. The median dates of birth among
16
17 148 cases were regarded as the reference cohort, while the second and penultimate period effects
18
19 149 were constrained to the reference groups, as birth cohort effect and period effect were
20
21 150 assessed with relative risks. For sex and immigration status, maximum likelihood framework
22
23 151 was applied to estimate the relative risks and 95% confidence intervals (CIs) by age groups,
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25 152 calendar period, and birth cohort.

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29 154 Several projection approaches for future cancer mortality have been developed, but a
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31 155 Bayesian age-period-cohort (BAPC) model built upon integrated nested Laplace
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33 156 approximations (INLA) [35] yields relatively higher coverage and better performance for all
34
35 157 evaluated parameter combinations [36]. To prevent some sampling problems caused by
36
37 158 Markov chain Monte Carlo (MCMC), this MCMC-free BAPC approach was applied to
38
39 159 predict future cancer mortality within a fully Bayesian inference setting and provide outputs
40
41 160 of interest simply, such as projected age-standardized and age-specific rates. Convergence
42
43 161 checks are not necessary for this technique [35]. The projections of age-standardized cancer
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45 162 mortality rates for each sex and migrant status, taking into account age, period, and birth
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47 163 cohort effects, were performed based on the weights of population age groups from the WHO
48
49 164 World Standard population [37], with 95% prediction intervals.

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53 166 All analyses were performed via R version 4.2.1 (R Core Team, R Foundation for Statistical
54
55 167 Computing, Vienna, Austria, 2013, <http://www.R-project.org/>). The APC models were
56
57 168 established using the Epi package, and the projections based on Bayesian APC models were
58
59 169 performed with the BAPC package.

60 61 170 62 63 171 64 65 172 66 67 173 **Results**

68
69 174 Figure 1ab, eFigure 1-4ab and eFigure 5a in Supplement 1 illustrate the estimates of age
70
71 175 (assessed by cancer mortality), period and cohort effects (assessed by relative risk) based on
72
73 176 APC models among three migrant groups for men and women with six types of cancers,
74
75 177 respectively. All the mortality rates for each gender and immigration status exhibit notable
76
77 178 increasing trends with age. Compared to other immigration groups, age, cohort and period

179 effects of six types of cancer for immigrants who stayed in Hong Kong for ≤ 10 years revealed
180 relatively more pronounced fluctuations and deviations from those effects in other immigration
181 groups. Significant increasing trends of age effect occurred in all types of cancer, regardless of
182 gender and immigration status. For example, compared to no significant effects of immigration
183 status for women on mortality rates of lung cancer by age (Figure 1b), the higher age effect for
184 men who have stayed in Hong Kong for > 10 years occurred after the age of 50 years and the
185 lower age effect of men who had short stays occurred before the age of 62 years (Figure 1a). In
186 addition to compatible dynamics of period effect for locals and long-stay immigrants, similar
187 birth cohort effects for locals and long-stay immigrants in lung, colon, liver and stomach
188 cancers occurred before 1945, whereas significant differences of birth cohort effects between
189 these two immigration groups occurred after 1960. Locals and long-stay immigrants in
190 pancreatic and prostate cancer perform almost similar cohort effects all the time. Local men
191 and women had sharper slopes of cohort effect of short stay after 1950 than other immigration
192 groups. Short-stay immigrants who have stayed in Hong Kong for ≤ 10 years had more
193 fluctuating period effects before 2020 than those for locals and long-stay immigrants. Lack of
194 young cases, especially young short-stay immigrants, of prostate cancer leads to significant
195 deviations and variances in age and cohort effects.

196
197 Figure 1c, eFigure 1-4c and eFigure 5b in Supplement 1 illustrates the age-standardized
198 mortality rates of six types of cancer from 1998 to 2021 and their projections by sex and
199 immigrant status from 2022 to 2030, taking into account age, period, and birth cohort effects.
200 Means and standard deviations of predictive mortality rates are shown in Table 1, Table 2 and
201 eTable 1-4 in Supplement 1. Monotone decreasing trends or plateau of forecasting occur for
202 both genders and all immigration groups in cancers except for increasing trends for male
203 immigrants who have stayed in Hong Kong for ≤ 10 years with colon cancer and male
204 immigrants who have stayed in Hong Kong for > 10 years with pancreatic cancer. Except for
205 prostate cancer, men will be at higher risk of mortality rates of cancers than women in the
206 future. Given the future developing trends of other groups, the group of immigrant men who
207 have stayed in Hong Kong for > 10 years with lung, liver, pancreatic, prostate and colon cancer
208 will have relatively higher mortality rates in each year compared with other immigration groups
209 and pronounced decline in predictive mean. Compared with other cancers and immigration
210 groups, male immigrants who have stayed in Hong Kong for > 10 years with lung cancer would
211 perform the most significant decline in predictive mean from 100.18 to 79.55 deaths per
212 100,000 population (average 2.92 deaths/100,000 per annum) (Table 1), while the same
213 immigration group with pancreatic cancer would indicate the most significant uptrend in each
214 year of 17.87 deaths and 23.49 deaths per 100,000 population in 2022 and 2030, respectively
215 (average 0.62 deaths/100,000 per annum) (Table 2).

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217

218 Discussion

219 Early detection of cancer is positive and instructive for increasing chances of cure. Nevertheless,
220 the high mortality rate of cancer results from late diagnosis among most patients after
221 progression to more advanced or severe stages. Individuals at high risk of cancer, such as
222 smokers, alcoholics or those who are frequently exposed to susceptible circumstances, should
223 be screened for early detections to increase opportunities for cure [38]. Therefore, the
224 differences in mortality rates among immigration groups are synonymous with detection means,
225 therapies, and social history in disparate periods and areas.

226
227 Age effects for both genders and all immigrant groups revealed pronounced increasing trends
228 on all cancer mortality rates. The group of long-stay immigrants had a higher risk of death
229 from lung, colon and liver cancers than the other two immigration groups after the age of 60
230 years. Short-stay male immigrants were less likely to die from lung cancer before the age of
231 65 years. The contrast in age effects among the immigration groups was partially consistent
232 with studies [25, 39] that highlighted the age effects for locals and immigrants on breast
233 cancer mortality in Hong Kong and lung cancer incidence in Sweden, as they both showed
234 similar trends and magnitudes between locals and immigrants before the age of 60 years.
235 They are also compatible with the results in [40] that diagnosis of liver cancer is the most
236 frequent among populations at 55 to 65 years old. According to these trends, young
237 individuals, especially new young immigrant men, who have benefited from all-rounded
238 development in mainland China and Hong Kong, are more likely to seek early detection and
239 be treated for cancers using more advanced treatments [41]. Differences in birth cohort effects
240 among immigrant groups partially comply with the interpretation above.

241
242 We observed significant trends of cohort effects among locals and immigrants. These findings
243 are partially consistent but subtly different from previous findings, regarding the effect of
244 immigration status on cancers. Zhao et al. [25] described multiple peaks of cohort effects on
245 breast cancer mortality between locals and immigrants in Hong Kong, as well as a significant
246 decline of cohort effects after 1950. In contrast, Sung et al. [42] investigated the difference in
247 breast cancer incidence between Chinese Americans and non-Hispanic whites in the U.S. and
248 emphasized that Chinese Americans were at lower risk of breast cancer than non-Hispanic
249 whites born in the same year. Here, we interpret the cohort-driven trends resulting from the
250 intricacy of social history and lifestyle. Compared to a relatively stable social development in
251 Hong Kong, representing downward trends of relative risks for locals, wars and social
252 instability in mainland China resulted in several immigration waves from mainland China to
253 Hong Kong before 1950. Additionally, remarkable increasing trends were recorded for new

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3 254 immigrants after 1950, which corresponded to the economic downturn after wars and famine
4 255 between 1959 and 1961 during their youth [43]. The increasing trends for new immigrants
5 256 and similar trends for locals and long-stay immigrants were consistent with the finding that
6 257 nutrient deficiency contributes to higher risk of severe mortality rates of cancers [44].
7
8 258 Furthermore, we speculate that these trends, especially those for locals and long-stay
9 259 immigrants, are most likely attributed to social development and personal behaviors, such as
10 260 daily habits, occupational history, different diagnoses and treatments, and domestic
11 261 environmental exposures. It's notable that short-stay immigrants suffered from lower risk of
12 262 death from colon cancer for all ages (eFigure 2ab in Supplement 1). As locals and immigrants
13 263 in Hong Kong transitioned to a more westernized lifestyles, higher consumption of meat was
14 264 associated with a higher risk of these types of cancer, whereas consumptions of vegetables
15 265 had a strong protective effect against pancreatic cancer, and moderate consumption of coffee
16 266 appeared to be beneficial against lung cancer [45,46]. Further studies on potential risk factors
17 267 are required.

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20 269 Short-stay immigrants had more fluctuating and non-stationary but inconspicuous period
21 270 effects before 2021 than locals and long-stay immigrants. Cumulatively, an arch pattern and
22 271 fluctuating curve depicting period effects externally resulted in an arch pattern of age-
23 272 standardized mortality rates for short-stay immigrant women and irregular rates for short-stay
24 273 immigrant men before 2021. The external performance of different period effects on mortality
25 274 rates could be most likely attributed to the higher effect of different lifestyles and social
26 275 development on new immigrants than on long-stay immigrants and locals in Hong Kong.
27 276 With respect to the age-standardized mortality rates and projections, consistent with previous
28 277 findings [47,48], we predict that the mortality rates of cancer in Hong Kong after 2021 will
29 278 continue to decline or remain relatively stable, consistent with the trends before 2020, except
30 279 for male immigrants who have stayed in Hong Kong for ≤ 10 years with colon cancer and
31 280 male immigrants who have stayed in Hong Kong for > 10 years with pancreatic cancer. Men
32 281 will be at higher risk of mortality rates of cancer than women, regardless of immigration
33 282 status. They are also compatible with the results in [4] that males suffer from higher risk of
34 283 these types of cancer except for prostate cancer than females. Furthermore, new immigrant
35 284 women will be at lower risk than local women, even though long-stay immigrants will suffer
36 285 from higher mortality rates than locals in the future. Potential interpretations could be
37 286 consistent with those for birth cohort effects, as age and period effect are considered as
38 287 confounders of cohort effect.

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40
41 289 In the past few decades, spurred by an increasing burden of high incidence and mortality rates
42 290 of cancer, several studies focused on the inherent identification dilemma of three effects in the
43 291 APC model. Further, complicated population distribution and immigration status in Hong

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4 292 Kong, one of the areas with the highest population density and migration frequency in the
5 293 world, have intricate causes and inherent dynamics of cancer and other diseases. To our
6 294 knowledge, few studies have assessed the relationship between immigration status and cancer
7 mortality. Therefore, this study is original to examine the effect of the length of stay in Hong
8 295 Kong and origins of previous residence on cancer deaths, which is instructive for further
9 296 immigration policy making and targeted strategies of disease detection and intervention.
10 297 However, this study had several limitations. Given the non-identifiability problem in age-
11 298 period-cohort models, we could only depict trends and variations among different
12 299 immigration and sex groups, as illustrated in figures, and insufficiently perform the estimates
13 300 of the contributions of three effects or subgroups to mortality rates. Furthermore, we adopted
14 301 cubic smoothing spline to estimate populations of immigrants and locals due to the large
15 302 proportion of unspecified immigration status from official demographic projections.
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306 **Conclusion**

307 We conclude that immigrants, especially short-stay immigrants, had more pronounced
308 fluctuations and sharper slopes of age, cohort, and period effects than locals. Men will be at a
309 higher risk of mortality rates of six types of cancer than women in the future. Male
310 immigrants who have stayed in Hong Kong for ≤ 10 years with colon cancer and male
311 immigrants who have stayed in Hong Kong for > 10 years with pancreatic cancer would
312 perform significant uptrend in the future, while other immigration groups for each type of
313 cancer would continue to decline or remain relatively stable. The predictive means of long-
314 stay immigrants for each type of cancer would be greater than locals.
315

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4 316 **Declaration**

5
6 317 **Ethical approval and consent to participate**

7
8 318 Ethical approval and consent to participate are not applicable. This study does not involve
9
10 319 human participants. Data was obtained from the Census and Statistics Department of Hong
11
12 320 Kong.

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14 321 **Consent for publication**

15
16 322 Not applicable.

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19 323 **Availability of data and materials**

20
21 324 Data of population in Hong Kong was retrieved from Census and Statistics Department. Codes
22
23 325 for APC and BAPC analysis are available in the GitHub repository
24
25 326 <https://github.com/kshz2164313/APC-population-projections-for-immigration-HK>

26
27 327 **Author contributions**

28
29 328 **Yanji Zhao:** Methodology, Formal analysis, Data Curation, Writing - Original Draft,
30 329 Visualization

31
32 330 **Zian Zhuang:** Methodology, Formal analysis, Data Curation, Writing - Review & Editing

33
34 331 **Lin Yang:** Validation, Writing - Review & Editing

35
36 332 **Daihai He:** Conceptualization, Writing - Review & Editing, Supervision

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39
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45
46 337 **Conflict of interest**

47
48 338 None declared.

49
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52 340 None.

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343 References

- 344
- 345 1. Fan S-C. The population projection of Hong Kong. *Southeast Asian Journal of Social Science*.
346 1974;2(1/2):105-17.
- 347 2. Department CaS. Hong Kong Statistics 1947-1967 (Report).
348 https://www.statistics.gov.hk/pub/hist/1961_1970/B10100031967AN67E0100.pdf,
349 Accessed 4th May 2019.
- 350 3. Department CaS. Demographic Trends in Hong Kong 1981-2011 (Report).
351 <http://www.statistics.gov.hk/pub/B1120017032012XXXXB0100.pdf>, Accessed 4th May 2019.
- 352 4. Sung H, Ferlay J, Siegel RL, Laversanne M, Soerjomataram I, Jemal A, et al. Global Cancer
353 Statistics 2020: GLOBOCAN Estimates of Incidence and Mortality Worldwide for 36 Cancers
354 in 185 Countries. *CA: A Cancer Journal for Clinicians*. 2021 2021/05/01;71(3):209-49. doi:
355 <https://doi.org/10.3322/caac.21660>.
- 356 5. Wang XR, Chiu YL, Qiu H, Au JSK, Yu ITS. The roles of smoking and cooking emissions
357 in lung cancer risk among Chinese women in Hong Kong. *Annals of Oncology*. 2009
358 2009/04/01;20(4):746-51. doi: <https://doi.org/10.1093/annonc/mdn699>.
- 359 6. Chiu Y-L, Wang X-R, Qiu H, Yu IT-S. Risk factors for lung cancer: a case-control study in
360 Hong Kong women. *Cancer Causes & Control*. 2010 2010/05/01;21(5):777-85. doi:
361 10.1007/s10552-010-9506-9.
- 362 7. Office on S, Health. Publications and Reports of the Surgeon General. Women and
363 Smoking: A Report of the Surgeon General. Atlanta (GA): Centers for Disease Control and
364 Prevention (US); 2001.
- 365 8. Escobedo LG, Peddicord JP. Smoking prevalence in US birth cohorts: the influence of gender
366 and education. *American Journal of Public Health*. 1996 1996/02/01;86(2):231-6. doi:
367 10.2105/AJPH.86.2.231.
- 368 9. Husten CG, Shelton DM, Chrismon JH, Lin YC, Mowery P, Powell FA. Cigarette smoking
369 and smoking cessation among older adults: United States, 1965-94. *Tobacco Control*.
370 1997;6(3):175. doi: 10.1136/tc.6.3.175.
- 371 10. Bolego C, Poli A, Paoletti R. Smoking and gender. *Cardiovascular Research*.
372 2002;53(3):568-76. doi: 10.1016/S0008-6363(01)00520-X.
- 373 11. Doll R, Hill AB. The mortality of doctors in relation to their smoking habits; a preliminary
374 report. *Br Med J*. 1954;1(4877):1451-5. PMID: 13160495. doi: 10.1136/bmj.1.4877.1451.
- 375 12. Ramada Rodilla JM, Calvo Cerrada B, Serra Pujadas C, Delclos GL, Benavides FG. Fiber
376 burden and asbestos-related diseases: an umbrella review. *Gaceta Sanitaria*. 2021 2021/06/11/.
377 doi: <https://doi.org/10.1016/j.gaceta.2021.04.001>.
- 378 13. Collishaw NE, Kirkbride J, Wigle DT. Tobacco smoke in the workplace: an occupational
379 health hazard. *Can Med Assoc J*. 1984;131(10):1199-204. PMID: 6498670.
- 380 14. Dresler CM, Fratelli C, Babb J, Everley L, Evans AA, Clapper ML. Gender differences in
381 genetic susceptibility for lung cancer. *Lung Cancer*. 2000 2000/12/01;30(3):153-60. doi:
382 [https://doi.org/10.1016/S0169-5002\(00\)00163-X](https://doi.org/10.1016/S0169-5002(00)00163-X).
- 383 15. Alexandrov K, Cascorbi I, Rojas M, Bouvier G, Kriek E, Bartsch H. CYP1A1 and GSTM1
384 genotypes affect benzo[a]pyrene DNA adducts in smokers' lung: comparison with
385 aromatic/hydrophobic adduct formation. *Carcinogenesis*. 2002;23(12):1969-77. doi:

- 1
2
3 386 10.1093/carcin/23.12.1969.
- 4 387 16. Samet JM. Radon and Lung Cancer. JNCI: Journal of the National Cancer Institute.
5 388 1989;81(10):745-58. doi: 10.1093/jnci/81.10.745.
- 6 389 17. Darby S, Hill D, Auvinen A, Barros-Dios JM, Baysson H, Bochicchio F, et al. Radon in
7 390 homes and risk of lung cancer: collaborative analysis of individual data from 13 European case-
8 391 control studies. BMJ. 2005;330(7485):223. doi: 10.1136/bmj.38308.477650.63.
- 9 392 18. Raaschou-Nielsen O, Andersen ZJ, Beelen R, Samoli E, Stafoggia M, Weinmayr G, et al.
10 393 Air pollution and lung cancer incidence in 17 European cohorts: prospective analyses from the
11 394 European Study of Cohorts for Air Pollution Effects (ESCAPE). The Lancet Oncology. 2013
12 395 2013/08/01/;14(9):813-22. doi: [https://doi.org/10.1016/S1470-2045\(13\)70279-1](https://doi.org/10.1016/S1470-2045(13)70279-1).
- 13 396 19. Abubakar II, Tillmann T, Banerjee A. Global, regional, and national age-sex specific all-
14 397 cause and cause-specific mortality for 240 causes of death, 1990-2013: a systematic analysis
15 398 for the Global Burden of Disease Study 2013. Lancet. 2015 Jan 10;385(9963):117-71.
- 16 399 20. Wild C. World cancer report 2014. Wild CP, Stewart BW, editors. Geneva, Switzerland:
17 400 World Health Organization; 2014.
- 18 401 21. *2018 Summary-20190719*. Retrieved August 26, 2022, from
19 402 [https://www.who.int/docs/default-source/wpro---documents/countries/china/2018-gats-china-](https://www.who.int/docs/default-source/wpro---documents/countries/china/2018-gats-china-factsheet-cn-en.pdf?sfvrsn=3f4e2da9_2)
20 403 [factsheet-cn-en.pdf?sfvrsn=3f4e2da9_2](https://www.who.int/docs/default-source/wpro---documents/countries/china/2018-gats-china-factsheet-cn-en.pdf?sfvrsn=3f4e2da9_2)
- 21 404 22. *Thematic household survey*. Retrieved August 26, 2022, from
22 405 https://www.censtatd.gov.hk/en/data/stat_report/product/B1130201/att/B11302702020XXXX
23 406 [B0100.pdf](https://www.censtatd.gov.hk/en/data/stat_report/product/B1130201/att/B11302702020XXXX)
- 24 407 23. Estimated alcohol consumption per capita in Hong Kong. Change4Health. (n.d.).
25 408 Retrieved December 1, 2022, from
26 409 [https://www.change4health.gov.hk/en/alcohol_aware/figures/alcohol_consumption/index.htm](https://www.change4health.gov.hk/en/alcohol_aware/figures/alcohol_consumption/index.html)
27 410 [l](https://www.change4health.gov.hk/en/alcohol_aware/figures/alcohol_consumption/index.html)
- 28 411 24. World Health Organization. Global status report on alcohol and health 2018. World
29 412 Health Organization; 2019 Feb 14.
- 30 413 25. Zhao S, Dong H, Qin J, Liu H, Li Y, Chen Y, et al. Breast cancer mortality in Chinese
31 414 women: does migrant status play a role? Annals of Epidemiology. 2019 2019/12/01/;40:28-
32 415 34.e2. doi: <https://doi.org/10.1016/j.annepidem.2019.10.006>.
- 33 416 26. Gomez SL, Yang J, Lin S-W, McCusker M, Sandler A, Cheng I, et al. Incidence trends of
34 417 lung cancer by immigration status among Chinese Americans. Cancer Epidemiol Biomarkers
35 418 Prev. 2015;24(8):1157-64. PMID: 25990553. doi: 10.1158/1055-9965.EPI-15-0123.
- 36 419 27. Hemminki K, Li X, Czene K. Cancer risks in first-generation immigrants to Sweden.
37 420 International Journal of Cancer. 2002 2002/05/10;99(2):218-28. doi:
38 421 <https://doi.org/10.1002/ijc.10322>.
- 39 422 28. Vanthomme K, Roskamp M, De Schutter H, Vandenneede H. Lung cancer incidence
40 423 differences in migrant men in Belgium, 2004–2013: histology-specific analyses. BMC Cancer.
41 424 2021 2021/03/30;21(1):328. doi: 10.1186/s12885-021-08038-6.
- 42 425 29. Schooling M, Leung GM, Janus ED, Ho SY, Hedley AJ, Lam TH. Childhood migration
43 426 and cardiovascular risk. International Journal of Epidemiology. 2004;33(6):1219-26. doi:
44 427 10.1093/ije/dyh221.
- 45 428 30. Leung JYY, Li AM, Leung GM, Schooling CM. Mode of delivery and childhood
46 429 hospitalizations for asthma and other wheezing disorders. Clinical & Experimental Allergy.

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2
3 430 2015 2015/06/01;45(6):1109-17. doi: <https://doi.org/10.1111/cea.12548>.
- 4 431 31. Baker A, Bray I. Bayesian projections: what are the effects of excluding data from younger
5 432 age groups?. *American Journal of Epidemiology*. 2005 Oct 15;162(8):798-805.
- 6 433 32. Rosenberg PS, Anderson WF. Age-Period-Cohort Models in Cancer Surveillance Research:
7 434 Ready for Prime Time? APC Models. *Cancer Epidemiology, Biomarkers & Prevention*. 2011
8 435 Jul 1;20(7):1263-8.
- 9 436 33. Holford T. Analyzing the effects of age, period and cohort on incidence and mortality rates.
10 437 *Stat Meth Med Res*. 1992;1:317-37.
- 11 438 34. Brookmeyer R, Stroup DF, editors. *Monitoring the health of populations: statistical*
12 439 *principles and methods for public health surveillance*. Oxford University Press; 2004.
- 13 440 35. Riebler A, Held L. Projecting the future burden of cancer: Bayesian age–period–cohort
14 441 analysis with integrated nested Laplace approximations. *Biometrical Journal*. 2017
15 442 May;59(3):531-49.
- 16 443 36. Knoll M, Furkel J, Debus J, Abdollahi A, Karch A, Stock C. An R package for an integrated
17 444 evaluation of statistical approaches to cancer incidence projection. *BMC medical research*
18 445 *methodology*. 2020 Dec;20(1):1-1.
- 19 446 37. Ahmad OB, Boschi-Pinto C, Lopez AD, Murray CJ, Lozano R, Inoue M. Age
20 447 standardization of rates: a new WHO standard. Geneva: World Health Organization. 2001
21 448 Jan;9(10):1-4.
- 22 449 38. Sung H, Ferlay J, Siegel RL, Laversanne M, Soerjomataram I, Jemal A, Bray F. Global
23 450 cancer statistics 2020: GLOBOCAN estimates of incidence and mortality worldwide for 36
24 451 cancers in 185 countries. *CA: a cancer journal for clinicians*. 2021 May;71(3):209-49.
- 25 452 39. Mousavi SM, Fallah M, Sundquist K, Hemminki K. Age-and time-dependent changes in
26 453 cancer incidence among immigrants to Sweden: colorectal, lung, breast and prostate cancers.
27 454 *International journal of cancer*. 2012 Jul 15;131(2):E122-8.
- 28 455 40. National Cancer Institute. SEER stat fact sheets: liver and intrahepatic bile duct cancer.
- 29 456 41. Wu X, Chung VC, Hui EP, Ziea ET, Ng BF, Ho RS, Tsoi KK, Wong S, Wu JC.
30 457 Effectiveness of acupuncture and related therapies for palliative care of cancer: overview of
31 458 systematic reviews. *Scientific reports*. 2015 Nov 26;5(1):1-5.
- 32 459 42. Sung H, Rosenberg PS, Chen WQ, Hartman M, Lim WY, Chia KS, Wai-Kong Mang O,
33 460 Tse L, Anderson WF, Yang XR. The impact of breast cancer-specific birth cohort effects among
34 461 younger and older Chinese populations. *International journal of cancer*. 2016 Aug
35 462 1;139(3):527-34.
- 36 463 43. *The world economy volume 1: a millennial perspective, 2, Historical statistics*: Academic
37 464 *Foundation, Gurgaon, India (2007)*
- 38 465 44. Elias SG, Peeters PH, Grobbee DE, van Noord PA. The 1944-1945 Dutch famine and
39 466 subsequent overall cancer incidence. *Cancer Epidemiology Biomarkers & Prevention*. 2005
40 467 Aug;14(8):1981-5.
- 41 468 45. Chiu YL, Wang XR, Qiu H, Yu IT. Risk factors for lung cancer: a case–control study in
42 469 Hong Kong women. *Cancer Causes & Control*. 2010 May;21(5):777-85.
- 43 470 46. Li J, Lam AS, Yau ST, Yiu KK, Tsoi KK. Antihypertensive treatments and risks of lung
44 471 Cancer: A large population-based cohort study in Hong Kong. *BMC cancer*. 2021 Dec;21(1):1-
45 472 9.
- 46 473 47. Du J, Sun H, Sun Y, Du J, Cao W, Sun S. Assessment of age, period, and cohort effects of

1
2
3 474 lung cancer incidence in Hong Kong and projection up to 2030 based on changing
4 475 demographics. *American Journal of Cancer Research*. 2021;11(12):5902.
5
6 476 48. *Centre for Health Protection, Department of Health - Lung Cancer*. Centre for Health
7 477 Protection. Retrieved August 10, 2022, from
8 478 <https://www.chp.gov.hk/en/healthtopics/content/25/49.html>
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4 480 **Figure 1.** Parameter estimates of age, period and cohort effects based on an age-period-cohort model of males' (a)
5 481 and females' (b) lung cancer mortality rates and projections from 2022 to 2030 (c) by immigrant groups: locals,
6 482 immigrants stay in Hong Kong for more than 10 years and immigrants stay in Hong Kong for less than or equal to
7 483 10 years. Age effect was assessed by mortality (left axis). Cohort and period effects were assessed by relative risk
8 484 (right axis), 95% confidence intervals are shown as shaded bands. Observations in (c) are shown as dots with the
9 485 predictive distribution between the 5% and 95% quantile, whereby each lighter shade of blue represents an
10 486 additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line
11 487 indicates where prediction started.
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Predictive mean of age-standardized mortality rates of lung cancer per 100,000 population						
Year	Female immigrants >10 (SD)	Female immigrants ≤10 (SD)	Female locals (SD)	Male immigrants >10 (SD)	Male immigrants ≤10 (SD)	Male locals (SD)
2022	41.33(1.86)	22.21(4.67)	30.21(3.54)	100.18(4.18)	79.89(10.40)	52.26(4.85)
2023	40.58(2.26)	20.55(5.37)	30.63(4.77)	97.17(5.33)	79.81(11.82)	50.82(5.38)
2024	39.86(2.74)	19.01(6.10)	31.05(6.38)	94.33(6.71)	79.72(13.42)	49.56(6.12)
2025	39.18(3.28)	17.57(6.80)	31.47(8.29)	91.69(8.24)	79.62(15.18)	48.17(6.96)
2026	38.52(3.85)	16.23(7.45)	31.89(10.46)	89.14(9.83)	79.49(17.08)	46.64(7.83)
2027	37.88(4.46)	15.00(8.04)	32.31(12.86)	86.65(11.46)	79.32(19.09)	45.12(8.75)
2028	37.26(5.09)	13.85(8.56)	32.73(15.48)	84.18(13.10)	79.08(21.17)	43.82(9.75)
2029	36.64(5.73)	12.79(9.01)	33.14(18.30)	81.80(14.73)	78.77(23.32)	42.66(10.79)
2030	36.04(6.39)	11.80(9.39)	33.55(21.32)	79.55(16.37)	78.40(25.52)	41.43(11.79)

490 **Table 1.** Predictive means and standard deviations of age-standardized mortality rates of lung
 491 cancer per 100,000 population for each gender and immigrant status from 2022 to 2030.
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Predictive mean of age-standardized morality rates of pancreatic cancer per 100,000 population						
Year	Female immigrants >10 (SD)	Female immigrants ≤10 (SD)	Female locals (SD)	Male immigrants >10 (SD)	Male immigrants ≤10 (SD)	Male locals (SD)
2022	11.11(0.74)	5.437(1.55)	9.011(1.22)	17.87(1.18)	7.874(2.37)	12.28(1.48)
2023	11.35(0.90)	5.436(1.69)	9.150(1.33)	18.48(1.49)	7.760(2.53)	12.48(1.64)
2024	11.61(1.09)	5.430(1.83)	9.289(1.47)	19.11(1.87)	7.639(2.70)	12.69(1.83)
2025	11.87(1.31)	5.420(1.99)	9.429(1.64)	19.77(2.31)	7.511(2.87)	12.89(2.06)
2026	12.14(1.56)	5.405(2.15)	9.569(1.83)	20.46(2.83)	7.376(3.05)	13.11(2.32)
2027	12.42(1.83)	5.386(2.31)	9.710(2.04)	21.18(3.41)	7.237(3.22)	13.32(2.63)
2028	12.70(2.14)	5.363(2.48)	9.851(2.28)	21.92(4.07)	7.094(3.40)	13.55(2.96)
2029	12.99(2.48)	5.337(2.66)	9.994(2.54)	22.69(4.79)	6.946(3.57)	13.78(3.33)
2030	13.29(2.84)	5.307(2.84)	10.13(2.82)	23.49(5.60)	6.796(3.75)	14.02(3.74)

493 **Table 2.** Predictive means and standard deviations of age-standardized morality rates of
 494 pancreatic cancer per 100,000 population for each gender and immigrant status from 2022 to
 495 2030.

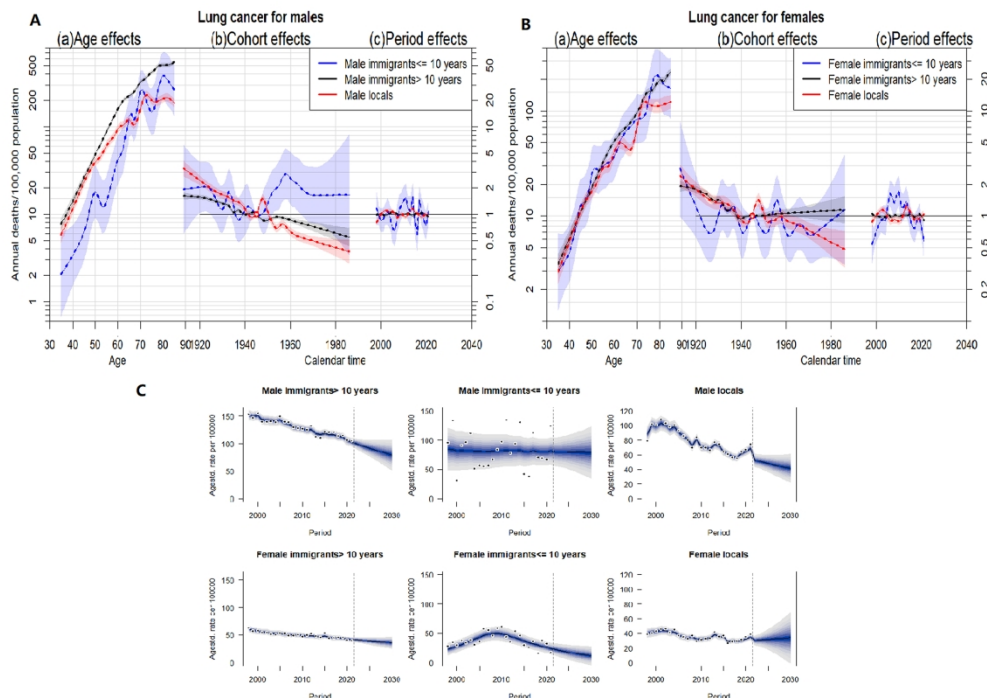


Figure 1. Parameter estimates of age, period and cohort effects based on an age-period-cohort model of males' (a) and females' (b) lung cancer mortality rates and projections from 2022 to 2030 (c) by immigrant groups: locals, immigrants stay in Hong Kong for more than 10 years and immigrants stay in Hong Kong for less than or equal to 10 years. Age effect was assessed by mortality (left axis). Cohort and period effects were assessed by relative risk (right axis), 95% confidence intervals are shown as shaded bands. Observations in (c) are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of blue represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.

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Predictive mean of age-standardized morality rates of colon cancer per 100,000 population

Year	Female immigrants >10 (SD)	Female immigrants ≤10 (SD)	Female locals (SD)	Male immigrants >10 (SD)	Male immigrants ≤10 (SD)	Male locals (SD)
2022	18.95(1.12)	7.704(2.50)	13.46(1.59)	29.81(1.45)	16.77(3.76)	19.80(2.07)
2023	18.76(1.36)	7.248(2.81)	13.23(1.71)	29.65(1.79)	17.00(4.17)	19.38(2.21)
2024	18.58(1.65)	6.819(3.10)	13.00(1.86)	29.51(2.18)	17.22(4.64)	18.97(2.39)
2025	18.42(1.97)	6.415(3.37)	12.76(2.04)	29.39(2.62)	17.45(5.14)	18.57(2.61)
2026	18.26(2.33)	6.034(3.61)	12.53(2.24)	29.30(3.11)	17.66(5.68)	18.17(2.85)
2027	18.11(2.70)	5.674(3.82)	12.29(2.45)	29.21(3.63)	17.88(6.27)	17.79(3.11)
2028	17.98(3.10)	5.334(4.01)	12.05(2.68)	29.13(4.19)	18.09(6.89)	17.42(3.40)
2029	17.85(3.52)	5.013(4.17)	11.82(2.91)	29.05(4.77)	18.30(7.56)	17.06(3.69)
2030	17.72(3.96)	4.710(4.30)	11.58(3.16)	28.98(5.38)	18.50(8.25)	16.70(4.00)

eTable 1. Predictive means and standard deviations of age-standardized morality rates of colon cancer per 100,000 population for each gender and immigrant status from 2022 to 2030.

Predictive mean of age-standardized morality rates of liver cancer per 100,000 population						
Year	Female immigrants >10 (SD)	Female immigrants ≤10 (SD)	Female locals (SD)	Male immigrants >10 (SD)	Male immigrants ≤10 (SD)	Male locals (SD)
2022	10.67(0.71)	8.65(1.81)	6.36(0.87)	49.22(2.36)	39.02(6.48)	22.16(2.08)
2023	10.09(0.85)	8.38(1.94)	6.07(0.90)	47.76(2.93)	37.38(7.46)	21.01(2.21)
2024	9.53(1.00)	8.11(2.08)	5.79(0.93)	46.35(3.59)	35.79(8.51)	19.91(2.38)
2025	9.01(1.15)	7.84(2.21)	5.52(0.97)	44.99(4.30)	34.25(9.58)	18.85(2.58)
2026	8.49(1.30)	7.58(2.35)	5.26(1.01)	43.66(5.04)	32.76(10.6)	17.83(2.78)
2027	8.02(1.45)	7.32(2.49)	5.01(1.06)	42.36(5.80)	31.31(11.6)	16.85(2.99)
2028	7.56(1.58)	7.07(2.62)	4.76(1.10)	41.10(6.56)	29.91(12.6)	15.91(3.20)
2029	7.13(1.71)	6.82(2.75)	4.53(1.15)	39.88(7.32)	28.55(13.5)	15.02(3.40)
2030	6.73(1.83)	6.58(2.88)	4.30(1.19)	38.70(8.08)	27.25(14.3)	14.17(3.58)

eTable 2. Predictive means and standard deviations of age-standardized morality rates of liver cancer per 100,000 population for each gender and immigrant status from 2022 to 2030.

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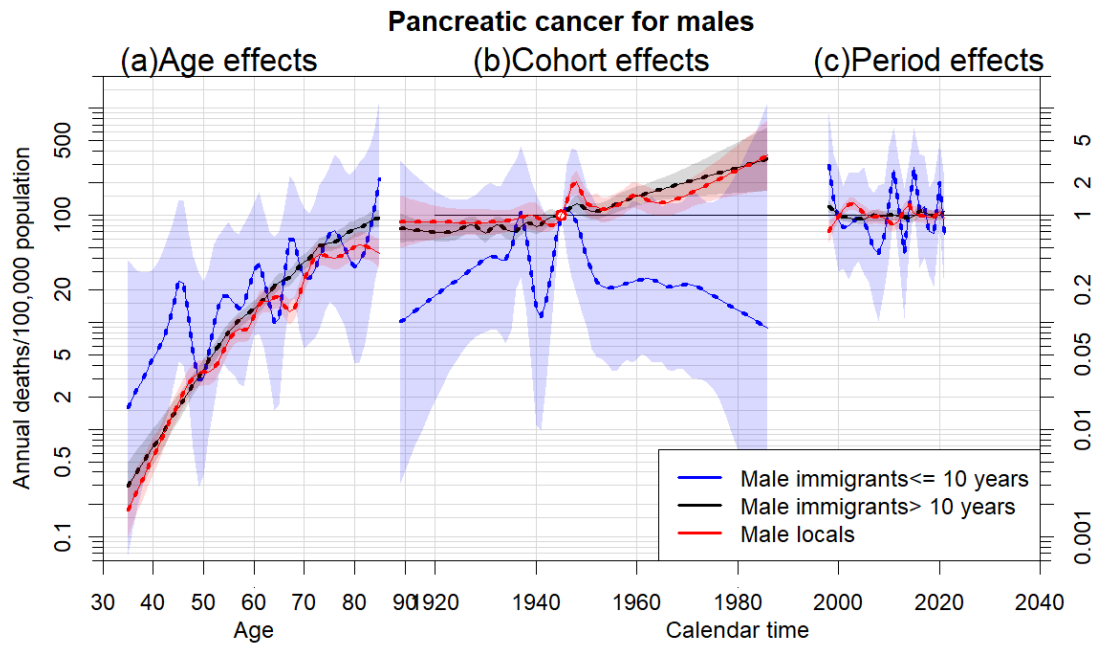
Predictive mean of age-standardized morality rates of stomach cancer per 100,000 population

Year	Female immigrants >10 (SD)	Female immigrants ≤10 (SD)	Female locals (SD)	Male immigrants >10 (SD)	Male immigrants ≤10 (SD)	Male locals (SD)
2022	7.94(0.62)	7.36(1.55)	4.89(0.51)	13.89(0.96)	15.19(3.38)	8.06(0.99)
2023	7.70(0.73)	7.32(1.69)	4.75(0.56)	13.33(1.20)	15.06(3.66)	7.73(1.02)
2024	7.47(0.86)	7.29(1.84)	4.61(0.62)	12.80(1.45)	14.92(3.97)	7.41(1.07)
2025	7.24(1.00)	7.28(2.01)	4.47(0.69)	12.30(1.72)	14.78(4.30)	7.09(1.12)
2026	7.03(1.14)	7.27(2.19)	4.33(0.76)	11.83(1.99)	14.64(4.65)	6.79(1.19)
2027	6.82(1.29)	7.27(2.39)	4.20(0.83)	11.38(2.25)	14.49(5.01)	6.50(1.25)
2028	6.62(1.43)	7.28(2.61)	4.07(0.91)	10.95(2.51)	14.34(5.39)	6.23(1.32)
2029	6.42(1.57)	7.30(2.84)	3.95(0.98)	10.53(2.76)	14.18(5.77)	5.96(1.39)
2030	6.24(1.71)	7.33(3.08)	3.82(1.06)	10.14(3.00)	14.03(6.16)	5.71(1.46)

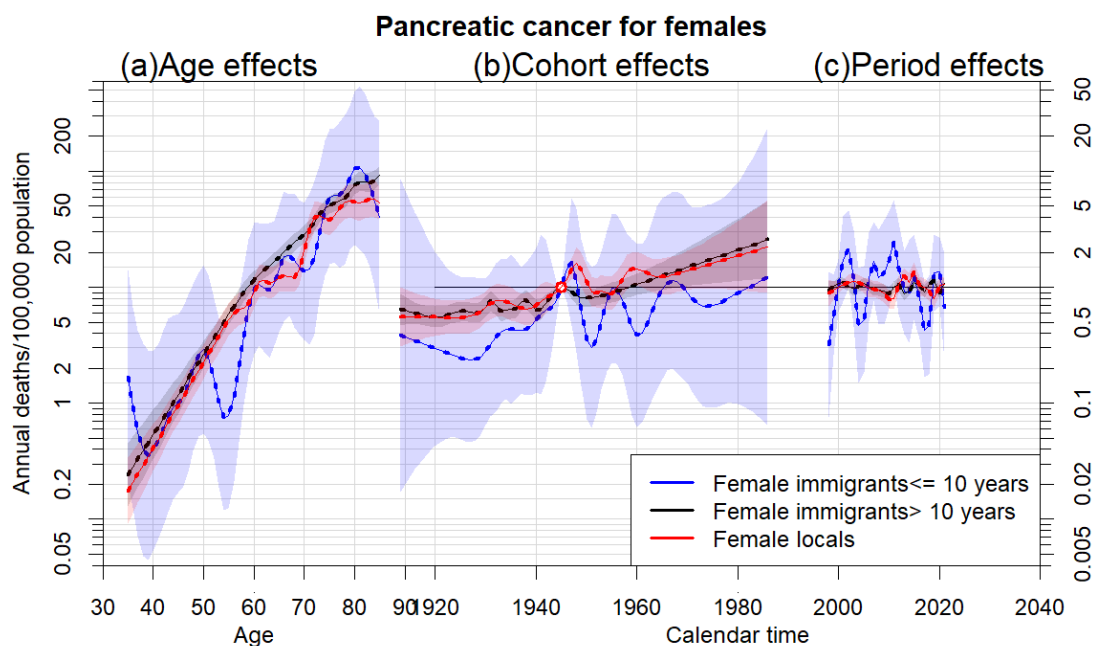
eTable 3. Predictive means and standard deviations of age-standardized morality rates of stomach cancer per 100,000 population for each gender and immigrant status from 2022 to 2030.

Predictive mean of age-standardized morality rates of prostate cancer per 100,000 population			
Year	Male immigrants >10 (SD)	Male immigrants ≤10 (SD)	Male locals (SD)
2022	14.58(0.79)	8.77(3.10)	9.65(1.56)
2023	14.57(0.95)	8.58(3.29)	9.67(1.65)
2024	14.55(1.14)	8.38(3.48)	9.69(1.76)
2025	14.53(1.36)	8.19(3.68)	9.71(1.90)
2026	14.51(1.60)	8.00(3.89)	9.74(2.05)
2027	14.48(1.86)	7.81(4.09)	9.78(2.23)
2028	14.45(2.13)	7.63(4.30)	9.81(2.43)
2029	14.41(2.42)	7.44(4.51)	9.85(2.64)
2030	14.37(2.71)	7.27(4.72)	9.89(2.87)

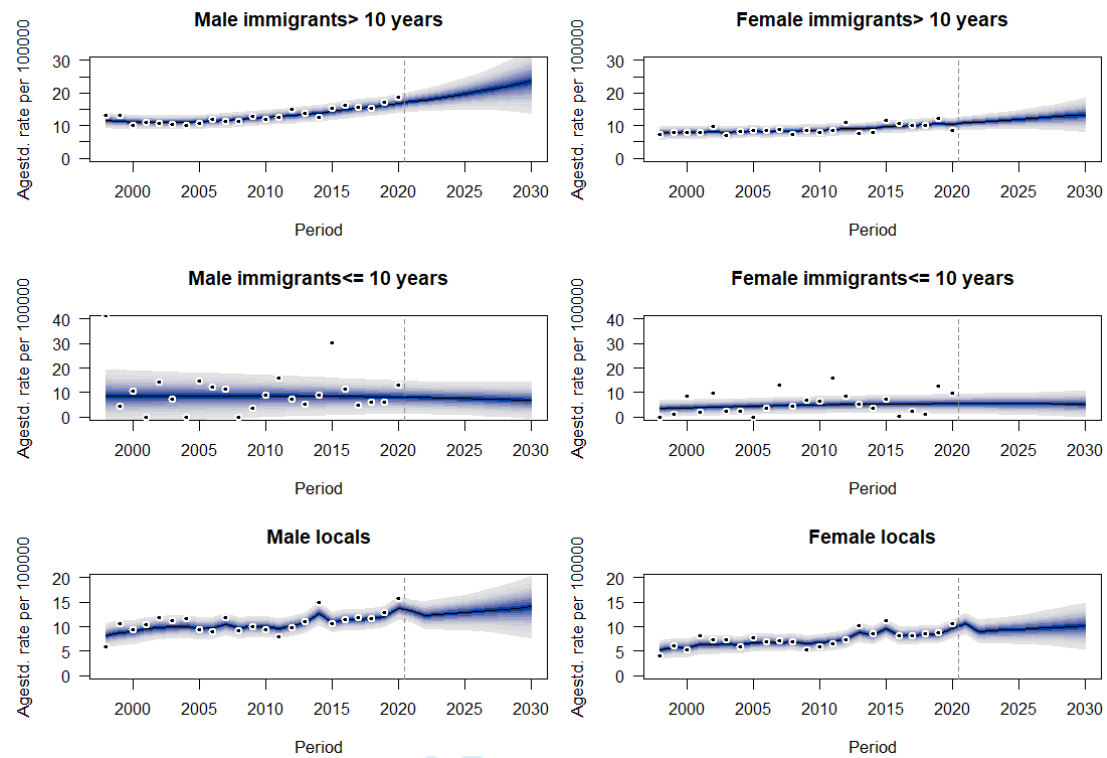
eTable 4. Predictive means and standard deviations of age-standardized morality rates of prostate cancer per 100,000 population for each gender and immigrant status from 2022 to 2030.



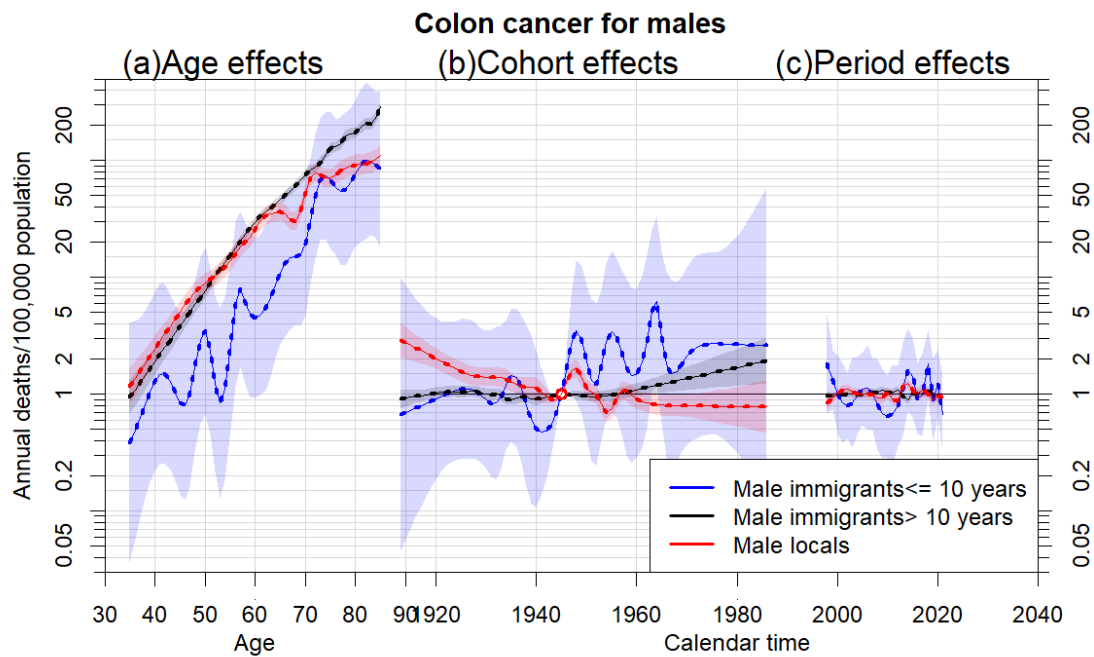
eFigure 1(a). Parameter estimates of age (a), period (b) and cohort (c) effects based on an age-period-cohort model of male pancreatic cancer mortality rates by immigrant groups: locals, immigrants stay in Hong Kong for more than 10 years and immigrants stay in Hong Kong for less than or equal to 10 years. Age effect was assessed by mortality (left axis). Cohort and period effects were assessed by relative risk (right axis), 95% confidence intervals are shown as shaded bands.



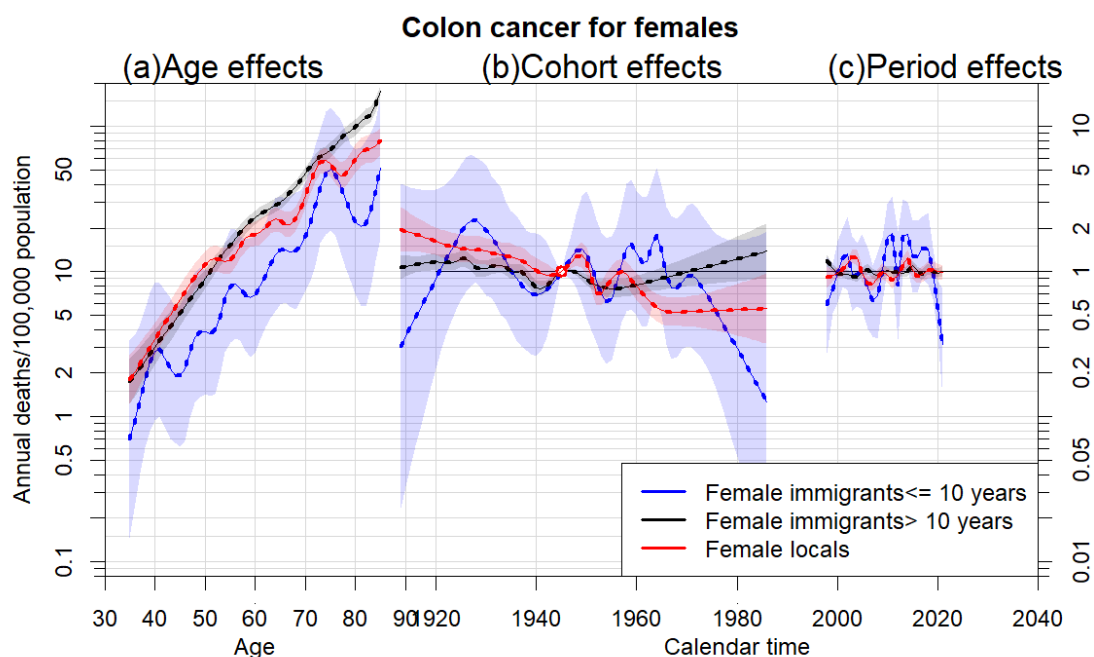
eFigure 1(b). Parameter estimates of age (a), period (b) and cohort (c) effects based on an age-period-cohort model of female pancreatic cancer mortality rates by immigrant groups: locals, immigrants stay in Hong Kong for more than 10 years and immigrants stay in Hong Kong for less than or equal to 10 years. Age effect was assessed by mortality (left axis). Cohort and period effects were assessed by relative risk (right axis), 95% confidence intervals are shown as shaded bands.



eFigure 1(c). Projections of pancreatic cancer mortality rates by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of blue represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.

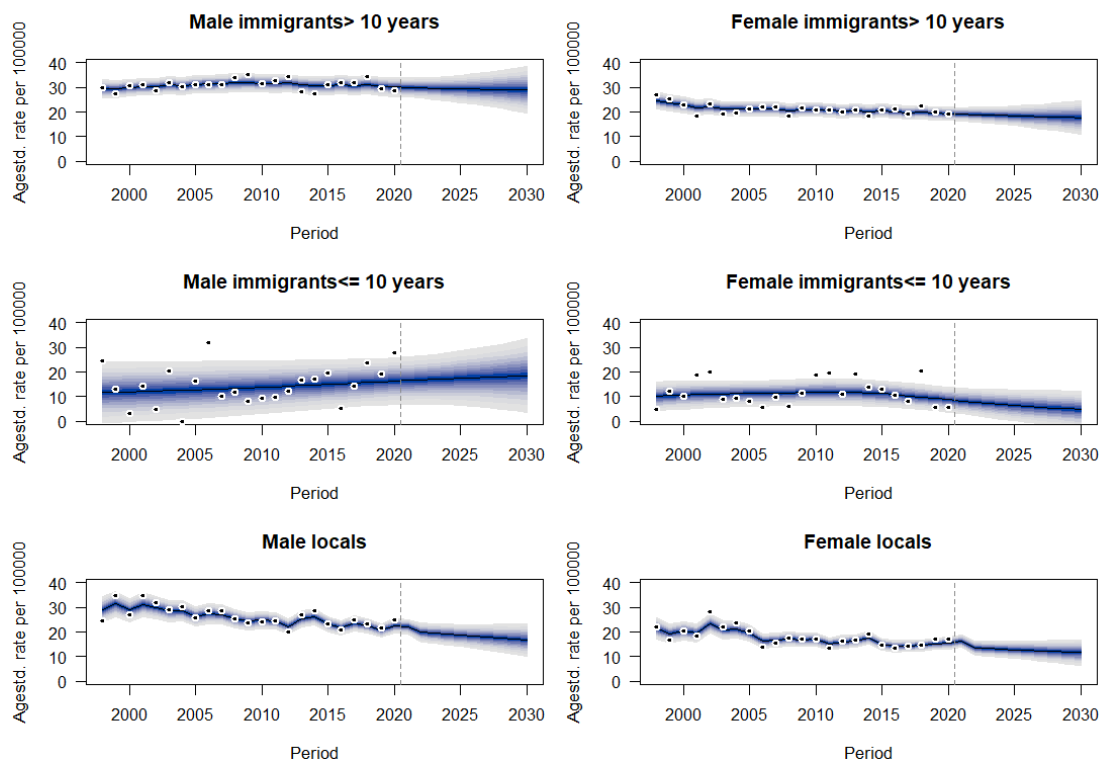


28 **eFigure 2(a).** Parameter estimates of age (a), period (b) and cohort (c) effects based on an
29 age-period-cohort model of male colon cancer mortality rates by immigrant groups: locals,
30 immigrants stay in Hong Kong for more than 10 years and immigrants stay in Hong Kong for
31 less than or equal to 10 years. Age effect was assessed by mortality (left axis). Cohort and
32 period effects were assessed by relative risk (right axis), 95% confidence intervals are shown
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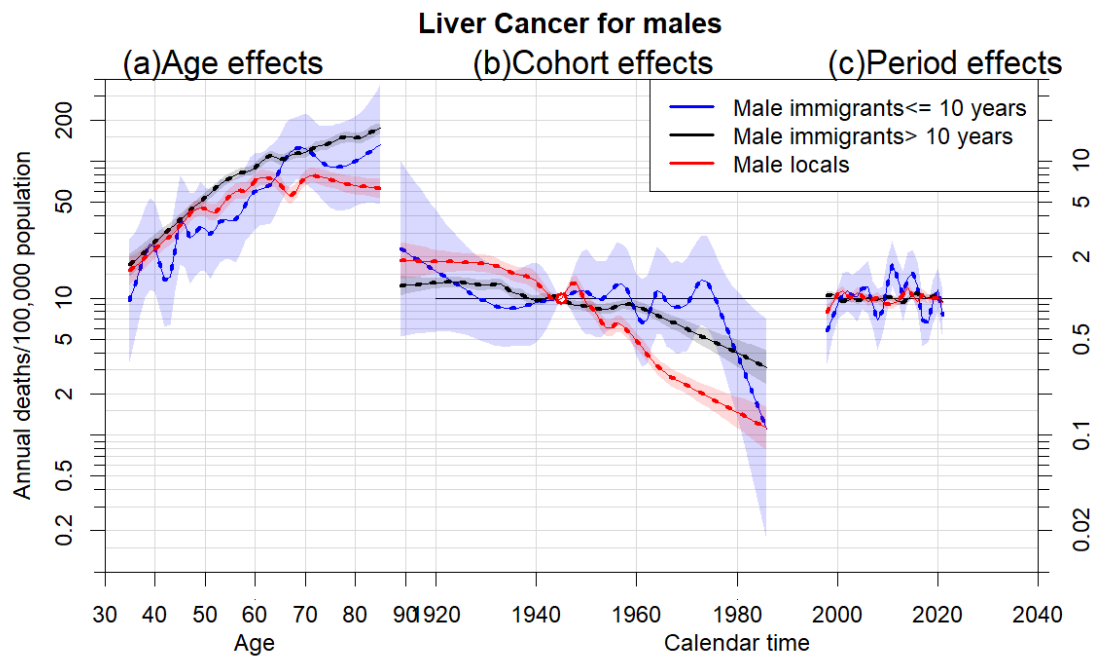


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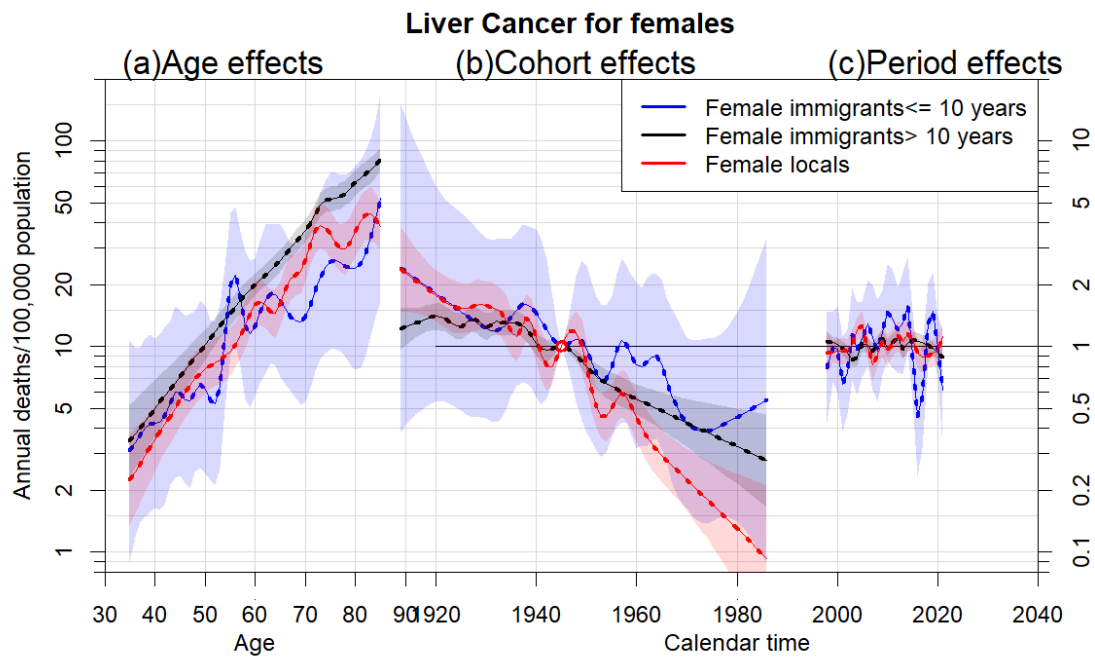
Figure 2(b). Parameter estimates of age (a), period (b) and cohort (c) effects based on an age-period-cohort model of female colon cancer mortality rates by immigrant groups: locals, immigrants stay in Hong Kong for more than 10 years and immigrants stay in Hong Kong for less than or equal to 10 years. Age effect was assessed by mortality (left axis). Cohort and period effects were assessed by relative risk (right axis), 95% confidence intervals are shown as shaded bands.



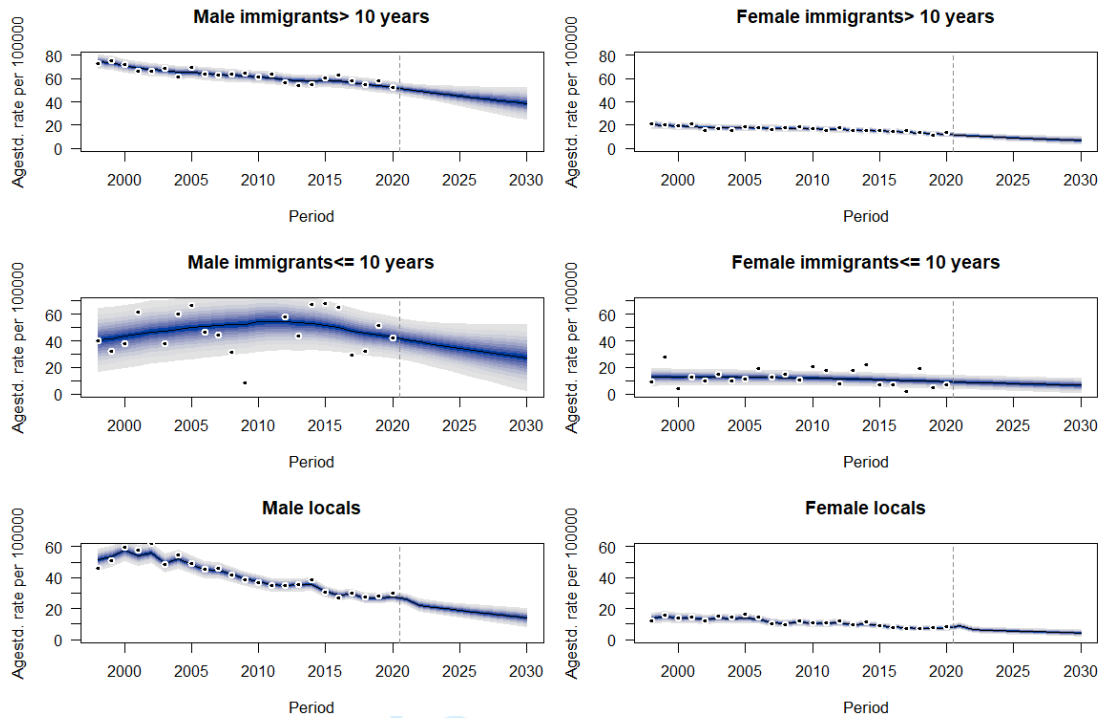
eFigure 2(c). Projections of colon cancer mortality rates by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of blue represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



eFigure 3(a). Parameter estimates of age (a), period (b) and cohort (c) effects based on an age-period-cohort model of male liver cancer mortality rates by immigrant groups: locals, immigrants stay in Hong Kong for more than 10 years and immigrants stay in Hong Kong for less than or equal to 10 years. Age effect was assessed by mortality (left axis). Cohort and period effects were assessed by relative risk (right axis), 95% confidence intervals are shown as shaded bands.



eFigure 3(b). Parameter estimates of age (a), period (b) and cohort (c) effects based on an age-period-cohort model of female liver cancer mortality rates by immigrant groups: locals, immigrants stay in Hong Kong for more than 10 years and immigrants stay in Hong Kong for less than or equal to 10 years. Age effect was assessed by mortality (left axis). Cohort and period effects were assessed by relative risk (right axis), 95% confidence intervals are shown as shaded bands.



eFigure 3(c). Projections of liver cancer mortality rates by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of blue represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.

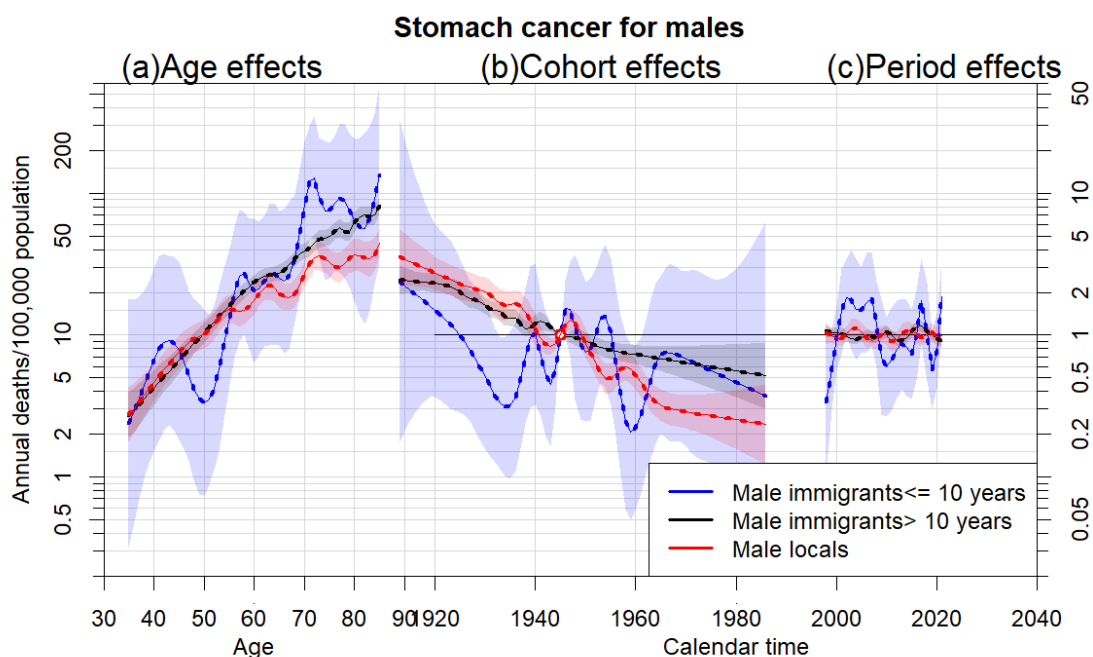


Figure 4(a). Parameter estimates of age (a), period (b) and cohort (c) effects based on an age-period-cohort model of male stomach cancer mortality rates by immigrant groups: locals, immigrants stay in Hong Kong for more than 10 years and immigrants stay in Hong Kong for less than or equal to 10 years. Age effect was assessed by mortality (left axis). Cohort and period effects were assessed by relative risk (right axis), 95% confidence intervals are shown as shaded bands.

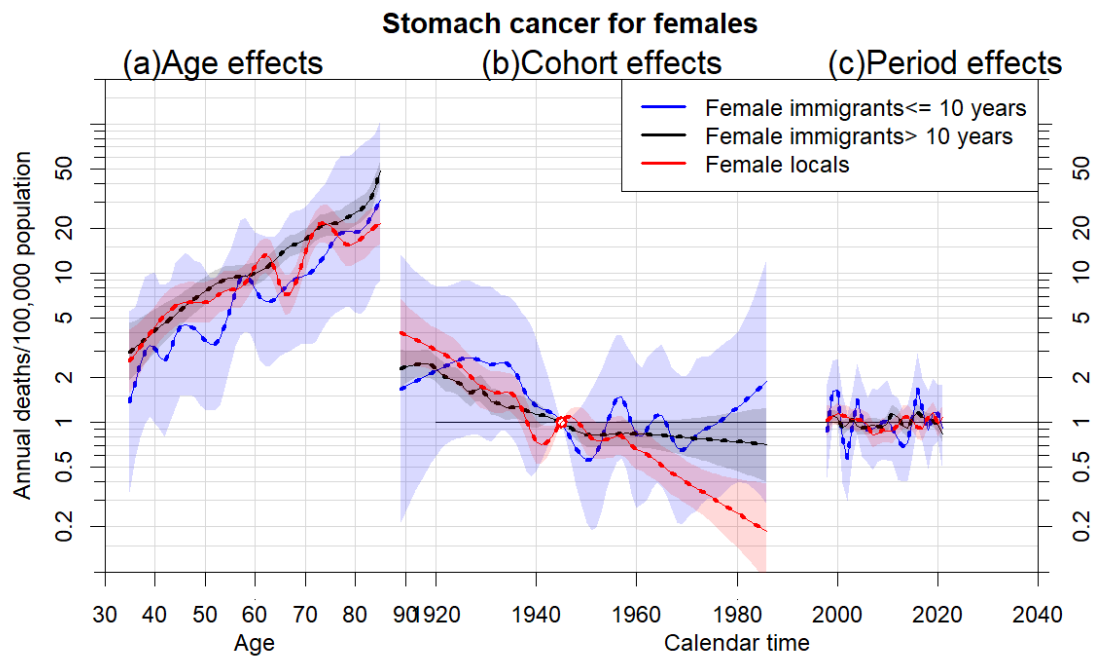
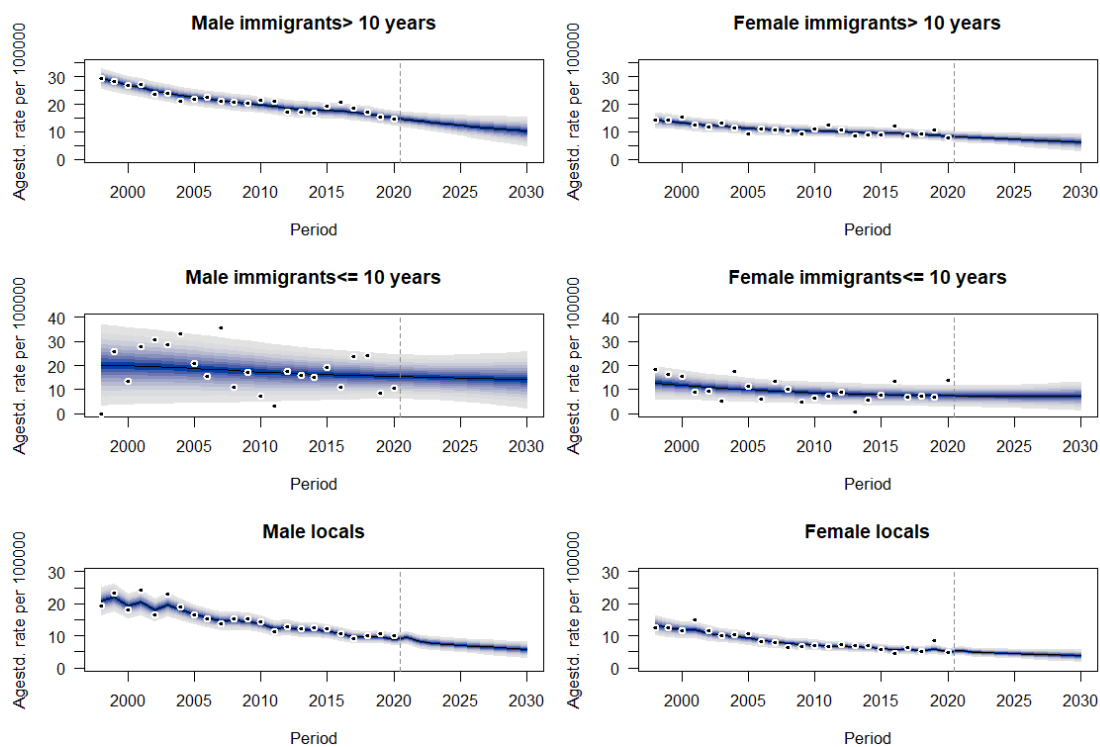
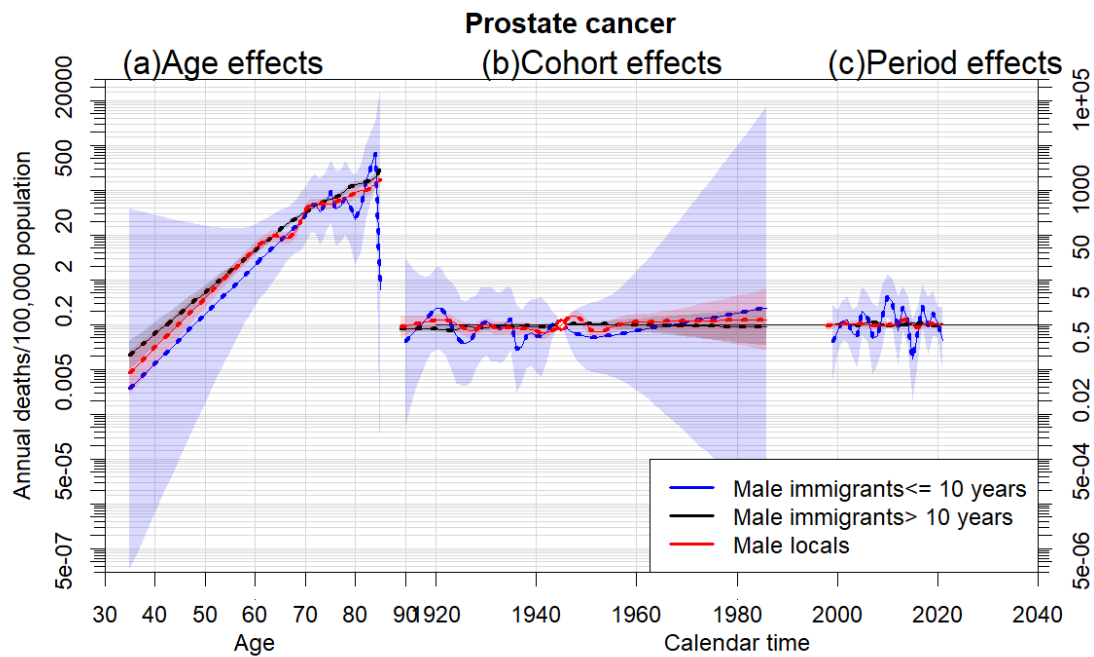


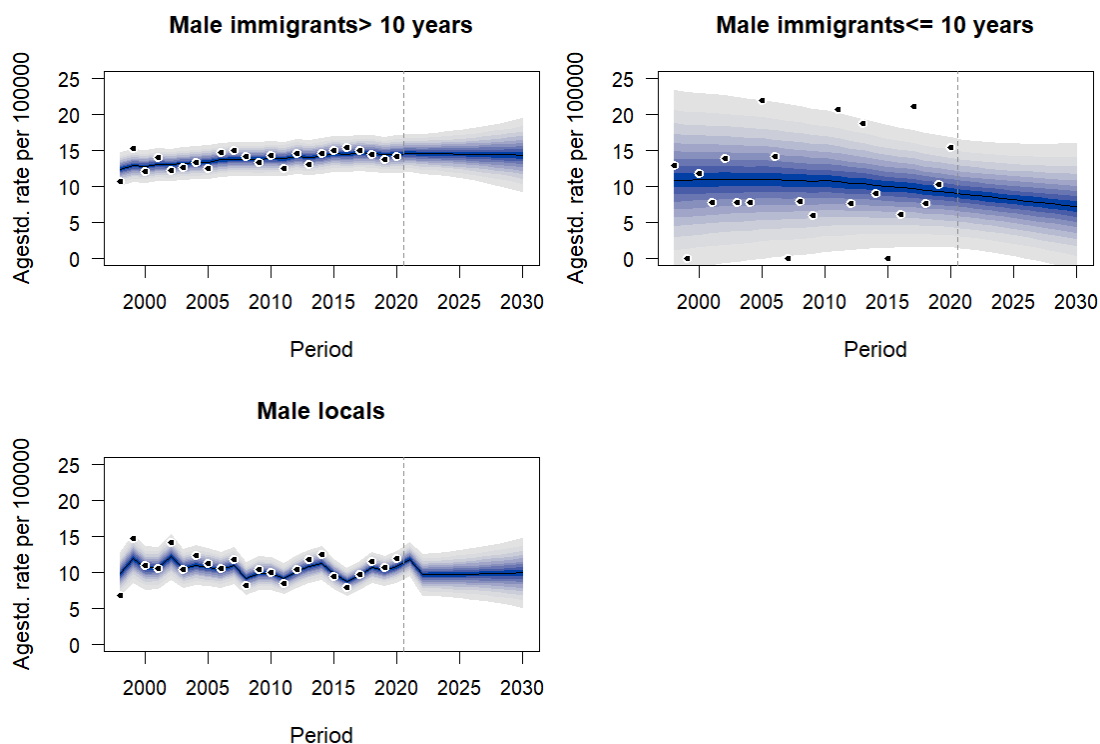
Figure 4(b). Parameter estimates of age (a), period (b) and cohort (c) effects based on an age-period-cohort model of female stomach cancer mortality rates by immigrant groups: locals, immigrants stay in Hong Kong for more than 10 years and immigrants stay in Hong Kong for less than or equal to 10 years. Age effect was assessed by mortality (left axis). Cohort and period effects were assessed by relative risk (right axis), 95% confidence intervals are shown as shaded bands.



eFigure 4(c). Projections of stomach cancer mortality rates by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of blue represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



28 **eFigure 5(a).** Parameter estimates of age (a), period (b) and cohort (c) effects based on an
29 age-period-cohort model of male prostate cancer mortality rates by immigrant groups: locals,
30 immigrants stay in Hong Kong for more than 10 years and immigrants stay in Hong Kong for
31 less than or equal to 10 years. Age effect was assessed by mortality (left axis). Cohort and
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eFigure 5(b). Projections of prostate cancer mortality rates by immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of blue represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.

Reporting checklist for cohort study.

Based on the STROBE cohort guidelines.

Instructions to authors

Complete this checklist by entering the page numbers from your manuscript where readers will find each of the items listed below.

Your article may not currently address all the items on the checklist. Please modify your text to include the missing information. If you are certain that an item does not apply, please write "n/a" and provide a short explanation.

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			Page Number
Title and abstract			
Title	#1a	Indicate the study's design with a commonly used term in the title or the abstract	1
Abstract	#1b	Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background / rationale	#2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	#3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	#4	Present key elements of study design early in the paper	5
Setting	#5	Describe the setting, locations, and relevant dates, including periods	5

		of recruitment, exposure, follow-up, and data collection	
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3	Eligibility criteria	#6a Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up.	5
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6	Eligibility criteria	#6b For matched studies, give matching criteria and number of exposed and unexposed	n/a
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10	Variables	#7 Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
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15	Data sources /		
16	measurement	#8 For each variable of interest give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group. Give information separately for for exposed and unexposed groups if applicable.	5
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22	Bias	#9 Describe any efforts to address potential sources of bias	5
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24	Study size	#10 Explain how the study size was arrived at	5
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27	Quantitative		
28	variables	#11 Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why	5
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31	Statistical		
32	methods	#12a Describe all statistical methods, including those used to control for confounding	
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37	Statistical	#12b Describe any methods used to examine subgroups and interactions	5
38	methods		
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41	Statistical	#12c Explain how missing data were addressed	5
42	methods		
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44	Statistical	#12d If applicable, explain how loss to follow-up was addressed	n/a
45	methods		
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48	Statistical	#12e Describe any sensitivity analyses	
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52	n/a		
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54	Results		
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57	Participants	#13a Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible,	n/a
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included in the study, completing follow-up, and analysed. Give information separately for for exposed and unexposed groups if applicable.

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5	Participants	#13b	Give reasons for non-participation at each stage 5
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7	Participants	#13c	Consider use of a flow diagram
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12	Descriptive data	#14a	Give characteristics of study participants (eg demographic, clinical, 5
13			social) and information on exposures and potential confounders. Give
14			information separately for exposed and unexposed groups if
15			applicable.
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19	Descriptive data	#14b	Indicate number of participants with missing data for each variable of
20			interest
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25	Descriptive data	#14c	Summarise follow-up time (eg, average and total amount)
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30	Outcome data	#15	Report numbers of outcome events or summary measures over time.
31			Give information separately for exposed and unexposed groups if
32			applicable.
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38	Main results	#16a	Give unadjusted estimates and, if applicable, confounder-adjusted 6
39			estimates and their precision (eg, 95% confidence interval). Make
40			clear which confounders were adjusted for and why they were
41			included
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44	Main results	#16b	Report category boundaries when continuous variables were n/a
45			categorized
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48	Main results	#16c	If relevant, consider translating estimates of relative risk into absolute
49			risk for a meaningful time period
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54	Other analyses	#17	Report other analyses done—eg analyses of subgroups and 7
55			interactions, and sensitivity analyses
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Discussion

1	Key results	#18	Summarise key results with reference to study objectives	8
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3	Limitations	#19	Discuss limitations of the study, taking into account sources of	10
4			potential bias or imprecision. Discuss both direction and magnitude of	
5			any potential bias.	
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8	Interpretation	#20	Give a cautious overall interpretation considering objectives,	8
9			limitations, multiplicity of analyses, results from similar studies, and	
10			other relevant evidence.	
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13	Generalisability	#21	Discuss the generalisability (external validity) of the study results	9
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16	Other			
17	Information			
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20	Funding	#22	Give the source of funding and the role of the funders for the present	11
21			study and, if applicable, for the original study on which the present	
22			article is based	
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26 This checklist was completed on 11. February 2023 using <https://www.goodreports.org/>, a tool made by the

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An age-period-cohort analysis and projection of cancer mortality in Hong Kong, 1998–2030

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An age-period-cohort analysis and projection of cancer mortality in Hong Kong, 1998–2030

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Word count: 3263

24 Abstract

25 **Objectives:** Complicated population distribution and immigration status in Hong Kong have
26 brought out intricate causes of diseases. This study was aimed to explore age, period, birth
27 cohort effects and effects across genders and immigration groups on mortality rates of lung,
28 pancreatic, colon, liver, prostate and stomach cancers and their projections.

30 **Design, Setting, and Participants:** Death registry data in Hong Kong between 1998 and 2021,
31 which were stratified by age, sex and immigration status. Immigration status was classified into
32 three groups: locals born in Hong Kong, long-stay immigrants and short-stay immigrants.

34 **Methods:** Age-period-cohort analysis was used to examine age, period, and birth cohort effects
35 for genders and immigration groups from 1998 to 2021. Bayesian age-period-cohort models
36 were applied to predict the mortality rates from 2022 to 2030.

38 **Results:** Short-stay immigrants revealed pronounced fluctuations of mortality rates by age and
39 of relative risks by cohort and period effects for six types of cancers than those of long-stay
40 immigrants and locals. Decreasing trends ($p<0.05$) or plateau ($p>0.05$) of forecasting mortality
41 rates of cancers occur for all immigration groups, except for increasing trends for short-stay
42 male immigrants with colon cancer (16.77 deaths to 18.50 deaths/100,000 $p<0.05$) and long-
43 stay male immigrants with pancreatic cancer (17.87 deaths to 23.49 deaths/100,000 $p<0.05$).
44 Men will be at a higher risk of mortality from cancers than women in the future (excluding
45 prostate cancer). Immigrants for each type of cancer and gender will be at a higher mortality
46 risk than locals.

48 **Conclusions:** Findings underscore the effect of gender and immigration status in Hong Kong
49 on mortality risks of cancers that immigrants for each type of cancer and gender will be at a
50 higher mortality risk than locals.

52 **Keywords:** Age-period-cohort analysis, immigration, mortality, lung cancer, pancreatic cancer,
53 colon cancer, liver cancer, prostate cancer, stomach cancer

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55 **Strengths and limitations of this study**

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57 • This study provides new evidence regarding the relationship between immigration status
58 and cancer mortality, given the effects of age, period, birth cohort and their predictions.

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60 • The non-identifiability problem has not been interpreted in APC models

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62 • The future perspective of cancer therapies and techniques have not been considered.

For peer review only

64 **Introduction**

65 Several migration waves from mainland China to Hong Kong have occurred over the past
66 century. These migration waves included a large-scale migration inflow from 1945 to 1950 (the
67 Chinese Civil War) and a few small-scale inflows in the 1950s, 1970s, and 1990s [1-3]. In 2016,
68 immigrants from mainland China formed approximately 38% of the population of Hong Kong.
69 These inflows have led to a growing interest in research on the disparity of health conditions
70 between the locals and immigrants.

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72 Cancer has been one of most common causes of death, as an estimated 19.3 million new cancer
73 cases and 9.9 million new cancer-associated deaths occurred worldwide in 2020 [4]. In Hong
74 Kong, lung cancer is one of the most common causes of cancer deaths [5, 6]. Previous studies
75 suggested that the primary cause of lung cancer is cigarette smoking [7-11]. Genetic factors,
76 asbestos, radon gas, second-hand smoke, and other forms of air pollution have been proven to
77 influence the risk of lung cancer [12-18]. The overall daily smoking rate in mainland China was
78 approximately 23.2% in 2018 [19], whereas the daily smoking rate in Hong Kong was only
79 10.2% in 2019 [20]. The leading causes of liver cancer include viral infection, drinking of
80 alcohol and polluted water and food supplies which are also culprits for colon, stomach and
81 pancreatic cancer [21]. Alcohol consumption per capita in Hong Kong has reached to 2.37 liters
82 in 2021 [22], compared to 7.0 liters of per capita consumption of alcohol in mainland China in
83 2018 [23]. As approximately 99% of prostate cancer cases occur after age 50, factors of prostate
84 cancer have been regarded as old age, race, family history and the diet of red meat consumption
85 [24]. In addition to these risk factors, studies have suggested that cancer mortality rates vary
86 depending on migrant status [25-28]. According to data from the Census and Statistics
87 Department of Hong Kong, approximately 81% of immigrants in Hong Kong immigrated from
88 China mainland, Macau, and Taiwan. Immigrants from mainland China account for a bulk of
89 this population. Previous studies have shown that child immigrants in Hong Kong tend to suffer
90 from a higher risk of wheezing disorders and cardiovascular diseases, and immigrant women
91 have higher age-specific mortality rates of breast cancer than locally-born women in Hong
92 Kong [29, 30]. However, to date, few studies have investigated the effect of length of stay in
93 Hong Kong and birthplace on the risk of other types of cancer.

94
95 In this study, we compared the mortality rates of lung, pancreatic, colon, liver, prostate and
96 stomach cancers between locally born residents in Hong Kong and immigrants from mainland
97 China. Both populations are widely considered as ethnically homogeneous with similar cultures.
98 Nevertheless, due to different early life experiences, immigrants are exposed to more various
99 social economy and lifestyle than locals. Therefore, it's constructive to ascertain whether
100 immigrants from mainland China have a different mortality pattern of cancers with locals to

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4 101 verify the significance of migration status for this health outcome. As Age-period-cohort (APC)
5 102 analysis plays a vital role in studying time-specific phenomena in epidemiology, in this study,
6 103 we developed APC models specified by sex and migrant status to assess the effects of age,
7 104 period, birth cohort, and of the length of stay in Hong Kong on the mortality risks of cancers.
8 105 Additionally, we explore the projection of mortality rates for the locally born population and
9 106 immigrants in Hong Kong who were younger or older than 60 using a predictive model, taking
10 107 into account age, period, and birth cohort effects as well.
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15 16 109 **Methods**

17 18 110 *Data*

19 111 We obtained the death registry data in Hong Kong between 1998 and 2021 from the Census
20 112 and Statistics Department of Hong Kong, as the data in 2022 has not been available up to now.
21 113 The data was extracted a routine census held by Hong Kong government as subjective errors
22 114 caused by resampling can be neglected. The population data were stratified by age, sex,
23 115 immigration status, and length of stay in Hong Kong. We retrieved six types of cancer cases
24 116 from the death registry data using ICD codes, such as ICD-9 code 162 and ICD-10 codes
25 117 C34.0–C34.3, C348, and C349 for lung cancer. To assure comparability among
26 118 registries, deaths from the age group of 35–85 years were selected, since cases younger than 35
27 119 and older than 85 were relatively trivial for lack of statistical interpretability [31]. Immigration
28 120 status was classified into three groups: locals born in Hong Kong, immigrants who have lived
29 121 in Hong Kong for >10 years before death defined as long-stay immigrants, and immigrants who
30 122 have lived in Hong Kong for ≤10 years before death defined as short-stay immigrants. Notably,
31 123 much focus was placed on immigrants from mainland China, because approximately 81% of
32 124 immigrants in Hong Kong came from mainland China, Macau, and Taiwan based on the data
33 125 from the Census and Statistics Department of Hong Kong. Moreover, few cases recorded from
34 126 Macau and Taiwan are statistically insignificant in the analysis. Demographics and population
35 127 projections from 2022 to 2030 were retrieved from the Census and Statistics Department of
36 128 Hong Kong and estimated with cubic smoothing spline as the prerequisite of the predictive
37 129 model. Codes for APC and BAPC analysis are available in the GitHub repository
38 130 (<https://github.com/kshz2164313/APC-population-projections-for-immigration-HK>).
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53 133 *Statistical analysis*

54 134 We modeled cancer mortality rates in Hong Kong using APC analysis based on log-linear
55 135 Poisson regression models. The model aimed to disentangle age, period, and cohort effects of
56 136 time-varying phenomena simultaneously [32, 33], given that

$$57 137 \log(E_{ij}) = \alpha_i + \beta_j + \gamma_k + \mu + \log(\theta_{ij}) \quad (1)$$

1
2
3 138 where E_{ij} denotes expected mortality; α_i , β_j , and γ_k denote age, period, and cohort
4 139 effect, respectively, for $i = 1, \dots, I$, $j = 1, \dots, J$, $k = 1, \dots, K$ with $k = I - i + j$.
5
6 140 $\log(\theta_{ij})$ is the offset. We mainly focused on the contributions of sex and immigration status
7
8 141 due to the non-identifiability problem that the effects of these three components are collinear
9 142 with each other (denoted as period – age = cohort) [34]. Birth cohort effect and period effect
10 143 were assessed with relative risks. The median date of birth among cases were regarded as the
11 144 reference cohort. Since cases aged at 35–85 years between 1998 and 2021 were selected, the
12 145 range of birth cohort from 1913 to 1986 covered observations and further projections until
13 146 2030. The second and penultimate period effects were constrained to the reference for period.
14 147 For sex and immigration status, maximum likelihood framework was applied to estimate the
15 148 relative risks and 95% confidence intervals (CIs) by age groups, calendar period, and birth
16 149 cohort.

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21 151 Several projection approaches for future cancer mortality have been developed, but a
22 152 Bayesian age-period-cohort (BAPC) model built upon integrated nested Laplace
23 153 approximations (INLA) [35] yields relatively higher coverage and better performance for all
24 154 evaluated parameter combinations [36]. To prevent some sampling problems caused by
25 155 Markov chain Monte Carlo (MCMC), this MCMC-free BAPC approach was applied to
26 156 predict future cancer mortality within a fully Bayesian inference setting and provide outputs
27 157 of interest simply, such as projected age-standardized and age-specific rates. Convergence
28 158 checks are not necessary for this technique [35]. The projections of age-standardized cancer
29 159 mortality rates for each sex, age group (younger or older than 60 years) and migrant status,
30 160 taking into account age, period, and birth cohort effects, were performed based on the weights
31 161 of population age groups from the WHO World Standard population [37], with 95%
32 162 prediction intervals. Mann-Kendall trend test was applied to verify the projection trend.

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36 163
37 164 All analyses were performed via R version 4.2.1 (R Core Team, R Foundation for Statistical
38 165 Computing, Vienna, Austria, 2013, <http://www.R-project.org/>). The APC models were
39 166 established using the Epi package, and the projections based on Bayesian APC models were
40 167 performed with the BAPC package.

41 168 42 169 Patient and Public Involvement

43 170 None.

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46 173 **Results**

47 174 Figure 1 and eFigure 1(a-e) in **Supplementary Material** illustrate the estimates of age
48 175 (assessed by cancer mortality), cohort and period effects (assessed by relative risk) based on
49 176 APC models among three migrant groups for men and women with six types of cancers,

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4 177 respectively. All the mortality rates for each gender and immigration status exhibit notable
5 178 increasing trends with age. Age, cohort and period effects of six types of cancer for immigrants
6 179 who stayed in Hong Kong for ≤ 10 years revealed relatively more pronounced fluctuations and
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8 180 deviations from those effects in other two immigration groups. Significant increasing trends of
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10 181 age effect occurred in all types of cancer, regardless of gender and immigration status. For
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12 182 example, while relatively insignificant differences in lung cancer mortality rates by
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14 183 immigration status among females, male immigrants who remained in Hong Kong for > 10 years
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16 184 had higher lung cancer mortality rates at ages above 50 years and those who arrived ≤ 10 years
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18 185 had lower lung cancer mortality at ages below 62 years compared to local men Figure 1. In
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20 186 addition to compatible dynamics of period effect for locals and long-stay immigrants, similar
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22 187 change of relative risks by birth cohort for locals and long-stay immigrants in lung, colon, liver
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24 188 and stomach cancers occurred before 1945, whereas significant differences of relative risks by
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26 189 birth cohort between these two immigration groups occurred after 1960 (Figure 1 & eFigure
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28 190 1(a,b,d)). Locals and long-stay immigrants in pancreatic and prostate cancer perform almost
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30 191 similar change of relative risks by birth cohort effects all the time (eFigure 1(c,e)). Short-stay
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32 192 immigrants who have stayed in Hong Kong for ≤ 10 years had more fluctuating relative risks
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34 193 affected by period effects before 2020 than those for locals and long-stay immigrants. Lack of
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36 194 young cases, especially young short-stay immigrants, of prostate cancer leads to significant
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38 195 deviations and variances in age and cohort effects.
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42 197 Figure 2-4, eFigure 2-6 in **Supplementary Material** illustrate the age-standardized mortality
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44 198 rates of six types of cancer from 1998 to 2021 and their projections by sex, immigrant status
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46 199 and age groups from 2022 to 2030, taking into account age, period, and birth cohort effects.
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48 200 Means and standard deviations of predictive mortality rates are shown in eTable 1-6 in
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50 201 **Supplementary Material**. For all ages projection (Figure 2 & eFigure 2-6), monotone
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52 202 decreasing trends or plateau of forecasting occur for both genders and all immigration groups
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54 203 in cancers, except for increasing trends for male immigrants who have stayed in Hong Kong
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56 204 for ≤ 10 years with colon cancer (p-value < 0.05) and immigrants who have stayed in Hong
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58 205 Kong for > 10 years with pancreatic cancer (p-values < 0.05). Most of predictive trends for
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60 206 younger cases (< 60 years) and older cases (≥ 60 years) reach a consensus with those for all ages
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208 207 population, except for two phenomenon: 1.) mortality rates of lung cancer for men immigrants
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210 208 ≤ 10 that insignificant trend for all ages (p-value > 0.05) vs. decline for younger cases (p-value
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212 209 < 0.05) vs. increase for older cases (p-value < 0.05); 2.) mortality rates of liver cancer for men
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214 210 immigrants > 10 that decline for all ages (p-value < 0.05) vs. decline for younger cases (p-value
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216 211 < 0.05) vs. insignificant trend for older cases (p-value > 0.05). Men will be at higher risk of
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218 212 mortality rates of cancers (excluding prostate cancer) than women in the future for all three age
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220 213 groups (all ages, young and older than 60 years). Given the future developing trends,

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3 214 immigrants, especially the group of immigrant who have stayed in Hong Kong for >10 years
4 215 with lung, liver, pancreatic, prostate and colon cancer, will have relatively higher mortality
5 216 rates in each year for each gender compared with locals and pronounced decline in predictive
6 217 means (all p-values < 0.05). Some particular cases occur in the projection of prostate cancer
7 218 that young long-stay male immigrants (0.44 deaths/100,000) aged less than 60 will be at lower
8 219 mortality rate than locals (0.69 deaths/100,000) in 2030 (eTable 6). Compared with other
9 220 cancers and immigration groups, male immigrants who have stayed in Hong Kong for >10
10 221 years with lung cancer would perform the most significant decline in predictive mean from
11 222 100.18 to 79.55 deaths per 100,000 population (average 2.92 deaths/100,000 per annum)
12 223 (eTable 1), while the same immigration group with pancreatic cancer would indicate the most
13 224 significant uptrend in each year of 17.87 deaths and 23.49 deaths per 100,000 population in
14 225 2022 and 2030, respectively (average 0.62 deaths/100,000 per annum) (eTable 4).
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26 229 **Discussion**

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28 230 Early detection of cancer is positive and instructive for increasing chances of cure. Nevertheless,
29 231 the high mortality rate of cancer results from late diagnosis among most patients after
30 232 progression to more advanced or severe stages. Individuals at high risk of cancer, such as
31 233 smokers, alcoholics or those who are frequently exposed to susceptible circumstances, should
32 234 be screened for early detections to increase opportunities for cure [38]. Therefore, the
33 235 differences in mortality rates among immigration groups are synonymous with detection means,
34 236 therapies, and social history in disparate periods and areas.
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40 238 While the changes in mortality rates by age for long-stay immigrants reached approximate
41 239 harmony with those for locals, the changes in mortality rates by age for short-stay immigrants
42 240 revealed clear differences with those for other two populations. The group of long-stay
43 241 immigrants had a higher risk of death from lung, colon and liver cancers than the other two
44 242 immigration groups after the age of 60 years. Short-stay male immigrants were less likely to
45 243 die from lung cancer before the age of 65 years. The contrast in age effects among the
46 244 immigration groups was partially consistent with studies [25, 39] that highlighted the age
47 245 effects for locals and immigrants on breast cancer mortality in Hong Kong and lung cancer
48 246 incidence in Sweden, as they both showed similar trends and magnitudes between locals and
49 247 immigrants before the age of 60 years. They are also compatible with the results in [40] that
50 248 diagnosis of liver cancer is the most frequent among populations at 55 to 65 years old.
51 249 According to these trends, young individuals, especially new young immigrant men, who
52 250 have benefited from all-rounded development in mainland China and Hong Kong, are more
53 251 likely to seek early detection and be treated for cancers using more advanced treatments [41].
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3 252 Differences in birth cohort effects among immigrant groups partially comply with the
4 253 interpretation above.

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8 255 We observed significant trends of cohort effects among locals and immigrants. These findings
9 256 are partially consistent but subtly different from previous findings, regarding the effect of
10 257 immigration status on cancers. Zhao et al. [25] described multiple peaks of cohort effects on
11 258 breast cancer mortality between locals and immigrants in Hong Kong, as well as a significant
12 259 decline of cohort effects after 1950. In contrast, Sung et al. [42] investigated the difference in
13 260 breast cancer incidence between Chinese Americans and non-Hispanic whites in the U.S. and
14 261 emphasized that Chinese Americans were at lower risk of breast cancer than non-Hispanic
15 262 whites born in the same year. Here, we interpret the cohort-driven trends resulting from the
16 263 intricacy of social history and lifestyle. Compared to a relatively stable social development in
17 264 Hong Kong, representing downward trends of relative risks for locals, wars and social
18 265 instability in mainland China resulted in several immigration waves from mainland China to
19 266 Hong Kong before 1950. Additionally, remarkable increasing trends were recorded for new
20 267 immigrants after 1950, which corresponded to the economic downturn after wars and famine
21 268 between 1959 and 1961 during their youth [43]. The increasing trends for new immigrants
22 269 and similar trends for locals and long-stay immigrants were consistent with the finding that
23 270 nutrient deficiency contributes to higher risk of severe mortality rates of cancers [44].

24 271 Furthermore, we speculate that these trends, especially those for locals and long-stay
25 272 immigrants, are most likely attributed to social development and personal behaviors, such as
26 273 daily habits, occupational history, different diagnoses and treatments, and domestic
27 274 environmental exposures. It's notable that short-stay immigrants suffered from lower risk of
28 275 death from colon cancer for all ages (eFigure 1a in **Supplementary Material**). As locals and
29 276 immigrants in Hong Kong transitioned to a more westernized lifestyles, higher consumption
30 277 of meat was associated with a higher risk of these types of cancer, whereas consumptions of
31 278 vegetables had a strong protective effect against pancreatic cancer, and moderate
32 279 consumption of coffee appeared to be beneficial against lung cancer [45,46]. Further studies
33 280 on potential risk factors are required.

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35 282 Short-stay immigrants had more fluctuating and non-stationary but inconspicuous relative
36 283 risks by period effects before 2021 than locals and long-stay immigrants. Cumulatively, an
37 284 arch pattern and fluctuating curve depicting period effects externally resulted in an arch
38 285 pattern of age-standardized mortality rates for short-stay immigrant women and irregular rates
39 286 for short-stay immigrant men before 2021. The external performance of different period
40 287 effects on mortality rates could be most likely attributed to the higher effect of different
41 288 lifestyles and social development on new immigrants than on long-stay immigrants and locals
42 289 in Hong Kong. With respect to the age-standardized mortality rates and projections,

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4 290 consistent with previous findings [47,48], we predict that the mortality rates of cancer in
5 291 Hong Kong after 2021 will continue to decline or remain relatively stable, consistent with the
6 292 trends before 2020, except for male immigrants who have stayed in Hong Kong for ≤ 10 years
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8 293 with colon cancer and male immigrants who have stayed in Hong Kong for >10 years with
9 294 pancreatic cancer. Men will be at higher risk of mortality rates of cancer than women,
10 295 regardless of immigration status. They are also compatible with the results in [4] that men
11 296 suffer from higher risk of these types of cancer than women, excluding prostate cancer.
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13 297 Furthermore, new immigrant women will be at lower risk than local women, even though
14 298 long-stay immigrants will suffer from higher mortality rates than locals in the future. Potential
15 299 interpretations could be consistent with those for birth cohort effects, as age and period effect
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17 300 are considered as confounders of cohort effect.
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20 302 In the past few decades, spurred by an increasing burden of high incidence and mortality rates
21 303 of cancer, several studies focused on the inherent identification dilemma of three effects in the
22 304 APC model. Further, complicated population distribution and immigration status in Hong
23 305 Kong, one of the areas with the highest population density and migration frequency in the
24 306 world, have intricate causes and inherent dynamics of cancer and other diseases. To our
25 307 knowledge, few studies have assessed the relationship between immigration status and cancer
26 308 mortality. Therefore, this study is original to examine the effect of the length of stay in Hong
27 309 Kong and origins of previous residence on cancer deaths, which is instructive for further
28 310 immigration policy making and targeted strategies of disease detection and intervention.
29 311 However, this study had several limitations. Given the non-identifiability problem in age-
30 312 period-cohort models, we could only depict trends and variations among different
31 313 immigration and sex groups, as illustrated in figures, and insufficiently perform the estimates
32 314 of the contributions of three effects or subgroups to mortality rates. Furthermore, we adopted
33 315 cubic smoothing spline to estimate populations of immigrants and locals due to the large
34 316 proportion of unspecified immigration status from official demographic projections. A few
35 317 acceptable cases resulted in a limited type of cancer so that some common cancers such as
36 318 ovary and cervix, were discarded. Since the issue of quantification, the future perspective of
37 319 cancer therapies and techniques have not been considered in the model of projection.
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322 **Conclusion**

323 We conclude that immigrants, especially short-stay immigrants, had more pronounced
324 324 fluctuations of mortality rates by age and of relative risks by cohort and period effects for six
325 325 types of cancers than those of long-stay immigrants and locals. Men will be at a higher risk of
326 326 mortality rates of six types of cancer than women in the future. Male immigrants who have

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4 327 stayed in Hong Kong for ≤ 10 years with colon cancer and male immigrants who have stayed
5 328 in Hong Kong for > 10 years with pancreatic cancer would perform significant uptrend in the
6 329 future, while other immigration groups for each type of cancer would continue to decline or
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8 330 remain relatively stable. Immigrants for each gender in Hong Kong would suffer from higher
9 331 mortality risks of cancers than locals in the future.
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4 333 **Declaration**

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6 334 **Ethical approval and consent to participate**

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8 335 Ethical approval and consent to participate are not applicable. This study does not involve
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10 336 human participants. Data was obtained from the Census and Statistics Department of Hong
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12 337 Kong.

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14 338 **Consent for publication**

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16 339 Not applicable.

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18 340 **Data Availability Statement**

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20 341 Data are available upon reasonable request.

21
22 342 **Author contributions**

23
24 343 **Yanji Zhao:** Methodology, Formal analysis, Data Curation, Writing - Original Draft,
25 344 Visualization

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27 345 **Zian Zhuang:** Methodology, Formal analysis, Data Curation, Writing - Review & Editing

28 346 **Lin Yang:** Validation, Writing - Review & Editing

29 347 **Daihai He:** Conceptualization, Writing - Review & Editing, Supervision

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36
37 352 **Conflict of interest**

38
39 353 None declared.

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41 354 **Acknowledgements**

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43 355 None.

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358 References

- 359
- 360 1. Fan S-C. The population projection of Hong Kong. *Southeast Asian Journal of Social Science*.
361 1974;2(1/2):105-17.
- 362 2. Department CaS. Hong Kong Statistics 1947-1967 (Report).
363 https://www.statistics.gov.hk/pub/hist/1961_1970/B10100031967AN67E0100.pdf,
364 Accessed 4th May 2019.
- 365 3. Department CaS. Demographic Trends in Hong Kong 1981-2011 (Report).
366 <http://www.statistics.gov.hk/pub/B1120017032012XXXXB0100.pdf>, Accessed 4th May 2019.
- 367 4. Sung H, Ferlay J, Siegel RL, Laversanne M, Soerjomataram I, Jemal A, et al. Global Cancer
368 Statistics 2020: GLOBOCAN Estimates of Incidence and Mortality Worldwide for 36 Cancers
369 in 185 Countries. *CA: A Cancer Journal for Clinicians*. 2021 2021/05/01;71(3):209-49. doi:
370 <https://doi.org/10.3322/caac.21660>.
- 371 5. Wang XR, Chiu YL, Qiu H, Au JSK, Yu ITS. The roles of smoking and cooking emissions
372 in lung cancer risk among Chinese women in Hong Kong. *Annals of Oncology*. 2009
373 2009/04/01;20(4):746-51. doi: <https://doi.org/10.1093/annonc/mdn699>.
- 374 6. Chiu Y-L, Wang X-R, Qiu H, Yu IT-S. Risk factors for lung cancer: a case-control study in
375 Hong Kong women. *Cancer Causes & Control*. 2010 2010/05/01;21(5):777-85. doi:
376 10.1007/s10552-010-9506-9.
- 377 7. Office on S, Health. Publications and Reports of the Surgeon General. Women and
378 Smoking: A Report of the Surgeon General. Atlanta (GA): Centers for Disease Control and
379 Prevention (US); 2001.
- 380 8. Escobedo LG, Peddicord JP. Smoking prevalence in US birth cohorts: the influence of gender
381 and education. *American Journal of Public Health*. 1996 1996/02/01;86(2):231-6. doi:
382 10.2105/AJPH.86.2.231.
- 383 9. Husten CG, Shelton DM, Chrismon JH, Lin YC, Mowery P, Powell FA. Cigarette smoking
384 and smoking cessation among older adults: United States, 1965-94. *Tobacco Control*.
385 1997;6(3):175. doi: 10.1136/tc.6.3.175.
- 386 10. Bolego C, Poli A, Paoletti R. Smoking and gender. *Cardiovascular Research*.
387 2002;53(3):568-76. doi: 10.1016/S0008-6363(01)00520-X.
- 388 11. Doll R, Hill AB. The mortality of doctors in relation to their smoking habits; a preliminary
389 report. *Br Med J*. 1954;1(4877):1451-5. PMID: 13160495. doi: 10.1136/bmj.1.4877.1451.
- 390 12. Ramada Rodilla JM, Calvo Cerrada B, Serra Pujadas C, Delclos GL, Benavides FG. Fiber
391 burden and asbestos-related diseases: an umbrella review. *Gaceta Sanitaria*. 2021 2021/06/11/.
392 doi: <https://doi.org/10.1016/j.gaceta.2021.04.001>.
- 393 13. Collishaw NE, Kirkbride J, Wigle DT. Tobacco smoke in the workplace: an occupational
394 health hazard. *Can Med Assoc J*. 1984;131(10):1199-204. PMID: 6498670.
- 395 14. Dresler CM, Fratelli C, Babb J, Everley L, Evans AA, Clapper ML. Gender differences in
396 genetic susceptibility for lung cancer. *Lung Cancer*. 2000 2000/12/01;30(3):153-60. doi:
397 [https://doi.org/10.1016/S0169-5002\(00\)00163-X](https://doi.org/10.1016/S0169-5002(00)00163-X).
- 398 15. Alexandrov K, Cascorbi I, Rojas M, Bouvier G, Kriek E, Bartsch H. CYP1A1 and GSTM1
399 genotypes affect benzo[a]pyrene DNA adducts in smokers' lung: comparison with
400 aromatic/hydrophobic adduct formation. *Carcinogenesis*. 2002;23(12):1969-77. doi:

- 1
2
3 401 10.1093/carcin/23.12.1969.
- 4 402 16. Samet JM. Radon and Lung Cancer. JNCI: Journal of the National Cancer Institute.
5 403 1989;81(10):745-58. doi: 10.1093/jnci/81.10.745.
- 6 404 17. Darby S, Hill D, Auvinen A, Barros-Dios JM, Baysson H, Bochicchio F, et al. Radon in
7 405 homes and risk of lung cancer: collaborative analysis of individual data from 13 European case-
8 406 control studies. BMJ. 2005;330(7485):223. doi: 10.1136/bmj.38308.477650.63.
- 9 407 18. Raaschou-Nielsen O, Andersen ZJ, Beelen R, Samoli E, Stafoggia M, Weinmayr G, et al.
10 408 Air pollution and lung cancer incidence in 17 European cohorts: prospective analyses from the
11 409 European Study of Cohorts for Air Pollution Effects (ESCAPE). The Lancet Oncology. 2013
12 410 2013/08/01/;14(9):813-22. doi: [https://doi.org/10.1016/S1470-2045\(13\)70279-1](https://doi.org/10.1016/S1470-2045(13)70279-1).
- 13 411 19. 2018 Summary-20190719. Retrieved August 26, 2022, from
14 412 [https://www.who.int/docs/default-source/wpro---documents/countries/china/2018-gats-china-](https://www.who.int/docs/default-source/wpro---documents/countries/china/2018-gats-china-factsheet-cn-en.pdf?sfvrsn=3f4e2da9_2)
15 413 [factsheet-cn-en.pdf?sfvrsn=3f4e2da9_2](https://www.who.int/docs/default-source/wpro---documents/countries/china/2018-gats-china-factsheet-cn-en.pdf?sfvrsn=3f4e2da9_2)
- 16 414 20. *Thematic household survey*. Retrieved August 26, 2022, from
17 415 https://www.censtatd.gov.hk/en/data/stat_report/product/B1130201/att/B11302702020XXXX
18 416 [B0100.pdf](https://www.censtatd.gov.hk/en/data/stat_report/product/B1130201/att/B11302702020XXXX)
- 19 417 21. Abubakar II, Tillmann T, Banerjee A. Global, regional, and national age-sex specific all-
20 418 cause and cause-specific mortality for 240 causes of death, 1990-2013: a systematic analysis
21 419 for the Global Burden of Disease Study 2013. Lancet. 2015 Jan 10;385(9963):117-71.
- 22 420 22. Estimated alcohol consumption per capita in Hong Kong. Change4Health. (n.d.).
23 421 Retrieved December 1, 2022, from
24 422 https://www.change4health.gov.hk/en/alcohol_aware/figures/alcohol_consumption/index.htm
25 423 1
- 26 424 23. World Health Organization. Global status report on alcohol and health 2018. World
27 425 Health Organization; 2019 Feb 14.
- 28 426 24. Wild C. World cancer report 2014. Wild CP, Stewart BW, editors. Geneva, Switzerland:
29 427 World Health Organization; 2014.
- 30 428
- 31 429 25. Zhao S, Dong H, Qin J, Liu H, Li Y, Chen Y, et al. Breast cancer mortality in Chinese
32 430 women: does migrant status play a role? Annals of Epidemiology. 2019 2019/12/01/;40:28-
33 431 34.e2. doi: <https://doi.org/10.1016/j.annepidem.2019.10.006>.
- 34 432 26. Gomez SL, Yang J, Lin S-W, McCusker M, Sandler A, Cheng I, et al. Incidence trends of
35 433 lung cancer by immigration status among Chinese Americans. Cancer Epidemiol Biomarkers
36 434 Prev. 2015;24(8):1157-64. PMID: 25990553. doi: 10.1158/1055-9965.EPI-15-0123.
- 37 435 27. Hemminki K, Li X, Czene K. Cancer risks in first-generation immigrants to Sweden.
38 436 International Journal of Cancer. 2002 2002/05/10;99(2):218-28. doi:
39 437 <https://doi.org/10.1002/ijc.10322>.
- 40 438 28. Vanthomme K, Roskamp M, De Schutter H, Vandenneede H. Lung cancer incidence
41 439 differences in migrant men in Belgium, 2004–2013: histology-specific analyses. BMC Cancer.
42 440 2021 2021/03/30;21(1):328. doi: 10.1186/s12885-021-08038-6.
- 43 441 29. Schooling M, Leung GM, Janus ED, Ho SY, Hedley AJ, Lam TH. Childhood migration
44 442 and cardiovascular risk. International Journal of Epidemiology. 2004;33(6):1219-26. doi:
45 443 10.1093/ije/dyh221.
- 46 444 30. Leung JYY, Li AM, Leung GM, Schooling CM. Mode of delivery and childhood

- 1
2
3 445 hospitalizations for asthma and other wheezing disorders. *Clinical & Experimental Allergy*.
4 446 2015 2015/06/01;45(6):1109-17. doi: <https://doi.org/10.1111/cea.12548>.
5
6 447 31. Baker A, Bray I. Bayesian projections: what are the effects of excluding data from younger
7 448 age groups?. *American Journal of Epidemiology*. 2005 Oct 15;162(8):798-805.
8
9 449 32. Rosenberg PS, Anderson WF. Age-Period-Cohort Models in Cancer Surveillance Research:
10 450 Ready for Prime Time? APC Models. *Cancer Epidemiology, Biomarkers & Prevention*. 2011
11 451 Jul 1;20(7):1263-8.
12 452 33. Holford T. Analyzing the effects of age, period and cohort on incidence and mortality rates.
13 453 *Stat Meth Med Res*. 1992;1:317-37.
14 454 34. Brookmeyer R, Stroup DF, editors. *Monitoring the health of populations: statistical*
15 455 *principles and methods for public health surveillance*. Oxford University Press; 2004.
16 456 35. Riebler A, Held L. Projecting the future burden of cancer: Bayesian age-period-cohort
17 457 analysis with integrated nested Laplace approximations. *Biometrical Journal*. 2017
18 458 May;59(3):531-49.
19 459 36. Knoll M, Furkel J, Debus J, Abdollahi A, Karch A, Stock C. An R package for an integrated
20 460 evaluation of statistical approaches to cancer incidence projection. *BMC medical research*
21 461 *methodology*. 2020 Dec;20(1):1-1.
22 462 37. Ahmad OB, Boschi-Pinto C, Lopez AD, Murray CJ, Lozano R, Inoue M. Age
23 463 standardization of rates: a new WHO standard. Geneva: World Health Organization. 2001
24 464 Jan;9(10):1-4.
25 465 38. Sung H, Ferlay J, Siegel RL, Laversanne M, Soerjomataram I, Jemal A, Bray F. Global
26 466 cancer statistics 2020: GLOBOCAN estimates of incidence and mortality worldwide for 36
27 467 cancers in 185 countries. *CA: a cancer journal for clinicians*. 2021 May;71(3):209-49.
28 468 39. Mousavi SM, Fallah M, Sundquist K, Hemminki K. Age-and time-dependent changes in
29 469 cancer incidence among immigrants to Sweden: colorectal, lung, breast and prostate cancers.
30 470 *International journal of cancer*. 2012 Jul 15;131(2):E122-8.
31 471 40. National Cancer Institute. SEER stat fact sheets: liver and intrahepatic bile duct cancer.
32 472 41. Wu X, Chung VC, Hui EP, Ziea ET, Ng BF, Ho RS, Tsoi KK, Wong S, Wu JC.
33 473 Effectiveness of acupuncture and related therapies for palliative care of cancer: overview of
34 474 systematic reviews. *Scientific reports*. 2015 Nov 26;5(1):1-5.
35 475 42. Sung H, Rosenberg PS, Chen WQ, Hartman M, Lim WY, Chia KS, Wai-Kong Mang O,
36 476 Tse L, Anderson WF, Yang XR. The impact of breast cancer-specific birth cohort effects among
37 477 younger and older Chinese populations. *International journal of cancer*. 2016 Aug
38 478 1;139(3):527-34.
39 479 43. *The world economy volume 1: a millennial perspective, 2, Historical statistics*: Academic
40 480 Foundation, Gurgaon, India (2007)
41 481 44. Elias SG, Peeters PH, Grobbee DE, van Noord PA. The 1944-1945 Dutch famine and
42 482 subsequent overall cancer incidence. *Cancer Epidemiology Biomarkers & Prevention*. 2005
43 483 Aug;14(8):1981-5.
44 484 45. Chiu YL, Wang XR, Qiu H, Yu IT. Risk factors for lung cancer: a case-control study in
45 485 Hong Kong women. *Cancer Causes & Control*. 2010 May;21(5):777-85.
46 486 46. Li J, Lam AS, Yau ST, Yiu KK, Tsoi KK. Antihypertensive treatments and risks of lung
47 487 Cancer: A large population-based cohort study in Hong Kong. *BMC cancer*. 2021 Dec;21(1):1-
48 488 9.

- 1
2
3 489 47. Du J, Sun H, Sun Y, Du J, Cao W, Sun S. Assessment of age, period, and cohort effects of
4 490 lung cancer incidence in Hong Kong and projection up to 2030 based on changing
5 491 demographics. *American Journal of Cancer Research*. 2021;11(12):5902.
6 492 48. *Centre for Health Protection, Department of Health - Lung Cancer*. Centre for Health
7 493 Protection. Retrieved August 10, 2022, from
8 494 <https://www.chp.gov.hk/en/healthtopics/content/25/49.html>
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3 496 **Figure 1.** Parameter estimates of age (a), cohort (b) and period (c) effects based on an age-period-cohort model of male
4 497 and female lung cancer mortality rates by immigrant groups: locals, immigrants stay in Hong Kong for more than 10
5 498 years and immigrants stay in Hong Kong for less than or equal to 10 years. Age effect was assessed by mortality (left
6 499 axis). Cohort and period effects were assessed by relative risk (right axis), 95% confidence intervals are shown as
7 500 shaded bands.
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Figure 2. Projections of lung cancer mortality rates by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.

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Figure 3. Projections of lung cancer mortality rates for the population younger than 60 by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.

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Figure 4. Projections of lung cancer mortality rates for the population older than or equal to 60 by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.

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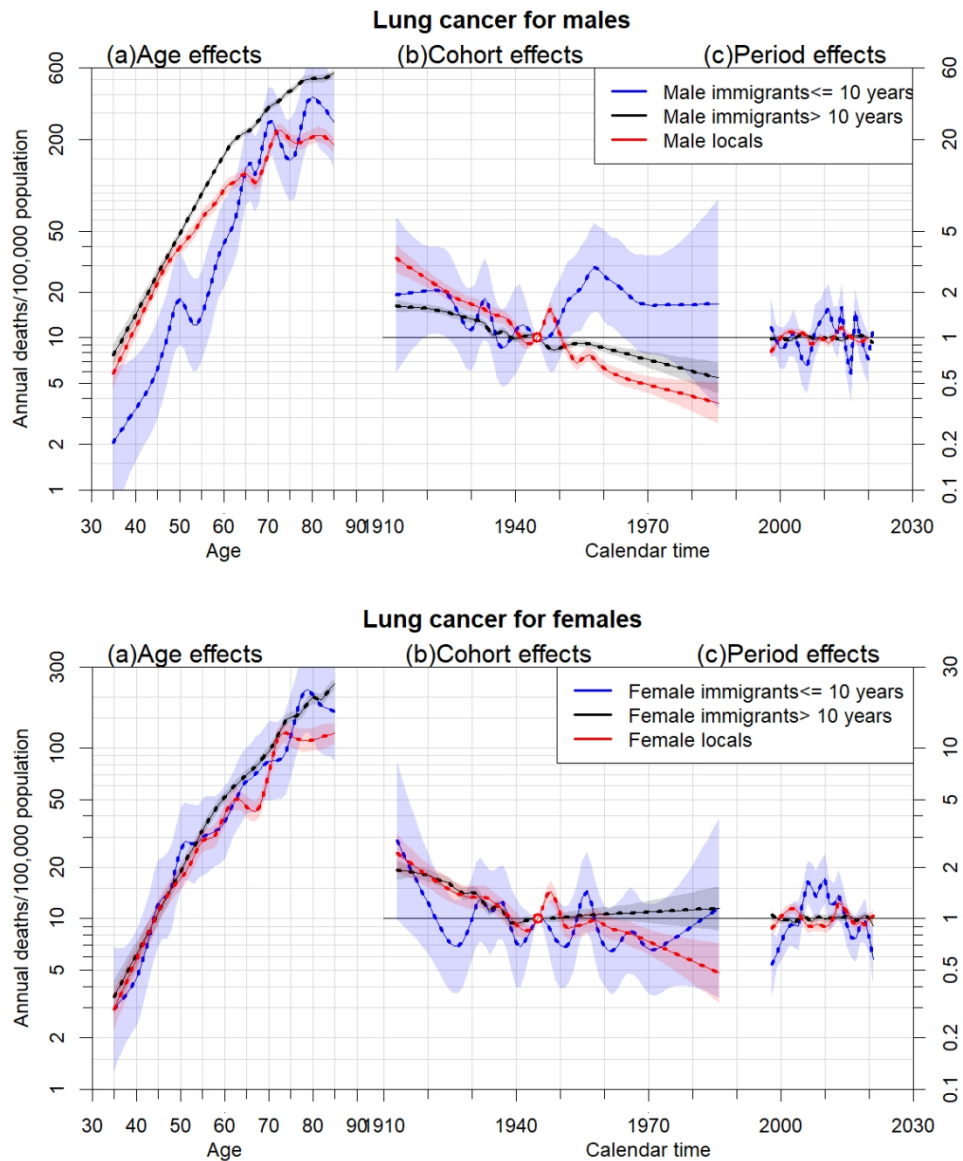


Figure 1. Parameter estimates of age (a), cohort (b) and period (c) effects based on an age-period-cohort model of male and female lung cancer mortality rates by immigrant groups: locals, immigrants stay in Hong Kong for more than 10 years and immigrants stay in Hong Kong for less than or equal to 10 years. Age effect was assessed by mortality (left axis). Cohort and period effects were assessed by relative risk (right axis), 95% confidence intervals are shown as shaded bands.

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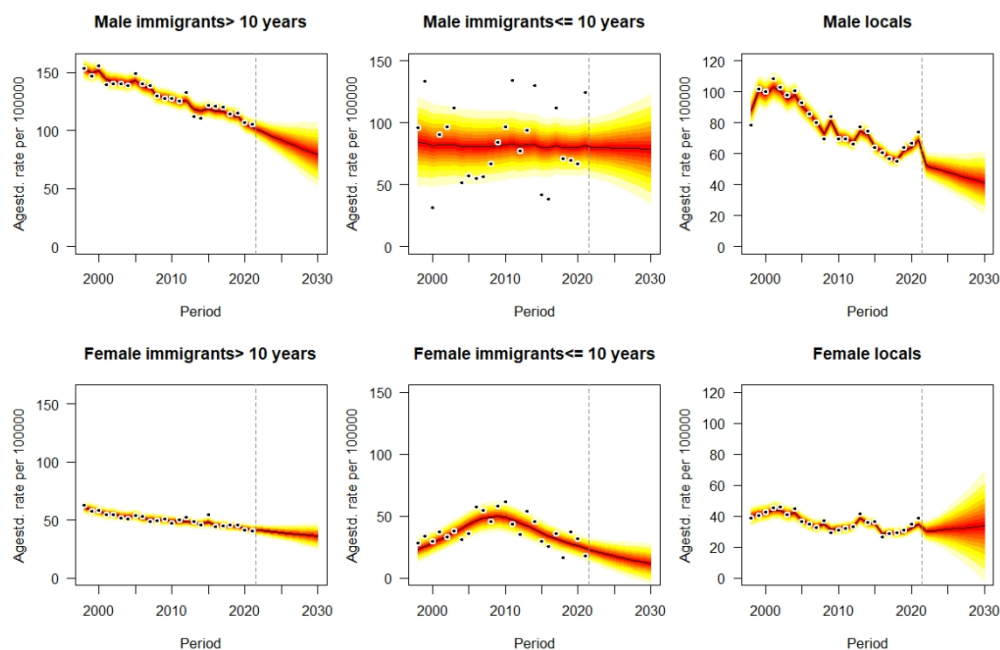


Figure 2. Projections of lung cancer mortality rates by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.

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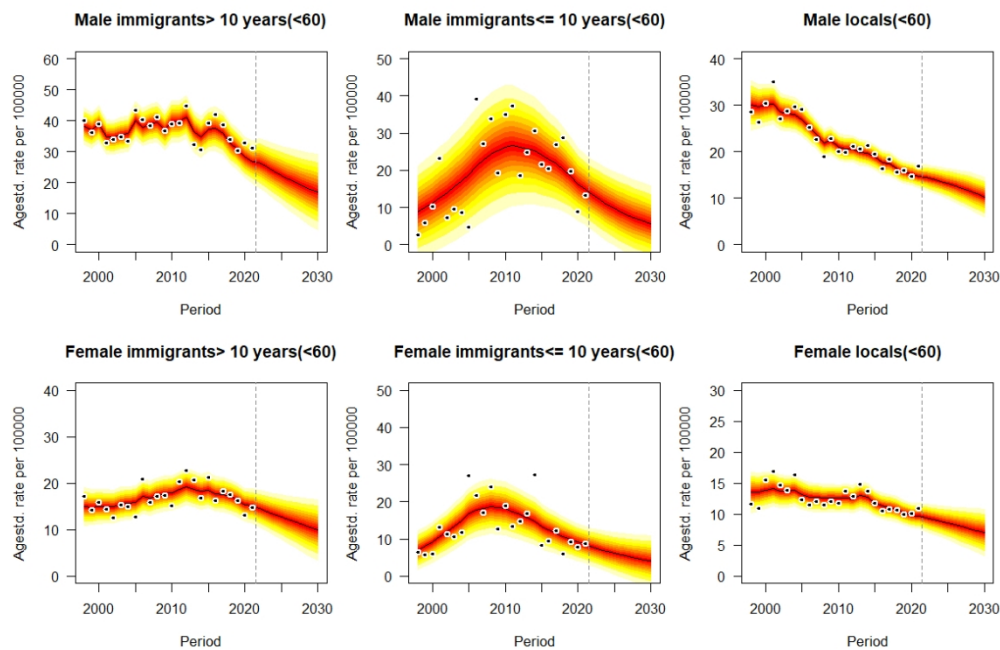


Figure 3. Projections of lung cancer mortality rates for the population younger than 60 by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.

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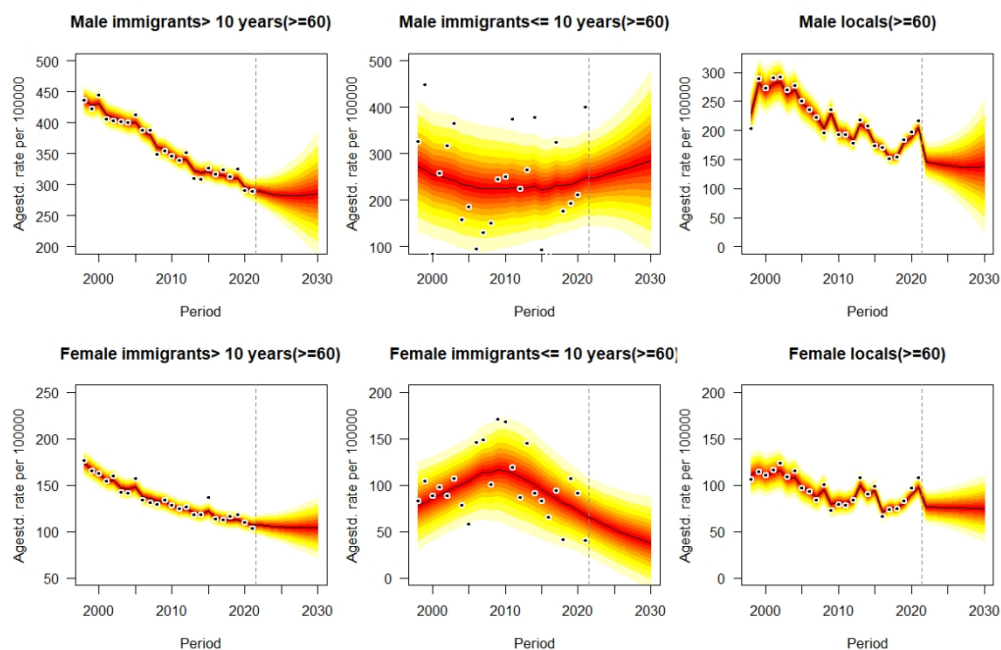


Figure 4. Projections of lung cancer mortality rates for the population older than or equal to 60 by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.

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Supplementary Material for

“An age-period-cohort analysis and projection of cancer mortality in Hong Kong, 1998–2030”

APC Figures

eFigure 1(a) Colon cancer	3
eFigure 1(b) Liver cancer	4
eFigure 1(c) Pancreatic cancer	5
eFigure 1(d) Stomach cancer	6
eFigure 1(e) Prostate cancer	7

Projection Figures

Colon cancer	
eFigure 2(a)Projection (all ages)	8
eFigure 2(b)Projection (<60 years)	9
eFigure 2(c)Projection (≥ 60 years)	10
Liver cancer	
eFigure 3(a)Projection (all ages)	11
eFigure 3(b)Projection (<60 years)	12
eFigure 3(c)Projection (≥ 60 years)	13
Pancreatic cancer	
eFigure 4(a)Projection (all ages)	14
eFigure 4(b)Projection (<60 years)	15
eFigure 4(c)Projection (≥ 60 years)	16
Stomach cancer	
eFigure 5(a)Projection (all ages)	17
eFigure 5(b)Projection (<60 years)	18

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eFigure 5(c)Projection (≥ 60 years)..... 19

Prostate cancer

eFigure 6 Projection (all ages, <60 years and ≥ 60 years)..... 20

Tables

eTable 1 Lung cancer..... 21

eTable 2 Colon cancer..... 22

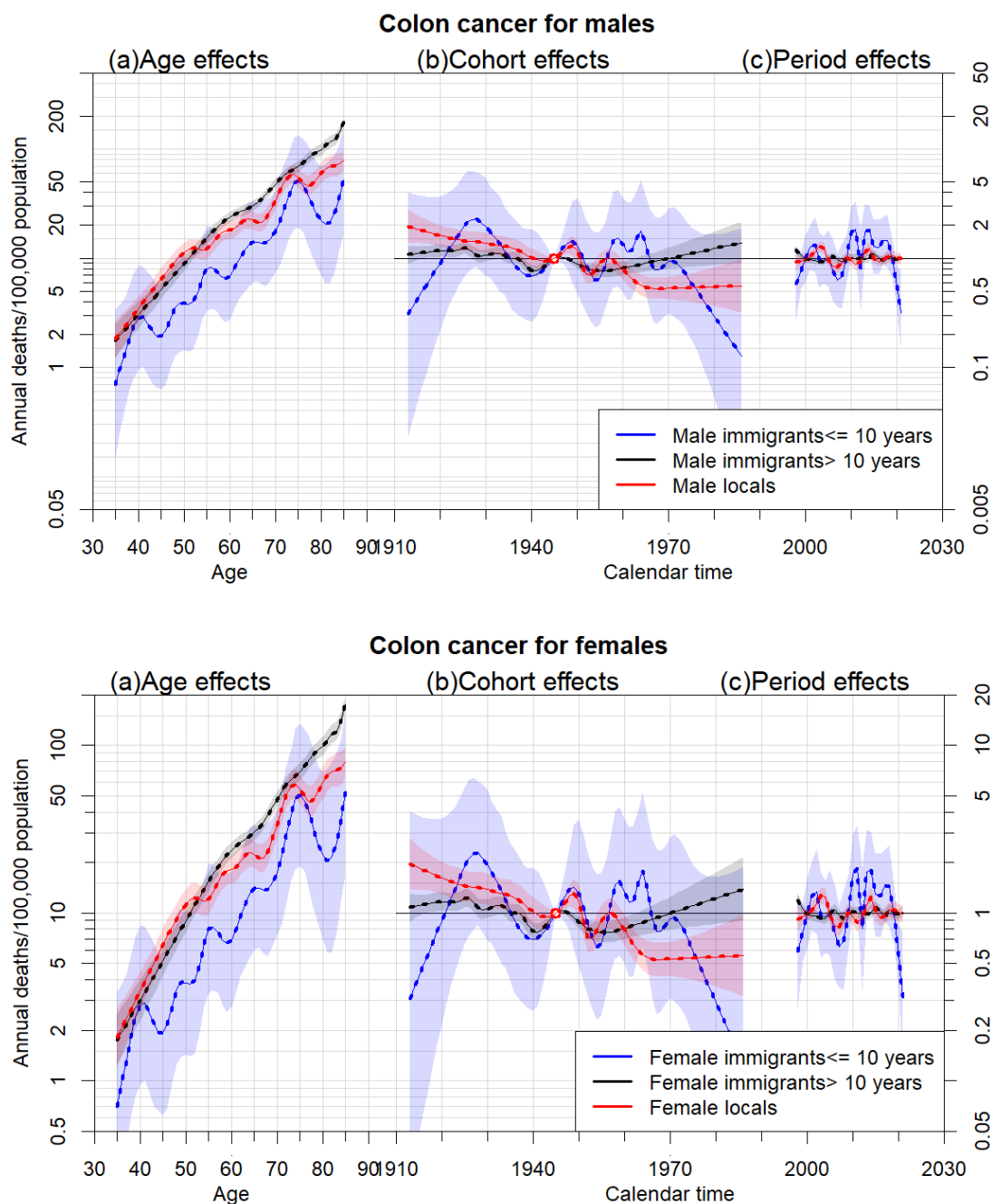
eTable 3 Liver cancer 23

eTable 4 Pancreatic cancer 24

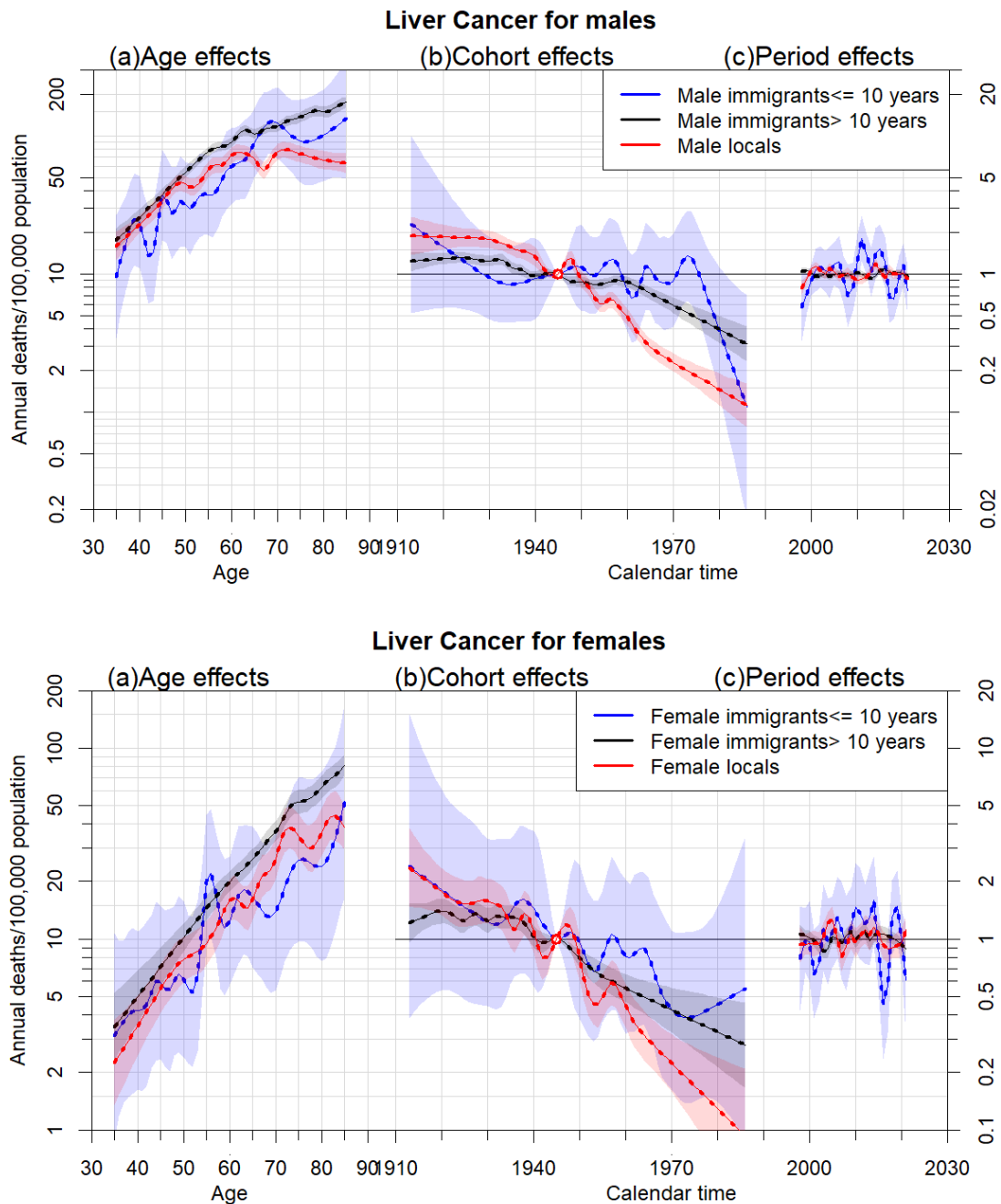
eTable 5 Stomach cancer 25

eTable 6 Prostate cancer 26

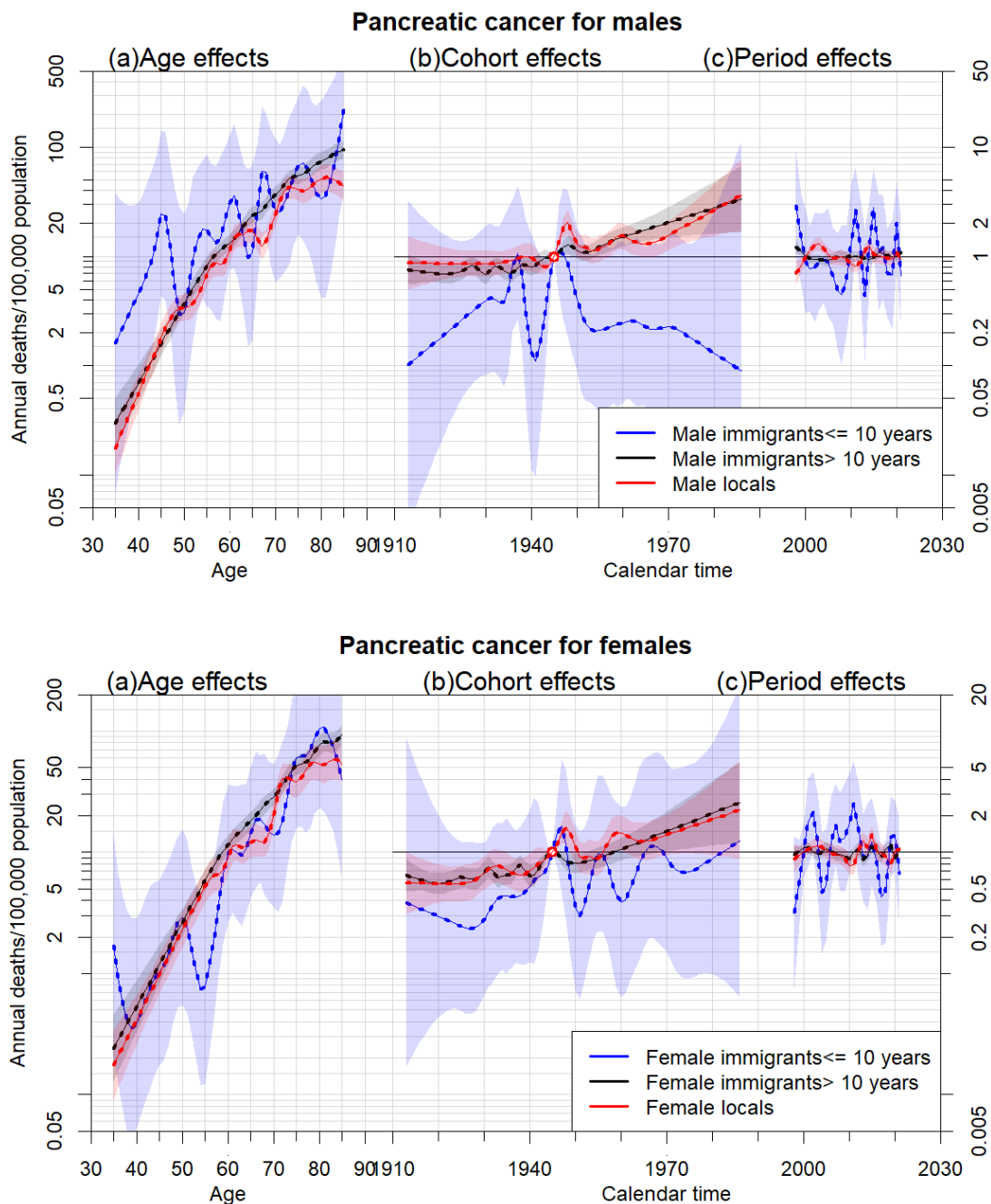
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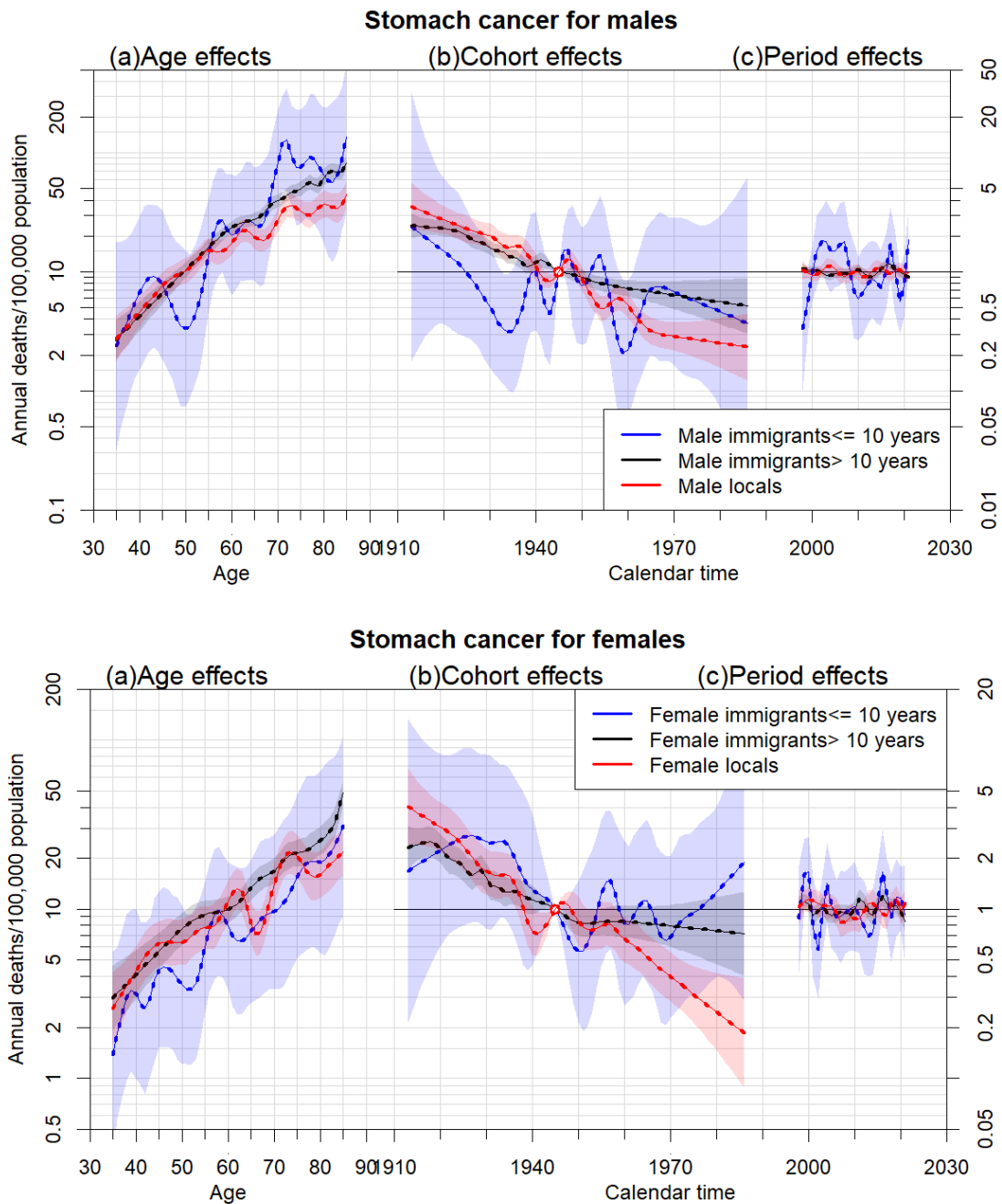
eFigure 1(a). Parameter estimates of age (a), cohort (b) and period (c) effects based on an age-period-cohort model of male and female colon cancer mortality rates by immigrant groups: locals, immigrants stay in Hong Kong for more than 10 years and immigrants stay in Hong Kong for less than or equal to 10 years. Age effect was assessed by mortality (left axis). Cohort and period effects were assessed by relative risk (right axis), 95% confidence intervals are shown as shaded bands.



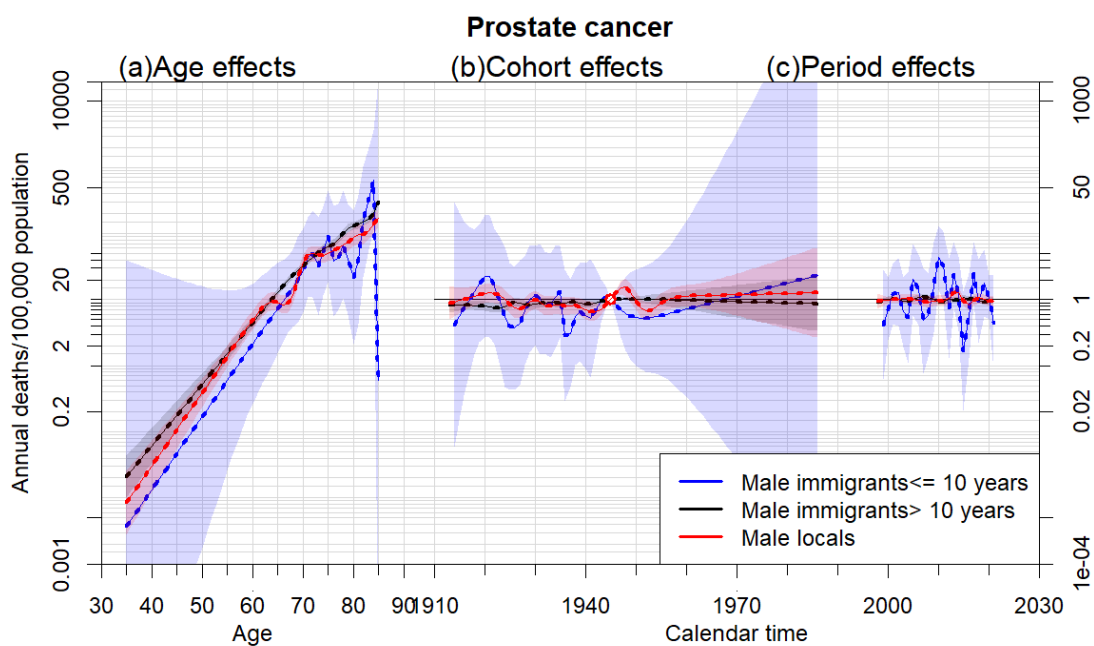
eFigure 1(b). Parameter estimates of age (a), cohort (b) and period (c) effects based on an age-period-cohort model of male and female liver cancer mortality rates by immigrant groups: locals, immigrants stay in Hong Kong for more than 10 years and immigrants stay in Hong Kong for less than or equal to 10 years. Age effect was assessed by mortality (left axis). Cohort and period effects were assessed by relative risk (right axis), 95% confidence intervals are shown as shaded bands.



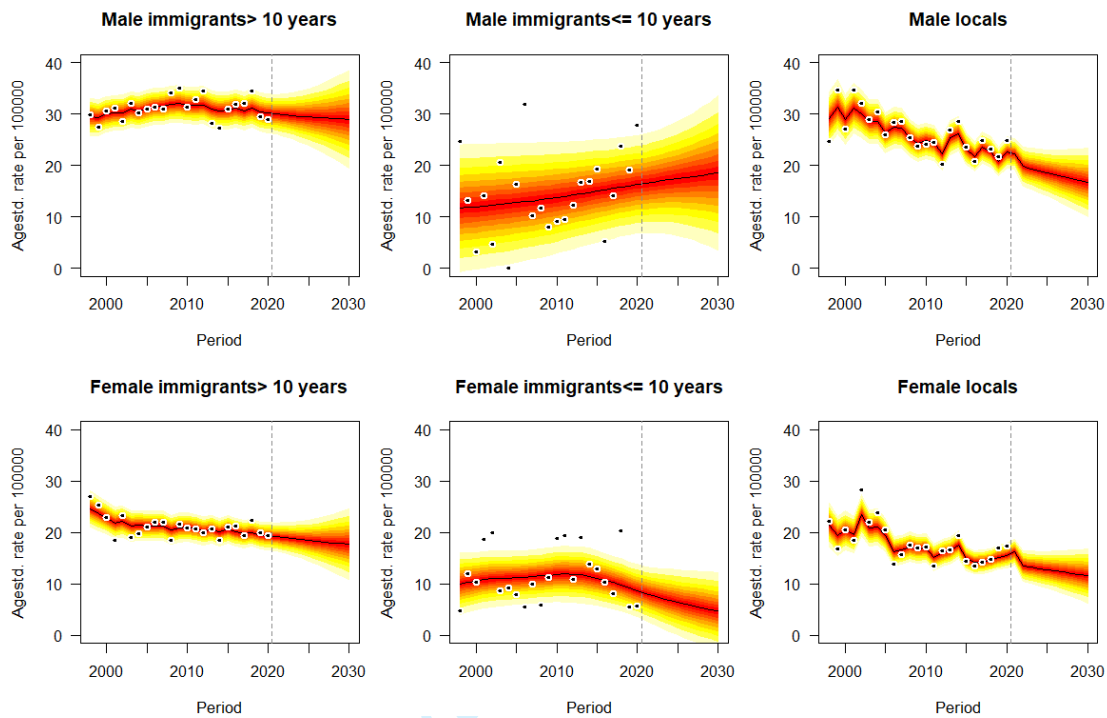
eFigure 1(c). Parameter estimates of age (a), cohort (b) and period (c) effects based on an age-period-cohort model of male and female pancreatic cancer mortality rates by immigrant groups: locals, immigrants stay in Hong Kong for more than 10 years and immigrants stay in Hong Kong for less than or equal to 10 years. Age effect was assessed by mortality (left axis). Cohort and period effects were assessed by relative risk (right axis), 95% confidence intervals are shown as shaded bands.



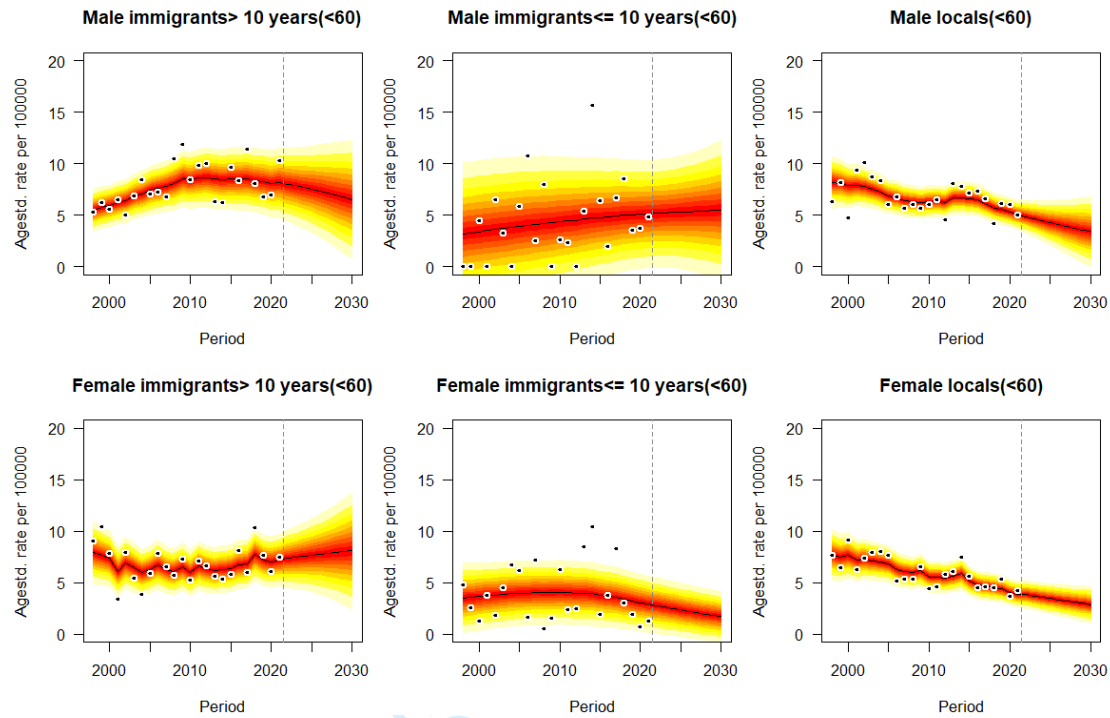
eFigure 1(d). Parameter estimates of age (a), cohort (b) and period (c) effects based on an age-period-cohort model of male and female stomach cancer mortality rates by immigrant groups: locals, immigrants stay in Hong Kong for more than 10 years and immigrants stay in Hong Kong for less than or equal to 10 years. Age effect was assessed by mortality (left axis). Cohort and period effects were assessed by relative risk (right axis), 95% confidence intervals are shown as shaded bands.



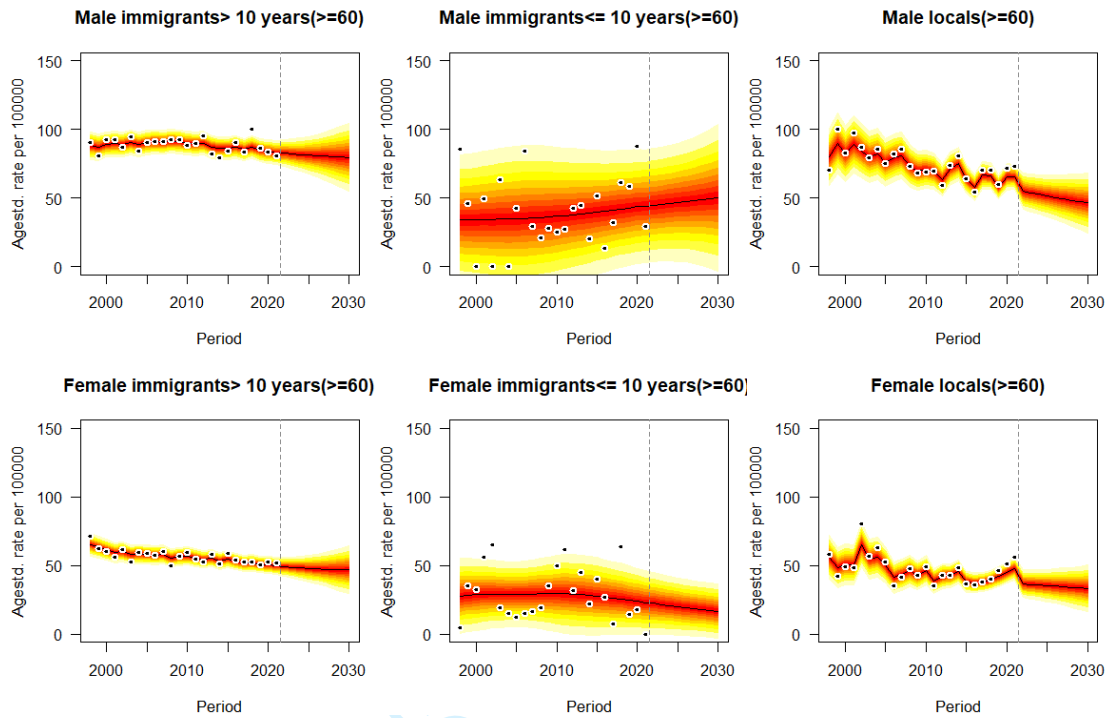
eFigure 1(e). Parameter estimates of age (a), cohort (b) and period (c) effects based on an age-period-cohort model of male prostate cancer mortality rates by immigrant groups: locals, immigrants stay in Hong Kong for more than 10 years and immigrants stay in Hong Kong for less than or equal to 10 years. Age effect was assessed by mortality (left axis). Cohort and period effects were assessed by relative risk (right axis), 95% confidence intervals are shown as shaded bands.



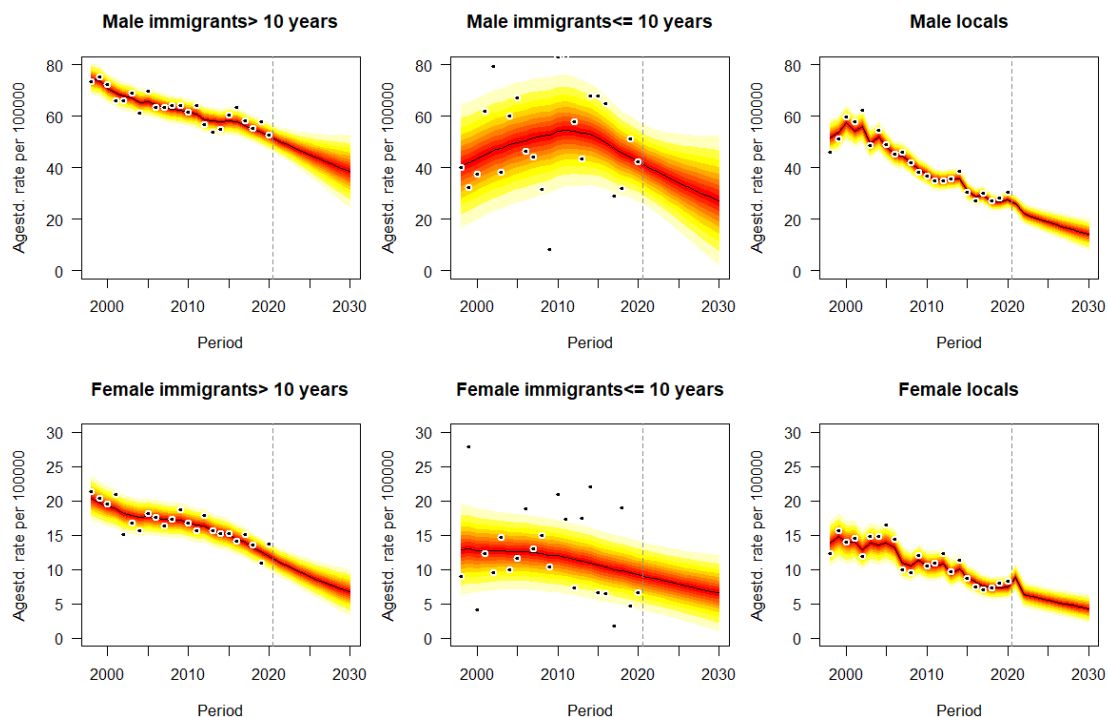
eFigure 2(a). Projections of colon cancer mortality rates by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



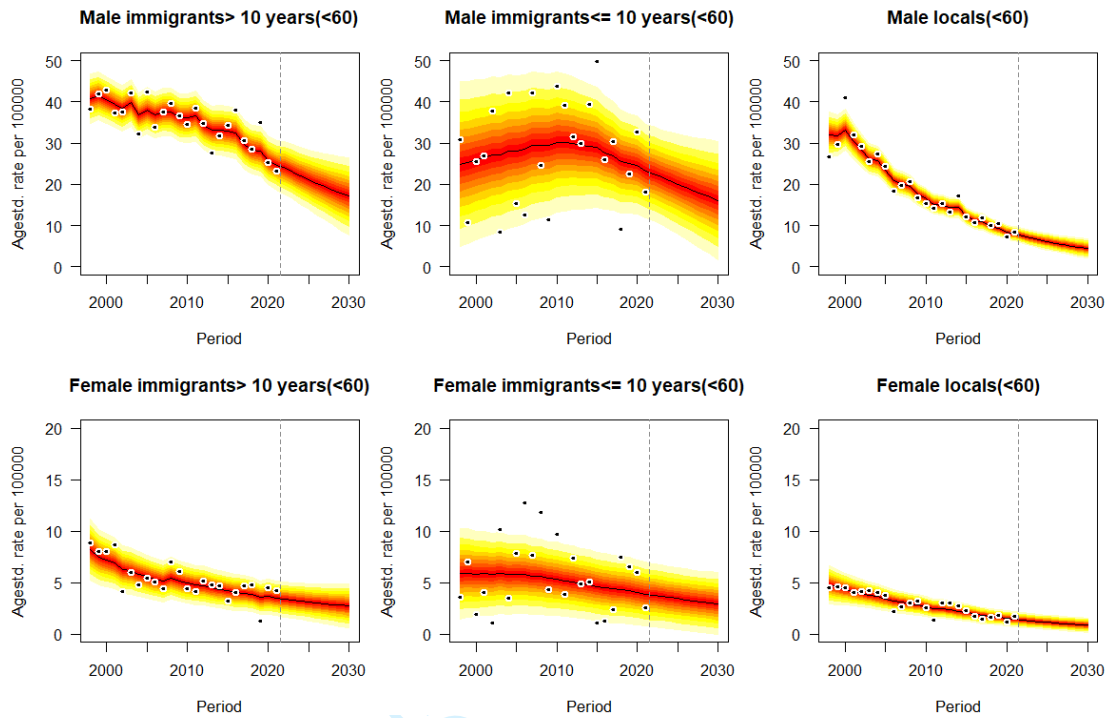
eFigure 2(b). Projections of colon cancer mortality rates for the population younger than 60 by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



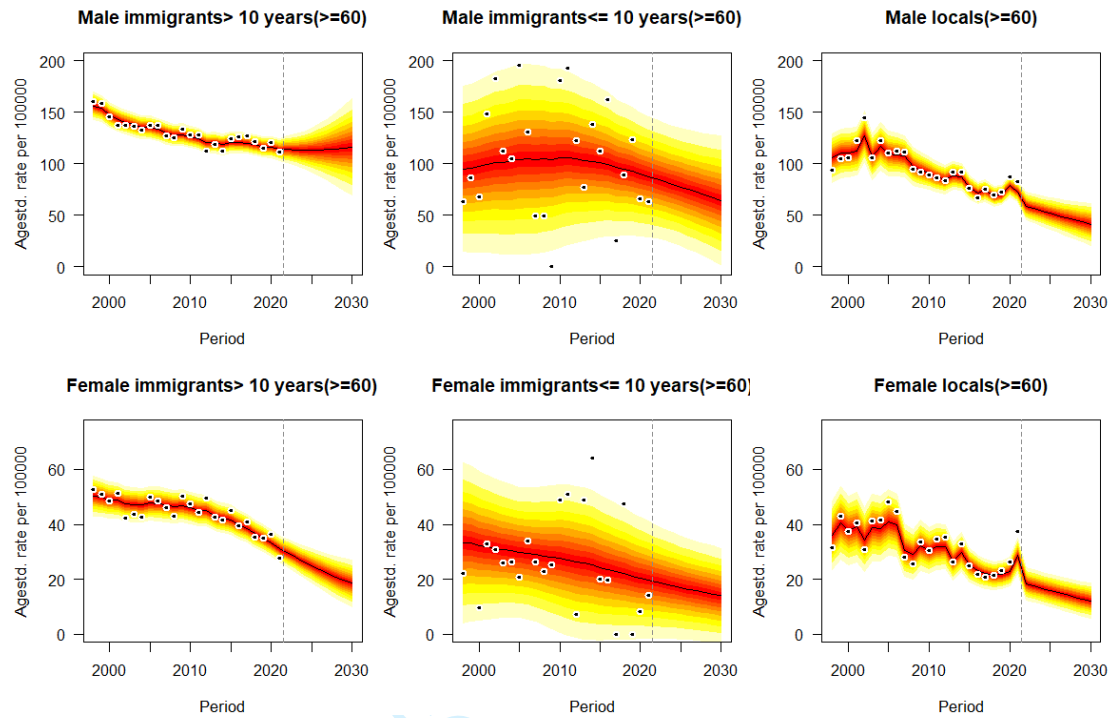
eFigure 2(c). Projections of colon cancer mortality rates for the population older than or equal to 60 by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



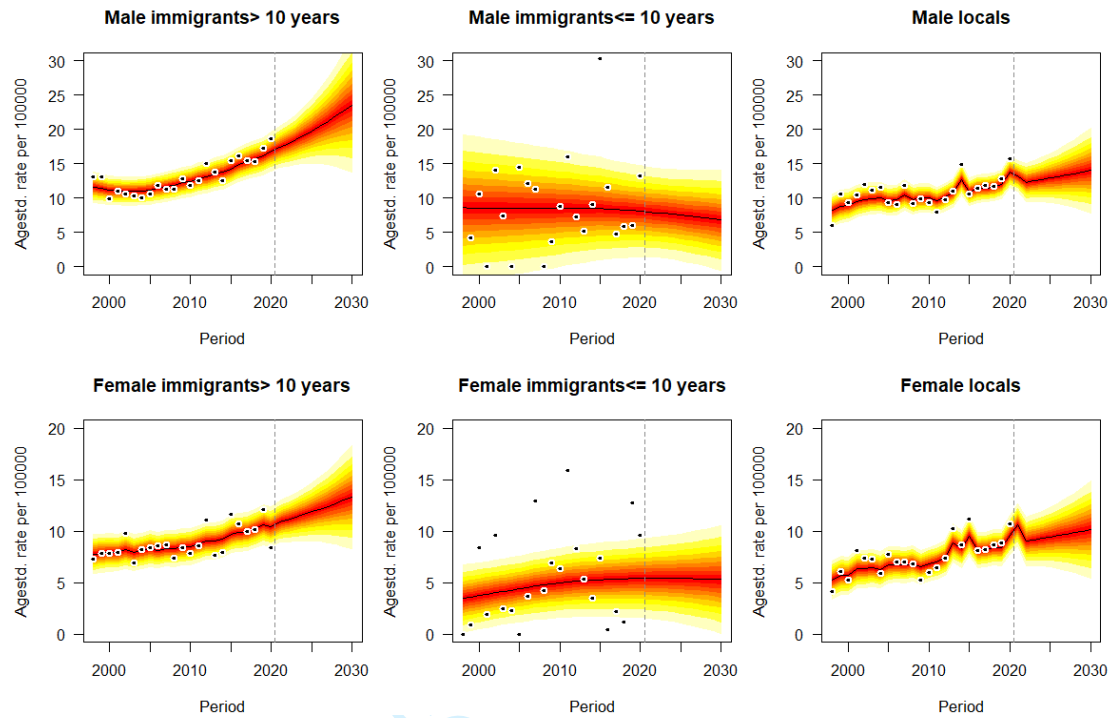
eFigure 3(a). Projections of liver cancer mortality rates by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



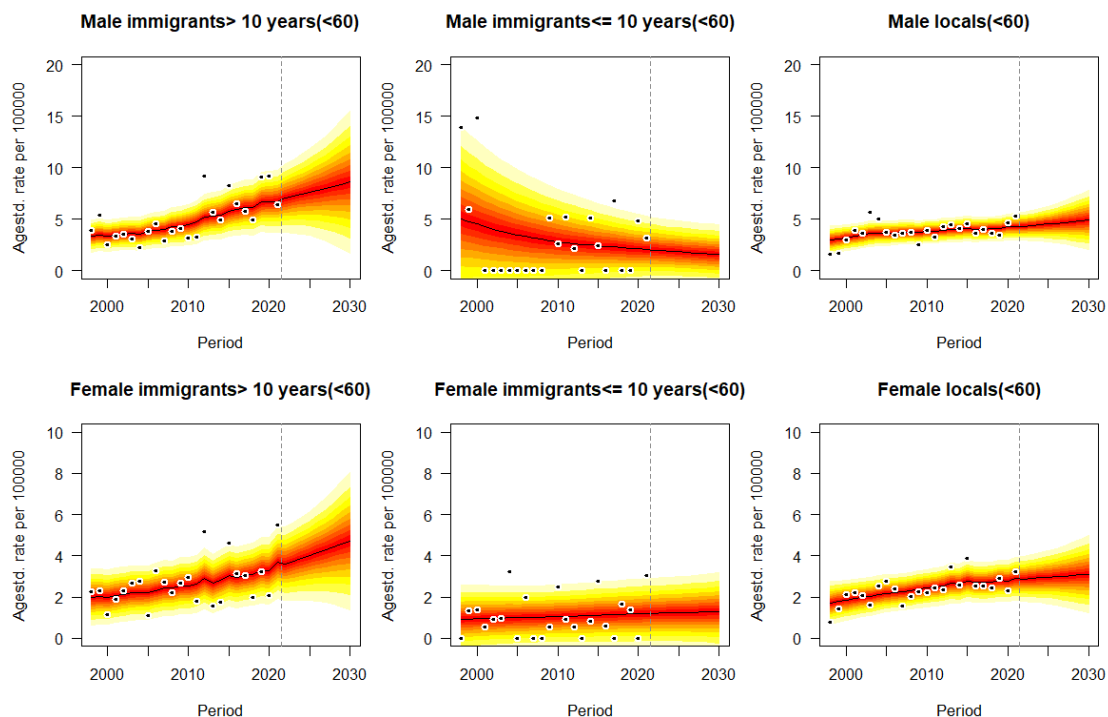
eFigure 3(b). Projections of liver cancer mortality rates for the population younger than 60 by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



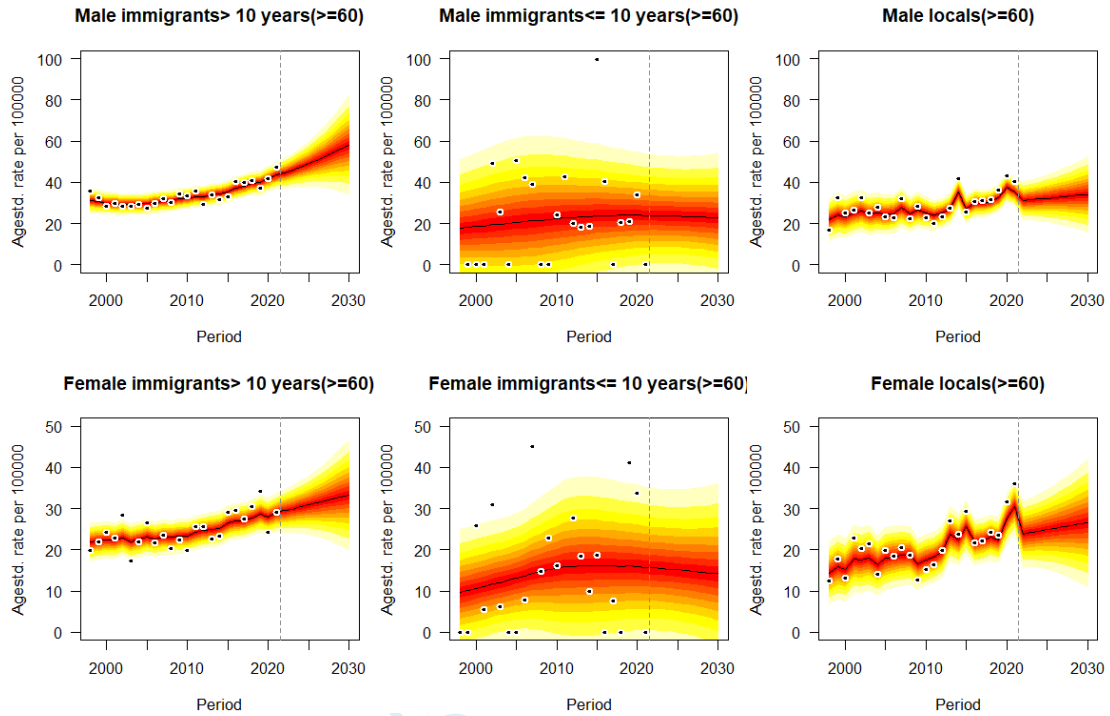
eFigure 3(c). Projections of liver cancer mortality rates for the population older than or equal to 60 by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



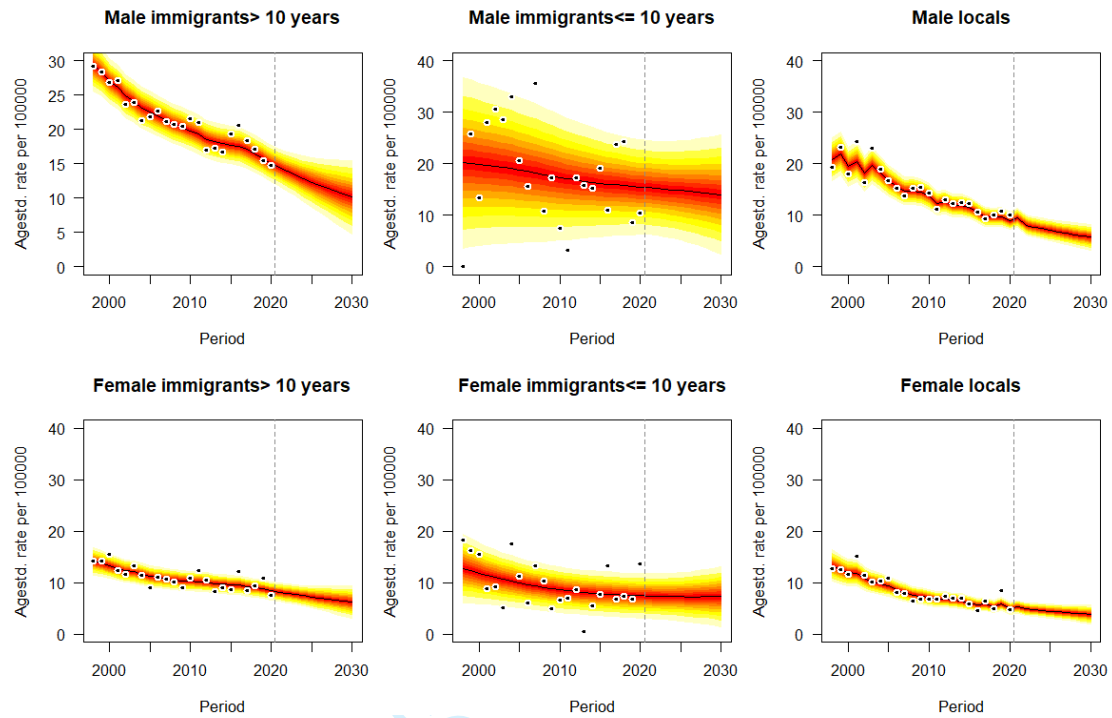
eFigure 4(a). Projections of pancreatic cancer mortality rates by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



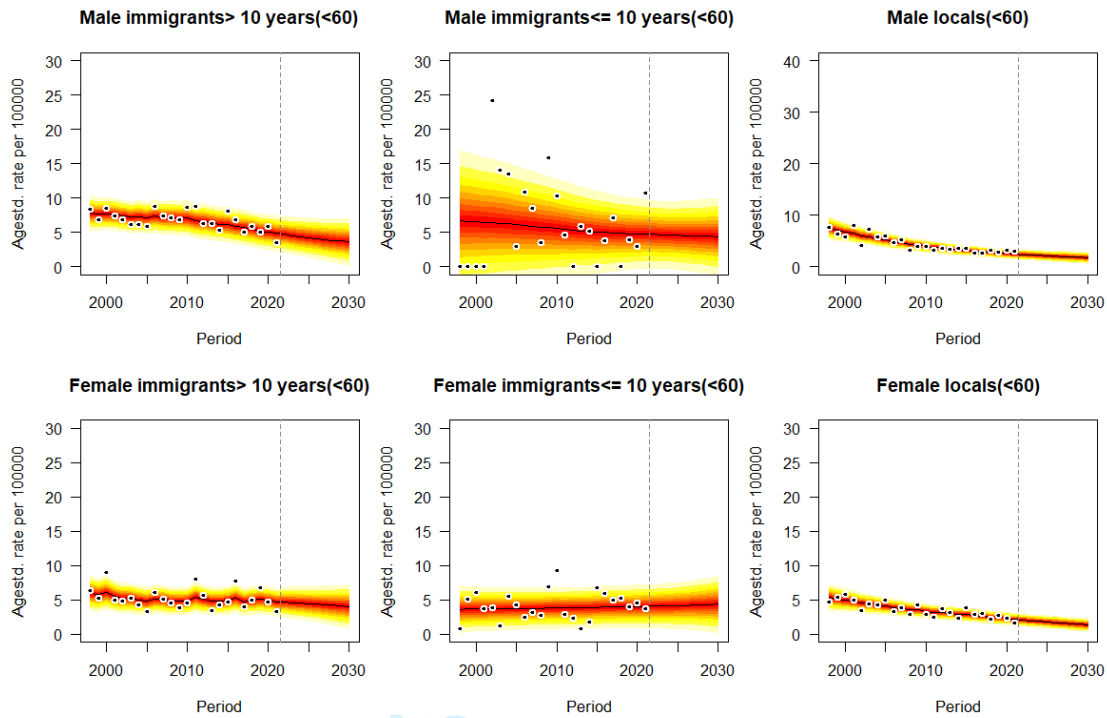
eFigure 4(b). Projections of pancreatic cancer mortality rates for the population younger than 60 by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



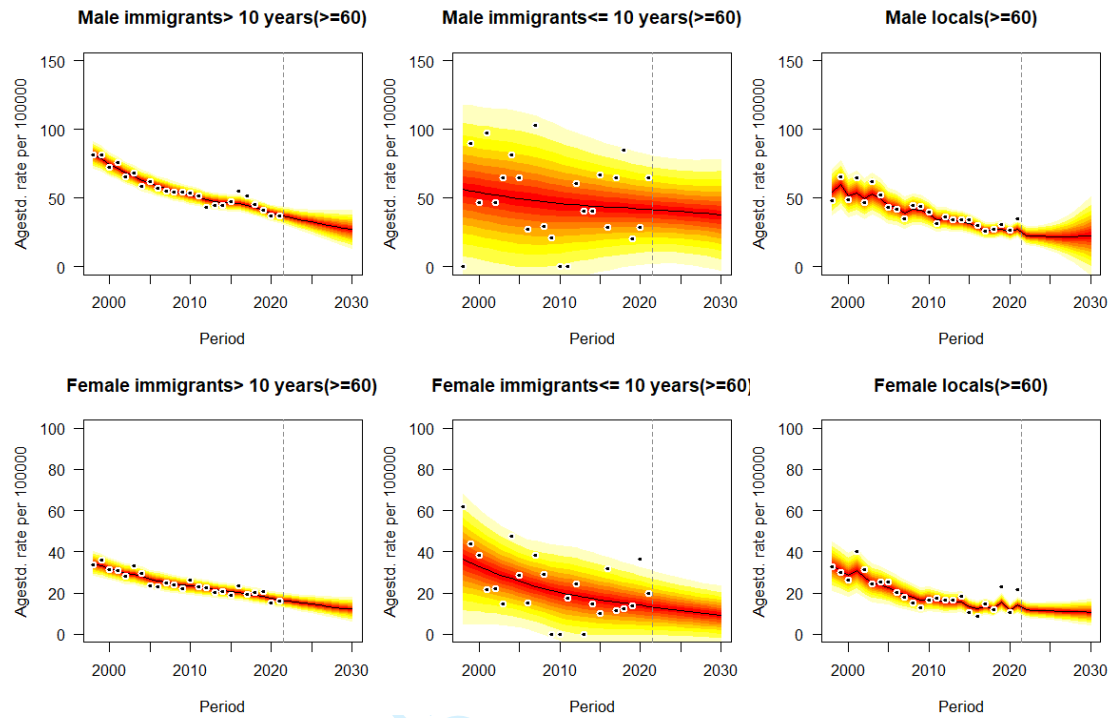
eFigure 4(c). Projections of pancreatic cancer mortality rates for the population older than or equal to 60 by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



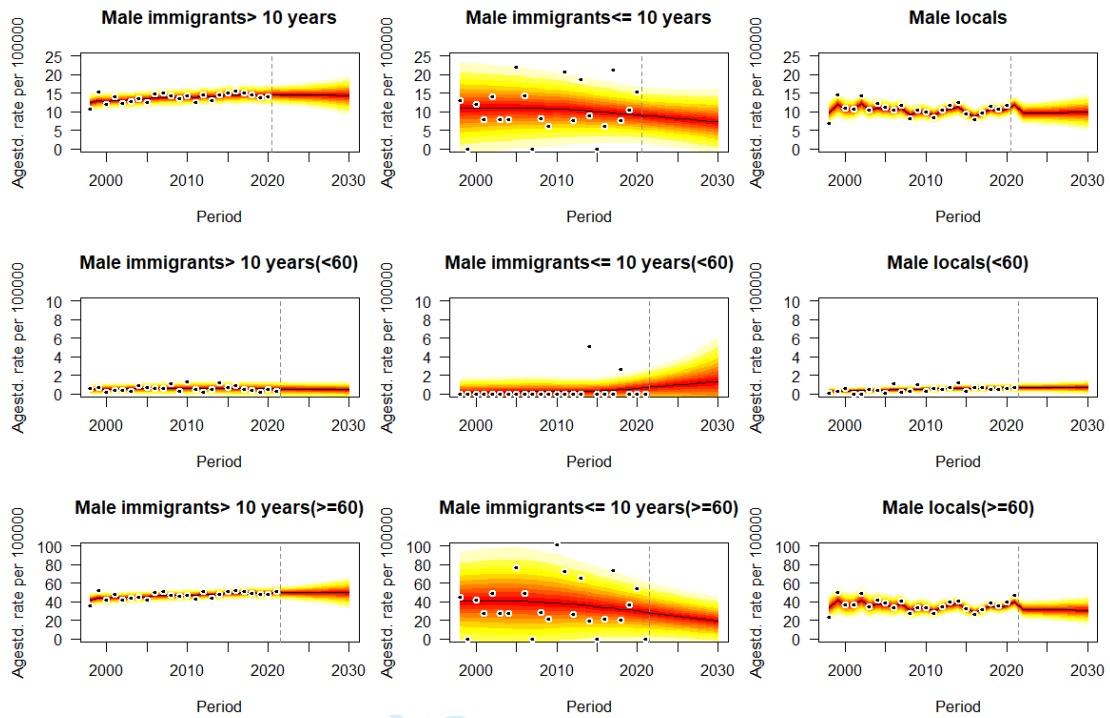
eFigure 5(a). Projections of stomach cancer mortality rates by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



eFigure 5(b). Projections of stomach cancer mortality rates for the population younger than 60 by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



eFigure 5(c). Projections of stomach cancer mortality rates for the population older than or equal to 60 by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



eFigure 6. Projections of prostate cancer mortality rates for males by immigrant status and age groups (less than, greater than or equal to 60 years old) from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.

Predictive mean of age-standardized mortality rates of lung cancer per 100,000 population									
Year	2022	2023	2024	2025	2026	2027	2028	2029	2030
Female immigrants >10	41.34 (1.86)	40.58 (2.27)	39.87 (2.75)	39.19 (3.28)	38.53 (3.86)	37.89 (4.46)	37.26 (5.09)	36.65 (5.74)	36.04 (6.4)
Female immigrants ≤ 10	22.22 (4.67)	20.56 (5.38)	19.01 (6.10)	17.57 (6.80)	16.24 (7.45)	15.00 (8.04)	13.85 (8.56)	12.79 (9.01)	11.81 (9.39)
Female locals	30.22 (3.54)	30.63 (4.77)	31.05 (6.38)	31.48 (8.29)	31.9 (10.47)	32.32 (12.87)	32.73 (15.48)	33.15 (18.31)	33.55 (21.33)
Male immigrants >10	100.18 (4.18)	97.18 (5.33)	94.34 (6.72)	91.71 (8.24)	89.15 (9.84)	86.66 (11.47)	84.19 (13.11)	81.81 (14.74)	79.55 (16.37)
Male immigrants ≤10	79.90 (10.41)	79.81 (11.82)	79.72 (13.42)	79.62 (15.19)	79.50 (17.09)	79.32 (19.09)	79.08 (21.18)	78.78 (23.32)	78.41 (25.53)
Male locals	52.27 (4.86)	50.83 (5.39)	49.56 (6.13)	48.18 (6.97)	46.64 (7.84)	45.13 (8.76)	43.83 (9.76)	42.67 (10.8)	41.43 (11.8)
Female immigrants>10(<60y)	14.51 (1.50)	13.90 (1.76)	13.29 (2.04)	12.71 (2.33)	12.13 (2.62)	11.57 (2.91)	11.02 (3.18)	10.49 (3.43)	9.98(3.68)
Female immigrants ≤ 10(<60y)	7.79 (1.95)	7.18(2.23)	6.62(2.53)	6.10(2.81)	5.63(3.08)	5.19(3.32)	4.79(3.53)	4.42(3.72)	4.09(3.88)
Female locals(<60y)	9.48 (0.89)	9.17(1.02)	8.87(1.16)	8.57(1.32)	8.27(1.49)	7.97(1.65)	7.68(1.82)	7.38(1.98)	7.09(2.13)
Male immigrants>10(<60y)	26.36 (3.58)	24.96 (3.94)	23.64 (4.35)	22.38 (4.79)	21.17 (5.23)	20.03 (5.67)	18.96 (6.10)	17.96 (6.51)	17.03 (6.90)
Male immigrants ≤ 10(<60y)	13.38 (3.71)	12.02 (4.17)	10.79 (4.59)	9.68 (4.95)	8.69 (5.24)	7.79 (5.46)	6.98 (5.61)	6.25 (5.69)	5.59 (5.72)
Male locals(<60y)	14.45 (1.15)	14.03 (1.29)	13.61 (1.46)	13.14 (1.64)	12.65 (1.82)	12.13 (2.01)	11.55 (2.17)	10.93 (2.31)	10.26 (2.43)
Female immigrants >10(≥ 60y)	107.21 (5.17)	106.26 (6.24)	105.52 (7.54)	104.94 (9.04)	104.51 (10.72)	104.21 (12.57)	104.07 (14.61)	104.06 (16.78)	104.16 (19.14)
Female immigrants ≤ 10(≥60y)	63.84 (15.72)	59.88 (17.50)	56.14 (19.31)	52.60 (21.03)	49.27 (22.66)	46.14 (24.16)	43.20 (25.52)	40.44 (26.74)	37.85 (27.81)
Female locals(≥60y)	76.53 (10.11)	76.22 (10.85)	75.94 (11.79)	75.69 (12.94)	75.49 (14.28)	75.32 (15.80)	75.19 (17.48)	75.10 (19.33)	75.03 (21.32)
Male immigrants>10(≥60y)	289.8 (11.7)	286.6 (15.19)	284.28 (19.51)	282.78 (24.49)	281.99 (30.07)	281.88 (36.31)	282.31 (43.15)	283.37 (50.66)	285.03 (58.86)
Male immigrants ≤ 10(≥60y)	247.01 (36.85)	251.24 (42.94)	255.62 (50.06)	260.14 (58.14)	264.82 (67.14)	269.61 (77.01)	274.52 (87.75)	279.55 (99.34)	284.69 (111.81)
Male locals(≥60y)	146.29 (18.46)	143.54 (20.58)	141.84 (23.97)	140.07 (28.24)	138.14 (33.39)	136.65 (39.82)	136.49 (47.87)	137.24 (57.47)	138.26 (68.52)

eTable 1. Predictive means and standard deviations (in brackets) of age-standardized mortality rates of lung cancer per 100,000 population for each gender, age group (less than, greater or equal to 60 years old) and immigrant status from 2022 to 2030.

Predictive mean of age-standardized mortality rates of colon cancer per 100,000 population									
Year	2022	2023	2024	2025	2026	2027	2028	2029	2030
Female immigrants >10	18.95 (1.13)	18.77 (1.37)	18.59 (1.66)	18.42 (1.98)	18.27 (2.33)	18.12 (2.71)	17.98 (3.11)	17.85 (3.53)	17.73 (3.96)
Female immigrants ≤ 10	7.70 (2.51)	7.25 (2.81)	6.82 (3.11)	6.42 (3.37)	6.03 (3.61)	5.67 (3.83)	5.33 (4.01)	5.01 (4.17)	4.71 (4.31)
Female locals	13.47 (1.61)	13.24 (1.72)	13.01 (1.87)	12.77 (2.04)	12.53 (2.24)	12.29 (2.46)	12.06 (2.68)	11.82 (2.92)	11.59 (3.16)
Male immigrants >10	29.82 (1.46)	29.66 (1.79)	29.52 (2.19)	29.41 (2.63)	29.30 (3.11)	29.21 (3.64)	29.14 (4.19)	29.06 (4.78)	28.98 (5.39)
Male immigrants ≤10	16.77 (3.77)	17.02 (4.18)	17.23 (4.64)	17.45 (5.14)	17.67 (5.69)	17.88 (6.27)	18.09 (6.91)	18.31 (7.56)	18.50 (8.26)
Male locals	19.81 (2.07)	19.39 (2.22)	18.97 (2.42)	18.57 (2.61)	18.18 (2.85)	17.81 (3.12)	17.43 (3.40)	17.06 (3.71)	16.71 (4.03)
Female immigrants >10(<60y)	7.36 (1.12)	7.46 (1.28)	7.56 (1.46)	7.65 (1.68)	7.74 (1.92)	7.83 (2.19)	7.92 (2.48)	8.01 (2.79)	8.09 (3.13)
Female immigrants ≤ 10(<60y)	2.82 (0.86)	2.65 (0.91)	2.51 (0.97)	2.36 (1.02)	2.22 (1.07)	2.08 (1.11)	1.95 (1.14)	1.83 (1.18)	1.72 (1.22)
Female locals(<60y)	3.87 (0.50)	3.73 (0.54)	3.61 (0.59)	3.47 (0.65)	3.34 (0.70)	3.22 (0.76)	3.11 (0.82)	2.99 (0.88)	2.88 (0.94)
Male immigrants >10(<60y)	7.9 (1.17)	7.85 (1.38)	7.71 (1.60)	7.54(1.83)	7.36(2.08)	7.17(2.32)	6.97(2.57)	6.76(2.81)	6.55(3.05)
Male immigrants ≤ 10(<60y)	5.18 (1.58)	5.22 (1.75)	5.26 (1.93)	5.30(2.14)	5.34(2.36)	5.38(2.59)	5.43(2.84)	5.47(3.11)	5.51(3.38)
Male locals(<60y)	4.88 (0.63)	4.66 (0.79)	4.46 (0.96)	4.26(1.13)	4.08(1.31)	3.91(1.48)	3.73(1.65)	3.57(1.82)	3.42(1.97)
Female immigrants >10(≥60y)	49.21 (2.99)	48.70 (3.56)	48.26 (4.26)	47.87 (5.05)	47.54 (5.94)	47.26 (6.90)	47.05 (7.94)	46.91 (9.06)	46.81 (10.26)
Female immigrants ≤ 10(≥60y)	22.44 (6.56)	21.69 (6.96)	20.95 (7.38)	20.23 (7.80)	19.52 (8.23)	18.84 (8.66)	18.17 (9.08)	17.51 (9.49)	16.86 (9.90)
Female locals(≥60y)	36.69 (5.74)	36.29 (6.06)	35.87 (6.46)	35.46 (6.95)	35.04(7.5)	34.61 (8.12)	34.19 (8.79)	33.77 (9.51)	33.34 (10.27)
Male immigrants >10(≥60y)	82.72 (4.09)	82.16 (4.95)	81.64 (5.97)	81.19 (7.12)	80.81 (8.39)	80.47 (9.77)	80.15 (11.24)	79.85 (12.81)	79.56 (14.45)
Male immigrants ≤ 10(≥60y)	44.93 (13.09)	45.62 (14.52)	46.30 (16.09)	46.96 (17.80)	47.61 (19.64)	48.25 (21.62)	48.88 (23.73)	49.51 (25.97)	50.13 (28.34)
Male locals(≥60y)	54.89 (7.65)	53.75 (8.03)	52.63 (8.52)	51.54 (9.12)	50.47 (9.8)	49.43 (10.55)	48.42 (11.37)	47.42 (12.25)	46.44 (13.16)

eTable 2. Predictive means and standard deviations (in brackets) of age-standardized mortality rates of colon cancer per 100,000 population for each gender, age group (less than, greater or equal to 60 years old) and immigrant status from 2022 to 2030.

Predictive mean of age-standardized mortality rates of liver cancer per 100,000 population									
Year	2022	2023	2024	2025	2026	2027	2028	2029	2030
Female immigrants >10	10.68 (0.71)	10.09 (0.85)	9.54 (1.01)	9.01 (1.16)	8.50 (1.31)	8.02(1.45)	7.57(1.59)	7.14(1.72)	6.74(1.83)
Female immigrants ≤10	8.66 (1.82)	8.38 (1.95)	8.11 (2.08)	7.84 (2.22)	7.58 (2.36)	7.32(2.49)	7.07(2.63)	6.82(2.76)	6.58(2.88)
Female locals	6.36 (0.88)	6.08 (0.90)	5.81 (0.93)	5.53 (0.97)	5.26 (1.01)	5.01(1.06)	4.77(1.11)	4.53(1.15)	4.3(1.21)
Male immigrants >10	49.22 (2.36)	47.76 (2.93)	46.35 (3.59)	45.01 (4.31)	43.67 (5.05)	42.37 (5.81)	41.1(6.56)	39.89 (7.33)	38.71 (8.08)
Male immigrants ≤10	39.03 (6.49)	37.39 (7.47)	35.81 (8.51)	34.26 (9.58)	32.76 (10.63)	31.31 (11.65)	29.91 (12.62)	28.56 (13.54)	27.25 (14.40)
Male locals	22.16 (2.09)	21.02 (2.22)	19.91 (2.39)	18.85 (2.58)	17.83 (2.79)	16.85 (3.03)	15.92 (3.21)	15.03 (3.40)	14.18 (3.59)
Female immigrants >10(<60y)	3.39 (0.52)	3.29 (0.57)	3.20 (0.63)	3.12 (0.69)	3.04 (0.75)	2.96(0.82)	2.89(0.89)	2.82(0.96)	2.75(1.03)
Female immigrants ≤10(<60y)	3.81 (0.91)	3.69 (0.96)	3.57 (1.02)	3.46 (1.08)	3.36 (1.15)	3.25(1.22)	3.15(1.29)	3.06(1.36)	2.97(1.43)
Female locals(<60y)	1.37 (0.2)	1.29 (0.21)	1.22 (0.23)	1.16 (0.24)	1.10 (0.26)	1.04(0.27)	0.99(0.29)	0.94(0.30)	0.89(0.31)
Male immigrants >10(<60y)	24.04 (2.35)	23.02 (2.63)	22.05 (2.94)	21.13 (3.27)	20.25 (3.61)	19.41 (3.95)	18.62 (4.30)	17.86 (4.64)	17.14 (4.98)
Male immigrants ≤10(<60y)	22.56 (3.96)	21.71 (4.44)	20.87 (4.94)	20.04 (5.45)	19.22 (5.95)	18.42 (6.45)	17.63 (6.91)	16.86 (7.36)	16.11 (7.78)
Male locals(<60y)	7.47 (0.74)	6.97 (0.79)	6.52 (0.86)	6.11 (0.93)	5.73 (1.01)	5.38(1.08)	5.04(1.15)	4.73(1.21)	4.44(1.27)
Female immigrants >10(≥60y)	29.63 (2.01)	27.99 (2.36)	26.42 (2.75)	24.92 (3.14)	23.49 (3.52)	22.13 (3.88)	20.85 (4.23)	19.64 (4.55)	18.50 (4.85)
Female immigrants ≤10(≥60y)	19.08 (5.81)	18.38 (6.14)	17.71 (6.48)	17.03 (6.83)	16.39 (7.16)	15.76 (7.49)	15.16 (7.80)	14.57 (8.11)	14.01 (8.39)
Female locals(≥60y)	18.41 (3.23)	17.55 (3.26)	16.72 (3.32)	15.91 (3.40)	15.11 (3.49)	14.34 (3.59)	13.59 (3.69)	12.87 (3.81)	12.17 (3.93)
Male immigrants >10(≥60y)	113.96 (5.95)	113.43 (7.65)	113.17 (9.70)	113.16 (12.04)	113.37 (14.66)	113.79 (17.56)	114.39 (20.73)	115.19 (24.18)	116.17 (27.91)
Male immigrants ≤10(≥60y)	85.14 (18.85)	82.59 (20.6)	80.02 (22.44)	77.42 (24.34)	74.83 (26.24)	72.23 (28.12)	69.64 (29.94)	67.07 (31.70)	64.52 (33.38)
Male locals(≥60y)	58.95 (7.91)	56.51 (8.20)	54.14 (8.61)	51.84 (9.12)	49.61 (9.70)	47.46 (10.33)	45.38 (11.01)	43.38 (11.68)	41.45(12.36)

eTable 3. Predictive means and standard deviations (in brackets) of age-standardized mortality rates of liver cancer per 100,000 population for each gender, age group (less than, greater or equal to 60 years old) and immigrant status from 2022 to 2030.

Predictive mean of age-standardized mortality rates of pancreatic cancer per 100,000 population									
Year	2022	2023	2024	2025	2026	2027	2028	2029	2030
Female immigrants >10	11.11 (0.75)	11.36 (0.91)	11.61 (1.09)	11.87 (1.31)	12.14 (1.56)	12.42 (1.84)	12.71 (2.15)	13.01 (2.48)	13.3(2.85)
Female immigrants ≤ 10	5.44 (1.56)	5.44 (1.69)	5.43(1.84)	5.42(1.99)	5.41(2.15)	5.39(2.32)	5.36(2.49)	5.34(2.66)	5.31(2.84)
Female locals	9.01 (1.22)	9.15 (1.34)	9.29(1.48)	9.43(1.64)	9.57(1.83)	9.71(2.05)	9.85(2.28)	9.99(2.54)	10.14 (2.83)
Male immigrants >10	17.87 (1.19)	18.48 (1.49)	19.11 (1.87)	19.78 (2.32)	20.47 (2.83)	21.18 (3.42)	21.92 (4.07)	22.69 (4.81)	23.49 (5.61)
Male immigrants ≤10	7.87 (2.37)	7.76 (2.53)	7.64(2.70)	7.51(2.87)	7.38(3.05)	7.24(3.23)	7.09(3.41)	6.95(3.58)	6.81(3.75)
Male locals	12.29 (1.49)	12.49 (1.64)	12.69 (1.83)	12.91 (2.06)	13.11 (2.33)	13.33 (2.63)	13.55 (2.97)	13.78 (3.34)	14.02 (3.74)
Female immigrants >10(<60y)	3.62 (0.57)	3.74 (0.66)	3.87(0.77)	4.01(0.89)	4.14(1.02)	4.28(1.18)	4.42(1.34)	4.57(1.53)	4.72(1.73)
Female immigrants ≤ 10(<60y)	1.21 (0.48)	1.22 (0.52)	1.23(0.56)	1.24(0.61)	1.25(0.66)	1.26(0.71)	1.26(0.77)	1.27(0.83)	1.28(0.89)
Female locals(<60y)	2.88 (0.36)	2.91 (0.41)	2.93(0.48)	2.96(0.55)	2.99(0.63)	3.02(0.71)	3.04(0.81)	3.07(0.90)	3.10(1.01)
Male immigrants >10(<60y)	7.05 (1.11)	7.24 (1.32)	7.43(1.56)	7.62(1.84)	7.82(2.16)	8.01(2.50)	8.21(2.88)	8.40(3.30)	8.61(3.75)
Male immigrants ≤ 10(<60y)	2.01 (0.85)	1.95 (0.91)	1.9(0.94)	1.84(0.99)	1.79(1.04)	1.74(1.09)	1.69(1.14)	1.64(1.19)	1.60(1.24)
Male locals(<60y)	4.33 (0.48)	4.41 (0.57)	4.46(0.68)	4.53(0.81)	4.61(0.94)	4.69(1.09)	4.77(1.26)	4.85(1.44)	4.93(1.63)
Female immigrants >10(≥60y)	29.45 (2.11)	29.91 (2.54)	30.38 (3.06)	30.85 (3.66)	31.33 (4.33)	31.81 (5.08)	32.29 (5.91)	32.78 (6.79)	33.27 (7.74)
Female immigrants ≤ 10(≥60y)	15.65 (6.08)	15.49 (6.71)	15.33 (7.36)	15.16 (8.03)	14.97 (8.73)	14.79 (9.43)	14.59 (10.14)	14.39 (10.86)	14.19 (11.58)
Female locals(≥60y)	23.85 (4.46)	24.21 (4.81)	24.56 (5.23)	24.91 (5.73)	25.25 (6.30)	25.58 (6.95)	25.90 (7.67)	26.22 (8.47)	26.54 (9.34)
Male immigrants >10(≥60y)	44.36 (3.02)	45.85 (3.76)	47.41 (4.69)	49.04 (5.78)	50.73 (7.05)	52.48 (8.50)	54.28 (10.13)	56.16 (11.95)	58.11 (13.98)
Male immigrants ≤ 10(≥60y)	23.96 (9.01)	23.87 (9.74)	23.75 (10.52)	23.61 (11.33)	23.45 (12.17)	23.28 (13.04)	23.09 (13.93)	22.89 (14.83)	22.68 (15.75)
Male locals(≥60y)	31.17 (5.22)	31.55 (5.63)	31.93 (6.14)	32.30 (6.75)	32.66 (7.45)	33.01 (8.23)	33.35 (9.11)	33.69 (10.08)	34.03 (11.12)

eTable 4. Predictive means and standard deviations (in brackets) of age-standardized mortality rates of pancreatic cancer per 100,000 population for each gender, age group (less than, greater or equal to 60 years old) and immigrant status from 2022 to 2030.

Predictive mean of age-standardized mortality rates of stomach cancer per 100,000 population									
Year	2022	2023	2024	2025	2026	2027	2028	2029	2030
Female immigrants >10	7.95 (0.62)	7.71 (0.74)	7.47 (0.87)	7.25 (1.01)	7.03 (1.15)	6.83 (1.29)	6.62 (1.43)	6.43 (1.57)	6.24 (1.71)
Female immigrants ≤10	7.36 (1.56)	7.33 (1.69)	7.30 (1.85)	7.28 (2.01)	7.27 (2.20)	7.27 (2.40)	7.28 (2.61)	7.31 (2.84)	7.33 (3.09)
Female locals	4.91 (0.52)	4.75 (0.57)	4.61 (0.63)	4.47 (0.71)	4.34 (0.77)	4.21 (0.84)	4.08 (0.91)	3.95 (0.99)	3.83 (1.06)
Male immigrants >10	13.89 (0.97)	13.34(1.21)	12.81 (1.46)	12.31 (1.73)	11.83 (1.99)	11.38 (2.26)	10.95 (2.51)	10.54 (2.76)	10.15 (3.01)
Male immigrants ≤10	15.21 (3.38)	15.07 (3.67)	14.93 (3.98)	14.79 (4.31)	14.64 (4.65)	14.51 (5.02)	14.35 (5.39)	14.19 (5.78)	14.03 (6.17)
Male locals	8.07 (0.99)	7.73 (1.03)	7.41(1.07)	7.10 (1.13)	6.81 (1.19)	6.51 (1.26)	6.23 (1.33)	5.97 (1.39)	5.71 (1.46)
Female immigrants >10(<60y)	4.69 (0.79)	4.62 (0.87)	4.55 (0.96)	4.47 (1.07)	4.39 (1.17)	4.31 (1.29)	4.22 (1.41)	4.13 (1.52)	4.03 (1.64)
Female immigrants ≤10(<60y)	4.08 (0.93)	4.10 (1.03)	4.13 (1.14)	4.17 (1.27)	4.21 (1.41)	4.24 (1.55)	4.28 (1.70)	4.32 (1.87)	4.36 (2.05)
Female locals(<60y)	2.08 (0.27)	1.98 (0.29)	1.88 (0.32)	1.79 (0.35)	1.71 (0.37)	1.61 (0.41)	1.53 (0.43)	1.44 (0.45)	1.37 (0.47)
Male immigrants >10(<60y)	4.71 (0.79)	4.55 (0.89)	4.41 (0.99)	4.25 (1.10)	4.12 (1.21)	3.98 (1.32)	3.86 (1.43)	3.74 (1.54)	3.63 (1.65)
Male immigrants ≤10(<60y)	4.70 (1.42)	4.66 (1.55)	4.63 (1.69)	4.59 (1.83)	4.55 (1.99)	4.52 (2.15)	4.48 (2.32)	4.44 (2.50)	4.41 (2.68)
Male locals(<60y)	2.37 (0.29)	2.28 (0.32)	2.21 (0.35)	2.12 (0.38)	2.04 (0.42)	1.97 (0.45)	1.91 (0.49)	1.83 (0.52)	1.77(0.55)
Female immigrants >10(≥60y)	16.23 (1.26)	15.65 (1.47)	15.08 (1.70)	14.55 (1.94)	14.03 (2.18)	13.54 (2.43)	13.07 (2.68)	12.62 (2.92)	12.19 (3.16)
Female immigrants ≤10(≥60y)	13.01 (4.83)	12.52 (5.11)	12.03 (5.37)	11.55 (5.63)	11.08 (5.88)	10.63 (6.12)	10.19 (6.35)	9.76(6.56)	9.34 (6.75)
Female locals(≥60y)	11.86 (1.84)	11.67 (1.98)	11.49 (2.15)	11.33 (2.35)	11.18 (2.58)	11.04 (2.84)	10.91 (3.11)	10.79(3.4)	10.68 (3.71)
Male immigrants >10(≥60y)	36.59 (2.56)	35.17(3.18)	33.82 (3.86)	32.55 (4.57)	31.34 (5.28)	30.19 (6.01)	29.08 (6.70)	28.02 (7.40)	27.01 (8.07)
Male immigrants ≤10(≥60y)	41.43 (11.78)	41.03 (12.71)	40.61 (13.70)	40.17 (14.75)	39.71 (15.85)	39.24 (16.99)	38.75 (18.16)	38.23 (19.35)	37.71 (20.57)
Male locals(≥60y)	22.69 (3.56)	22.37(4.07)	22.16(4.84)	21.89 (5.86)	21.61 (7.22)	21.52 (9.02)	21.74 (11.29)	22.17 (14.03)	22.73 (17.28)

eTable 5. Predictive means and standard deviations (in brackets) of age-standardized mortality rates of stomach cancer per 100,000 population for each gender, age group (less than, greater or equal to 60 years old) and immigrant status from 2022 to 2030.

Predictive mean of age-standardized mortality rates of prostate cancer per 100,000 population									
Year	2022	2023	2024	2025	2026	2027	2028	2029	2030
Male immigrants >10	14.59 (0.79)	14.57 (0.96)	14.56 (1.15)	14.54 (1.37)	14.51 (1.61)	14.48 (1.86)	14.45 (2.13)	14.42 (2.42)	14.38 (2.72)
Male immigrants ≤ 10	8.78 (3.11)	8.58(3.29)	8.39 (3.49)	8.19(3.69)	8.10(3.89)	7.82(4.11)	7.63(4.31)	7.45(4.51)	7.27(4.72)
Male locals	9.66 (1.57)	9.67(1.66)	9.69 (1.77)	9.72(1.91)	9.75(2.06)	9.78(2.23)	9.82(2.43)	9.86(2.64)	9.9(2.88)
Male immigrants >10(<60y)	0.52 (0.17)	0.51(0.19)	0.50 (0.21)	0.49(0.22)	0.48(0.24)	0.47(0.25)	0.46(0.27)	0.45(0.29)	0.44(0.31)
Male immigrants ≤ 10(<60y)	0.73 (0.77)	0.81(0.93)	0.87 (1.10)	0.94(1.31)	1.01(1.51)	1.09(1.75)	1.16(2.02)	1.24(2.32)	1.33(2.64)
Male locals(<60y)	0.66 (0.14)	0.66(0.16)	0.66 (0.19)	0.67(0.21)	0.67(0.24)	0.67(0.27)	0.68(0.31)	0.68(0.33)	0.69(0.37)
Male immigrants >10(≥ 60y)	49.61 (2.73)	49.63 (3.29)	49.64 (3.94)	49.64 (4.68)	49.64 (5.51)	49.63 (6.38)	49.62 (7.32)	49.61 (8.32)	49.58(9.37)
Male immigrants ≤ 10(≥60y)	27.66 (9.78)	26.53 (10.21)	25.4 (10.63)	24.28 (11.03)	23.16 (11.41)	22.07 (11.76)	21.01 (12.09)	19.96 (12.38)	18.95(12.63)
Male locals(≥60y)	31.48 (5.49)	31.40 (5.76)	31.32 (6.09)	31.24 (6.48)	31.15 (6.94)	31.06 (7.44)	30.96 (8.01)	30.86 (8.61)	30.74(9.26)

Table 6. Predictive means and standard deviations (in brackets) of age-standardized mortality rates of prostate cancer per 100,000 population for each age group (less than, greater or equal to 60 years old) and immigrant status from 2022 to 2030.

Reporting checklist for cohort study.

Based on the STROBE cohort guidelines.

Instructions to authors

Complete this checklist by entering the page numbers from your manuscript where readers will find each of the items listed below.

Your article may not currently address all the items on the checklist. Please modify your text to include the missing information. If you are certain that an item does not apply, please write "n/a" and provide a short explanation.

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In your methods section, say that you used the STROBE cohort reporting guidelines, and cite them as:

von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The Strengthening of Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies.

			Page Number
Title and abstract			
Title	#1a	Indicate the study's design with a commonly used term in the title or the abstract	1
Abstract	#1b	Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background / rationale	#2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	#3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	#4	Present key elements of study design early in the paper	5
Setting	#5	Describe the setting, locations, and relevant dates, including periods	5

1		of recruitment, exposure, follow-up, and data collection		
2	Eligibility criteria	#6a	Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up.	5
3				
4				
5				
6	Eligibility criteria	#6b	For matched studies, give matching criteria and number of exposed and unexposed	n/a
7				
8				
9				
10	Variables	#7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
11				
12				
13				
14				
15	Data sources /	#8	For each variable of interest give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group. Give information separately for for exposed and unexposed groups if applicable.	5
16	measurement			
17				
18				
19				
20				
21				
22	Bias	#9	Describe any efforts to address potential sources of bias	5
23				
24	Study size	#10	Explain how the study size was arrived at	5
25				
26				
27	Quantitative	#11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why	5
28	variables			
29				
30				
31	Statistical	#12a	Describe all statistical methods, including those used to control for confounding	
32	methods			
33				
34	5			
35				
36				
37	Statistical	#12b	Describe any methods used to examine subgroups and interactions	5
38	methods			
39				
40				
41	Statistical	#12c	Explain how missing data were addressed	5
42	methods			
43				
44	Statistical	#12d	If applicable, explain how loss to follow-up was addressed	n/a
45	methods			
46				
47				
48	Statistical	#12e	Describe any sensitivity analyses	
49	methods			
50				
51				
52	n/a			
53				
54	Results			
55				
56				
57	Participants	#13a	Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible,	n/a
58				
59				
60				

included in the study, completing follow-up, and analysed. Give information separately for for exposed and unexposed groups if applicable.

1			
2			
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4			
5	Participants	#13b	Give reasons for non-participation at each stage 5
6			
7	Participants	#13c	Consider use of a flow diagram
8			
9	n/a		
10			
11			
12	Descriptive data	#14a	Give characteristics of study participants (eg demographic, clinical, 5
13			social) and information on exposures and potential confounders. Give
14			information separately for exposed and unexposed groups if
15			applicable.
16			
17			
18			
19	Descriptive data	#14b	Indicate number of participants with missing data for each variable of
20			interest
21			
22			
23	n/a		
24			
25	Descriptive data	#14c	Summarise follow-up time (eg, average and total amount)
26			
27			
28	n/a		
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30	Outcome data	#15	Report numbers of outcome events or summary measures over time.
31			Give information separately for exposed and unexposed groups if
32			applicable.
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35	n/a		
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38	Main results	#16a	Give unadjusted estimates and, if applicable, confounder-adjusted 6
39			estimates and their precision (eg, 95% confidence interval). Make
40			clear which confounders were adjusted for and why they were
41			included
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44	Main results	#16b	Report category boundaries when continuous variables were n/a
45			categorized
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48	Main results	#16c	If relevant, consider translating estimates of relative risk into absolute
49			risk for a meaningful time period
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52	n/a		
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54	Other analyses	#17	Report other analyses done—eg analyses of subgroups and 7
55			interactions, and sensitivity analyses
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Discussion

1	Key results	#18	Summarise key results with reference to study objectives	8
2				
3	Limitations	#19	Discuss limitations of the study, taking into account sources of	10
4			potential bias or imprecision. Discuss both direction and magnitude of	
5			any potential bias.	
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8	Interpretation	#20	Give a cautious overall interpretation considering objectives,	8
9			limitations, multiplicity of analyses, results from similar studies, and	
10			other relevant evidence.	
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13	Generalisability	#21	Discuss the generalisability (external validity) of the study results	9
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16	Other			
17	Information			
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20	Funding	#22	Give the source of funding and the role of the funders for the present	11
21			study and, if applicable, for the original study on which the present	
22			article is based	
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An age-period-cohort analysis and projection of cancer mortality in Hong Kong, 1998–2030

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An age-period-cohort analysis and projection of cancer mortality in Hong Kong, 1998–2030

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24 Abstract

25 **Objectives:** To explore the relationship between immigration groups and cancer mortality, this
26 study aimed to explore age, period, birth cohort effects and effects across genders and
27 immigration groups on mortality rates of lung, pancreatic, colon, liver, prostate and stomach
28 cancers and their projections.

30 **Design, Setting, and Participants:** Death registry data in Hong Kong between 1998 and 2021,
31 which were stratified by age, sex and immigration status. Immigration status was classified into
32 three groups: locals born in Hong Kong, long-stay immigrants and short-stay immigrants.

34 **Methods:** Age-period-cohort analysis was used to examine age, period, and birth cohort effects
35 for genders and immigration groups from 1998 to 2021. Bayesian age-period-cohort models
36 were applied to predict the mortality rates from 2022 to 2030.

38 **Results:** Short-stay immigrants revealed pronounced fluctuations of mortality rates by age and
39 of relative risks by cohort and period effects for six types of cancers than those of long-stay
40 immigrants and locals. Immigrants for each type of cancer and gender will be at a higher
41 mortality risk than locals, as men will be at a higher risk of mortality from cancers than women
42 in the future (excluding prostate cancer). After 2021, decreasing trends ($p<0.05$) or plateau
43 ($p>0.05$) of forecasting mortality rates of cancers occur for all immigration groups, except for
44 increasing trends for short-stay male immigrants with colon cancer ($p<0.05$, Avg +0.30
45 deaths/100,000 per annum from 15.47 to 18.50 deaths/100,000) and long-stay male immigrants
46 with pancreatic cancer ($p<0.05$, Avg +0.72 deaths/100,000 per annum from 16.30 to 23.49
47 deaths/100,000).

49 **Conclusions:** Findings underscore the effect of gender and immigration status in Hong Kong
50 on mortality risks of cancers that immigrants for each type of cancer and gender will be at a
51 higher mortality risk than locals.

53 **Keywords:** Age-period-cohort analysis, immigration, mortality, lung cancer, pancreatic cancer,
54 colon cancer, liver cancer, prostate cancer, stomach cancer

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55 **Strengths and limitations of this study**

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57 • This study provides new evidence regarding the relationship between immigration status
58 and cancer mortality, given the effects of age, period, birth cohort and their predictions.

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60 • The non-identifiability problem has not been interpreted in APC models

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62 • The future perspective of cancer therapies and techniques have not been considered.

For peer review only

64 Introduction

65 Several migration waves from mainland China to Hong Kong have occurred over the past
66 century. These migration waves included a large-scale migration inflow from 1945 to 1950 (the
67 Chinese Civil War) and a few small-scale inflows in the 1950s, 1970s, and 1990s [1-3]. In 2016,
68 immigrants from mainland China formed approximately 38% of the population of Hong Kong.
69 These inflows have led to a growing interest in research on the disparity of health conditions
70 between the locals and immigrants.

71
72 Cancer has been one of the most common causes of death, as an estimated 19.3 million new
73 cancer cases and 9.9 million new cancer-associated deaths occurred worldwide in 2020 [4]. In
74 Hong Kong, lung cancer is one of the most common causes of cancer deaths [5, 6]. Previous
75 studies suggested that the primary cause of lung cancer is cigarette smoking [7-11]. Genetic
76 factors, asbestos, radon gas, second-hand smoke, and other forms of air pollution have been
77 proven to influence the risk of lung cancer [12-18]. The overall daily smoking rate in mainland
78 China was approximately 23.2% in 2018 [19], whereas the daily smoking rate in Hong Kong
79 was only 10.2% in 2019 [20]. The leading causes of liver cancer include viral infection,
80 drinking of alcohol and polluted water and food supplies which are also culprits for colon,
81 stomach and pancreatic cancer [21]. Alcohol consumption per capita in Hong Kong has reached
82 2.37 liters in 2021 [22], compared to 7.0 liters of per capita consumption of alcohol in mainland
83 China in 2018 [23]. As approximately 99% of prostate cancer cases occur after age 50, factors
84 of prostate cancer have been regarded as old age, race, family history and the diet of red meat
85 consumption [24]. In addition to these risk factors, studies have suggested that cancer mortality
86 rates vary depending on migrant status [25-28]. According to data from the Census and
87 Statistics Department of Hong Kong, approximately 81% of immigrants in Hong Kong
88 immigrated from mainland China, Macau, and Taiwan. Immigrants from mainland China
89 account for the bulk of this population. Previous studies have shown that child immigrants in
90 Hong Kong tend to suffer from a higher risk of wheezing disorders and cardiovascular diseases,
91 and immigrant women have higher age-specific mortality rates of breast cancer than locally-
92 born women in Hong Kong [29, 30]. However, to date, few studies have investigated the effect
93 of length of stay in Hong Kong and birthplace on the risk of other types of cancer.

94
95 In this study, we compared the mortality rates of lung, pancreatic, colon, liver, prostate and
96 stomach cancers between locally born residents in Hong Kong and immigrants from mainland
97 China. Both populations are widely considered as ethnically homogeneous with similar cultures.
98 Nevertheless, due to different early life experiences, immigrants are exposed to more various
99 social economy and lifestyles than locals. Therefore, it's constructive to ascertain whether
100 immigrants from mainland China have a different mortality pattern of cancers from locals to

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4 101 verify the significance of migration status for this health outcome. As Age-period-cohort (APC)
5 102 analysis plays a vital role in studying time-specific phenomena in epidemiology, in this study,
6 103 to evaluate the effect of immigration on cancer mortality in the past and future, we developed
7 104 APC models specified by sex and migrant status to assess the effects of age, period, birth cohort,
8 105 and of the length of stay in Hong Kong on the mortality risks of cancers. Additionally, we
9 106 explore the projection of mortality rates for the locally born population and immigrants in Hong
10 107 Kong who were younger or older than 60 using a predictive model, taking into account age,
11 108 period, and birth cohort effects as well.
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17 110 **Methods**

18 111 *Data*

19 112 We obtained the death registry data in Hong Kong between 1998 and 2021 from the Census
20 113 and Statistics Department of Hong Kong, as the data in 2022 has not been available up to now.
21 114 The data was extracted from a routine census held by the Hong Kong government as subjective
22 115 errors caused by resampling can be neglected. The population data were stratified by age, sex,
23 116 immigration status, and length of stay in Hong Kong. We retrieved six types of cancer cases
24 117 from the death registry data using ICD codes, such as ICD-9 code 162 and ICD-10 codes
25 118 C34.0–C34.3, C348, and C349 for lung cancer. To assure comparability among
26 119 registries, deaths from the age group of 35–85 years were selected, since cases younger than 35
27 120 and older than 85 were relatively trivial for lack of statistical interpretability [31]. Immigration
28 121 status was classified into three groups: locals born in Hong Kong, immigrants who have lived
29 122 in Hong Kong for >10 years before death defined as long-stay immigrants, and immigrants who
30 123 have lived in Hong Kong for ≤10 years before death defined as short-stay immigrants. Notably,
31 124 much focus was placed on immigrants from mainland China, because approximately 81% of
32 125 immigrants in Hong Kong came from mainland China, Macau, and Taiwan based on the data
33 126 from the Census and Statistics Department of Hong Kong. Moreover, few cases recorded from
34 127 Macau and Taiwan are statistically insignificant in the analysis. Demographics and population
35 128 projections from 2022 to 2030 were retrieved from the Census and Statistics Department of
36 129 Hong Kong and estimated with cubic smoothing spline as the prerequisite of the predictive
37 130 model. Codes for APC and BAPC analysis are available in the GitHub repository
38 131 (<https://github.com/kshz2164313/APC-population-projections-for-immigration-HK>).
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54 134 *Statistical analysis*

55 135 We modeled cancer mortality rates in Hong Kong using APC analysis based on log-linear
56 136 Poisson regression models. The model aimed to disentangle age, period, and cohort effects of
57 137 time-varying phenomena simultaneously [32, 33], given that
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$$\log(E_{ij}) = \alpha_i + \beta_j + \gamma_k + \mu + \log(\theta_{ij}) \quad (1)$$

where E_{ij} denotes expected mortality; α_i , β_j , and γ_k denote age, period, and cohort effect, respectively, for $i = 1, \dots, I$, $j = 1, \dots, J$, $k = 1, \dots, K$ with $k = I - i + j$. $\log(\theta_{ij})$ is the offset. We mainly focused on the contributions of sex and immigration status due to the non-identifiability problem that the effects of these three components are collinear with each other (denoted as period – age = cohort) [34]. Birth cohort effect and period effect were assessed with relative risks to evaluate the effect of three components. The median year of birth among cases was regarded as the reference cohort [35,36]. Since death cases aged at 35–85 years between 1998 and 2021 were selected, the range of birth cohort from 1913 to 1986 covered observations and further projections until 2030. The second and penultimate period effects were constrained to the reference for period. For sex and immigration status, maximum likelihood framework was applied to estimate the relative risks and 95% confidence intervals (CIs) by age groups, calendar period, and birth cohort.

Several projection approaches for future cancer mortality have been developed, but a Bayesian age-period-cohort (BAPC) model built upon integrated nested Laplace approximations (INLA) [37] yields relatively higher coverage and better performance for all evaluated parameter combinations [38]. To prevent some sampling problems caused by Markov chain Monte Carlo (MCMC), this MCMC-free BAPC approach was applied to predict future cancer mortality within a fully Bayesian inference setting and provide outputs of interest simply, such as projected age-standardized and age-specific rates. Convergence checks are not necessary for this technique [37]. The projections of age-standardized cancer mortality rates for each sex, age group (younger or older than 60 years) and migrant status, taking into account age, period, and birth cohort effects, were performed based on the weights of population age groups from the WHO World Standard population [39], with 95% prediction intervals. Mann-Kendall trend test was applied to verify the projection trend.

All analyses were performed via R version 4.2.1 (R Core Team, R Foundation for Statistical Computing, Vienna, Austria, 2013, <http://www.R-project.org/>). The APC models were established using the Epi package, and the projections based on Bayesian APC models were performed with the BAPC package.

Patient and Public Involvement

None.

Results

Figure 1 & 2 and eFigure 1(a-e) in **Supplementary Material** illustrate the estimates of age

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4 176 (assessed by cancer mortality), cohort and period effects (assessed by relative risk) based on
5 177 APC models among three migrant groups for men and women with six types of cancers,
6 178 respectively. All the mortality rates for each gender and immigration status exhibit notable
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8 179 increasing trends with age. Age, cohort and period effects of six types of cancer for immigrants
9 180 who stayed in Hong Kong for ≤ 10 years revealed relatively more pronounced fluctuations and
10 181 deviations from those effects in the other two immigration groups. Significant increasing trends
11 182 of age effect occurred in all types of cancer, regardless of gender and immigration status. For
12 183 example, while relatively insignificant differences in lung cancer mortality rates by
13 184 immigration status among females have performed, male immigrants who remained in Hong
14 185 Kong for > 10 years had higher lung cancer mortality rates at ages above 50 years and those
15 186 who arrived ≤ 10 years had lower lung cancer mortality at ages below 62 years compared to
16 187 local men Figure 1. In addition to compatible dynamics of period effect for locals and long-stay
17 188 immigrants, similar changes of relative risks by birth cohort for locals and long-stay immigrants
18 189 in lung, colon, liver and stomach cancers occurred before 1945, whereas significant differences
19 190 of relative risks by birth cohort between these two immigration groups occurred after 1960
20 191 (Figure 1 & eFigure 1(a,b,d)). Locals and long-stay immigrants in pancreatic and prostate
21 192 cancer perform almost similar changes of relative risks by birth cohort effects all the time
22 193 (eFigure 1(c,e)). Short-stay immigrants who have stayed in Hong Kong for ≤ 10 years had more
23 194 fluctuating relative risks affected by period effects before 2020 than those for locals and long-
24 195 stay immigrants. Lack of young cases, especially young short-stay immigrants, of prostate
25 196 cancer leads to significant deviations and variances in age and cohort effects.

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36 198 Figure 3-5, eFigure 2-6 in **Supplementary Material** illustrate the age-standardized mortality
37 199 rates of six types of cancer from 1998 to 2021 and their projections by sex, immigrant status
38 200 and age groups from 2022 to 2030, taking into account age, period, and birth cohort effects.
39 201 Means and standard deviations of predictive mortality rates are shown in eTable 1-6 in
40 202 **Supplementary Material**. For all ages projection (Figure 2 & eFigure 2-6), as men will be at
41 203 higher risk of mortality rates of cancers (excluding prostate cancer) than women in the future
42 204 for all three age groups (all ages, young and older than 60 years), given the projected trends,
43 205 immigrants for each gender, especially who have stayed in Hong Kong for > 10 years will suffer
44 206 from higher mortality rates of cancer in each year than locals. Monotone decreasing trends or
45 207 plateau of forecasting occur for both genders and all immigration groups in cancers, except for
46 208 increasing trends for male immigrants who have stayed in Hong Kong for ≤ 10 years with colon
47 209 cancer ($p < 0.05$, Avg +0.30 deaths/100,000 per annum) from 15.47 deaths/100,000 (95% CI:
48 210 11.28, 19.66) in 2021 to 18.50 deaths/100,000 (95% CI: 2.31, 34.69) in 2030, and male
49 211 immigrants who have stayed in Hong Kong for > 10 years with pancreatic cancer ($p < 0.05$,
50 212 Avg +0.72 deaths/100,000 per annum) from 16.30 deaths/100,000 (95% CI: 14.38,17.26) in
51 213 2021 to 23.49 deaths/100,000 (95% CI: 12.49, 34.49) in 2030. Most of predictive trends for

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4 214 younger cases (<60 years) and older cases (≥ 60 years) reach a consensus with those for all ages
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6 215 population, except for two phenomena: 1.) mortality rates of lung cancer for men immigrants
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8 216 ≤ 10 that insignificant trend for all ages ($p > 0.05$) vs. decline for younger cases ($p < 0.05$) vs.
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10 217 increase for older cases ($p < 0.05$); 2.) mortality rates of liver cancer for men immigrants > 10
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12 218 that decline for all ages ($p < 0.05$) vs. decline for younger cases ($p < 0.05$) vs. insignificant
13
14 219 trend for older cases ($p > 0.05$). Some particular cases occur in the projection of prostate cancer
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16 220 that young long-stay male immigrants (0.44 deaths/100,000, 95% CI: 0, 1.05) aged less than 60
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18 221 will be at lower mortality rate than locals (0.69 deaths/100,000, 95% CI: 0, 1.42) in 2030
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20 222 (eTable 6). Compared with other cancers and immigration groups, male immigrants who have
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22 223 stayed in Hong Kong for > 10 years with lung cancer would perform the most significant decline
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24 224 in predictive mean from 102.90 (95% CI: 98.14, 107.66) to 79.55 (95% CI: 47.46, 111.64)
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26 225 deaths per 100,000 population (Avg -2.34 deaths/100,000 per annum) (eTable 1), while the
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28 226 same immigration group with pancreatic cancer would indicate the most significant uptrend in
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30 227 each year of 16.30 (95% CI: 14.38, 17.26) and 23.49 (95% CI: 12.49, 34.49) deaths per 100,000
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32 228 population in 2021 and 2030, respectively (Avg +0.72 deaths/100,000 per annum) (eTable 4).
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31 232 **Discussion**

33 233 Early detection of cancer is positive and instructive for increasing chances of cure. Nevertheless,
34 234 the high mortality rate of cancer results from late diagnosis among most patients after
35 235 progression to more advanced or severe stages. Individuals at high risk of cancer, such as
36 236 smokers, alcoholics or those who are frequently exposed to susceptible circumstances, should
37 237 be screened for early detections to increase opportunities for cure [40]. Therefore, the
38 238 differences in mortality rates among immigration groups are synonymous with detection means,
39 239 therapies, and social history in disparate periods and areas.
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42 241 While the changes in mortality rates by age for long-stay immigrants reached approximate
43 242 harmony with those for locals, the changes in mortality rates by age for short-stay immigrants
44 243 revealed clear differences with those for the other two populations. The group of long-stay
45 244 immigrants had a higher risk of death from lung, colon and liver cancers than the other two
46 245 immigration groups after the age of 60 years. Short-stay male immigrants were less likely to
47 246 die from lung cancer before the age of 65 years. The contrast in age effects among the
48 247 immigration groups was partially consistent with studies [25, 41] that highlighted the age
49 248 effects for locals and immigrants on breast cancer mortality in Hong Kong and lung cancer
50 249 incidence in Sweden, as they both showed similar trends and magnitudes between locals and
51 250 immigrants before the age of 60 years. They are also compatible with the results in [42] that

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3 251 diagnosis of liver cancer is the most frequent among populations at 55 to 65 years old.
4 252 According to these trends, young individuals, especially new young immigrant men, who
5 253 have benefited from all-rounded development in mainland China and Hong Kong, are more
6 254 likely to seek early detection and be treated for cancers using more advanced treatments [43].
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8 255 Differences in birth cohort effects among immigrant groups partially comply with the
9 256 interpretation above.
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14 258 We observed significant trends of cohort effects among locals and immigrants. These findings
15 259 are partially consistent but subtly different from previous findings, regarding the effect of
16 260 immigration status on cancers. Zhao et al. [25] described multiple peaks of cohort effects on
17 261 breast cancer mortality between locals and immigrants in Hong Kong, as well as a significant
18 262 decline in cohort effects after 1950. In contrast, Sung et al. [44] investigated the difference in
19 263 breast cancer incidence between Chinese Americans and non-Hispanic whites in the U.S. and
20 264 emphasized that Chinese Americans were at lower risk of breast cancer than non-Hispanic
21 265 whites born in the same year. Here, we interpret the cohort-driven trends resulting from the
22 266 intricacy of social history and lifestyle. Compared to a relatively stable social development in
23 267 Hong Kong, representing downward trends of relative risks for locals, wars and social
24 268 instability in mainland China resulted in several immigration waves from mainland China to
25 269 Hong Kong before 1950. Additionally, remarkable increasing trends were recorded for new
26 270 immigrants after 1950, which corresponded to the economic downturn after wars and famine
27 271 between 1959 and 1961 during their youth [45]. The increasing trends for new immigrants
28 272 and similar trends for locals and long-stay immigrants were consistent with the finding that
29 273 nutrient deficiency contributes to a higher risk of severe mortality rates of cancers [46].
30 274 Furthermore, we speculate that these trends, especially those for locals and long-stay
31 275 immigrants, are most likely attributed to social development and personal behaviors, such as
32 276 daily habits, occupational history, different diagnoses and treatments, and domestic
33 277 environmental exposures. Notably, short-stay immigrants suffered from a lower risk of death
34 278 from colon cancer for all ages (eFigure 1a in **Supplementary Material**). As locals and
35 279 immigrants in Hong Kong transitioned to more westernized lifestyles, higher consumption of
36 280 meat was associated with a higher risk of these types of cancer, whereas consumption of
37 281 vegetables had a strong protective effect against pancreatic cancer, and moderate
38 282 consumption of coffee appeared to be beneficial against lung cancer [47,48]. Further studies
39 283 on potential risk factors are required.
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44 285 Short-stay immigrants had more fluctuating and non-stationary but inconspicuous relative
45 286 risks by period effects before 2021 than locals and long-stay immigrants. Cumulatively, an
46 287 arch pattern and fluctuating curve depicting period effects externally resulted in an arch
47 288 pattern of age-standardized mortality rates for short-stay immigrant women and irregular rates
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3 289 for short-stay immigrant men before 2021. The external performance of different period
4 290 effects on mortality rates could be most likely attributed to the higher effect of different
5 291 lifestyles and social development on new immigrants than on long-stay immigrants and locals
6 292 in Hong Kong. For the age-standardized mortality rates and projections, consistent with
7 293 previous findings [49,50], we predict that the mortality rates of cancer in Hong Kong after
8 294 2021 will continue to decline or remain relatively stable, consistent with the trends before
9 295 2020, except for male immigrants who have stayed in Hong Kong for ≤ 10 years with colon
10 296 cancer and male immigrants who have stayed in Hong Kong for >10 years with pancreatic
11 297 cancer. Men will be at higher risk of mortality rates of cancer than women, regardless of
12 298 immigration status. They are also compatible with the results in [4] that men suffer from a
13 299 higher risk of these types of cancer than women, excluding prostate cancer. Furthermore, new
14 300 immigrant women will be at lower risk than local women, even though long-stay immigrants
15 301 will suffer from higher mortality rates than locals in the future. Potential interpretations could
16 302 be consistent with those for birth cohort effects, as age and period effects are considered as
17 303 confounders of cohort effect.
18 304

19 305 In the past few decades, spurred by an increasing burden of high incidence and mortality rates
20 306 of cancer, several studies focused on the inherent identification dilemma of three effects in the
21 307 APC model. Further, complicated population distribution and immigration status in Hong
22 308 Kong, one of the areas with the highest population density and migration frequency in the
23 309 world, have intricate causes and inherent dynamics of cancer and other diseases. To our
24 310 knowledge, few studies have assessed the relationship between immigration status and cancer
25 311 mortality. Therefore, this study is original to examine the effect of the length of stay in Hong
26 312 Kong and origins of previous residence on cancer deaths, which is instructive for further
27 313 immigration policy-making and targeted strategies of disease detection and intervention.
28 314 However, this study had several limitations. Given the non-identifiability problem in age-
29 315 period-cohort models, we could only depict trends and variations among different
30 316 immigration and sex groups, as illustrated in figures, and insufficiently perform the estimates
31 317 of the contributions of three effects or subgroups to mortality rates. Furthermore, we adopted
32 318 a cubic smoothing spline to estimate populations of immigrants and locals due to the large
33 319 proportion of unspecified immigration status from official demographic projections. A few
34 320 acceptable cases resulted in a limited type of cancer so that some common cancers, such as
35 321 the ovary and cervix, were discarded. Since the issue of quantification, the future perspective
36 322 of cancer therapies and techniques have not been considered in the model of projection.

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39 325 **Conclusion**

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3 326 We conclude that immigrants, especially short-stay immigrants, had more pronounced
4 327 fluctuations of mortality rates by age and of relative risks by cohort and period effects for six
5 328 types of cancers than those of long-stay immigrants and locals. Men will be at a higher risk of
6 329 mortality rates of six types of cancer than women in the future. Male immigrants who have
7 330 stayed in Hong Kong for ≤ 10 years with colon cancer and male immigrants who have stayed
8 331 in Hong Kong for > 10 years with pancreatic cancer would perform significant uptrend in the
9 332 future, while other immigration groups for each type of cancer would continue to decline or
10 333 remain relatively stable. Immigrants for each gender in Hong Kong would suffer from higher
11 334 mortality risks of cancers than locals in the future.
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For peer review only

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4 335 **Declaration**

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6 336 **Ethical approval and consent to participate**

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8 337 Ethical approval and consent to participate are not applicable. This study does not involve
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10 338 human participants. Data was obtained from the Census and Statistics Department of Hong
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12 339 Kong.

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14 340 **Consent for publication**

15
16 341 Not applicable.

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18 342 **Data Availability Statement**

19
20 343 Data are available upon reasonable request.

21
22 344 **Author contributions**

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24 345 **Yanji Zhao:** Methodology, Formal analysis, Data Curation, Writing - Original Draft,
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27 347 **Zian Zhuang:** Methodology, Formal analysis, Data Curation, Writing - Review & Editing

28 348 **Lin Yang:** Validation, Writing - Review & Editing

29 349 **Daihai He:** Conceptualization, Writing - Review & Editing, Supervision

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38
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43 357 None.

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360 References

- 361
- 362 1. Fan S-C. The population projection of Hong Kong. *Southeast Asian Journal of Social Science*.
363 1974;2(1/2):105-17.
- 364 2. Department CaS. Hong Kong Statistics 1947-1967 (Report).
365 https://www.statistics.gov.hk/pub/hist/1961_1970/B10100031967AN67E0100.pdf,
366 Accessed 4th May 2019.
- 367 3. Department CaS. Demographic Trends in Hong Kong 1981-2011 (Report).
368 <http://www.statistics.gov.hk/pub/B1120017032012XXXXB0100.pdf>, Accessed 4th May 2019.
- 369 4. Sung H, Ferlay J, Siegel RL, Laversanne M, Soerjomataram I, Jemal A, et al. Global Cancer
370 Statistics 2020: GLOBOCAN Estimates of Incidence and Mortality Worldwide for 36 Cancers
371 in 185 Countries. *CA: A Cancer Journal for Clinicians*. 2021 2021/05/01;71(3):209-49. doi:
372 <https://doi.org/10.3322/caac.21660>.
- 373 5. Wang XR, Chiu YL, Qiu H, Au JSK, Yu ITS. The roles of smoking and cooking emissions
374 in lung cancer risk among Chinese women in Hong Kong. *Annals of Oncology*. 2009
375 2009/04/01;20(4):746-51. doi: <https://doi.org/10.1093/annonc/mdn699>.
- 376 6. Chiu Y-L, Wang X-R, Qiu H, Yu IT-S. Risk factors for lung cancer: a case-control study in
377 Hong Kong women. *Cancer Causes & Control*. 2010 2010/05/01;21(5):777-85. doi:
378 10.1007/s10552-010-9506-9.
- 379 7. Office on S, Health. Publications and Reports of the Surgeon General. Women and
380 Smoking: A Report of the Surgeon General. Atlanta (GA): Centers for Disease Control and
381 Prevention (US); 2001.
- 382 8. Escobedo LG, Peddicord JP. Smoking prevalence in US birth cohorts: the influence of gender
383 and education. *American Journal of Public Health*. 1996 1996/02/01;86(2):231-6. doi:
384 10.2105/AJPH.86.2.231.
- 385 9. Husten CG, Shelton DM, Chrismon JH, Lin YC, Mowery P, Powell FA. Cigarette smoking
386 and smoking cessation among older adults: United States, 1965-94. *Tobacco Control*.
387 1997;6(3):175. doi: 10.1136/tc.6.3.175.
- 388 10. Bolego C, Poli A, Paoletti R. Smoking and gender. *Cardiovascular Research*.
389 2002;53(3):568-76. doi: 10.1016/S0008-6363(01)00520-X.
- 390 11. Doll R, Hill AB. The mortality of doctors in relation to their smoking habits; a preliminary
391 report. *Br Med J*. 1954;1(4877):1451-5. PMID: 13160495. doi: 10.1136/bmj.1.4877.1451.
- 392 12. Ramada Rodilla JM, Calvo Cerrada B, Serra Pujadas C, Delclos GL, Benavides FG. Fiber
393 burden and asbestos-related diseases: an umbrella review. *Gaceta Sanitaria*. 2021 2021/06/11/.
394 doi: <https://doi.org/10.1016/j.gaceta.2021.04.001>.
- 395 13. Collishaw NE, Kirkbride J, Wigle DT. Tobacco smoke in the workplace: an occupational
396 health hazard. *Can Med Assoc J*. 1984;131(10):1199-204. PMID: 6498670.
- 397 14. Dresler CM, Fratelli C, Babb J, Everley L, Evans AA, Clapper ML. Gender differences in
398 genetic susceptibility for lung cancer. *Lung Cancer*. 2000 2000/12/01;30(3):153-60. doi:
399 [https://doi.org/10.1016/S0169-5002\(00\)00163-X](https://doi.org/10.1016/S0169-5002(00)00163-X).
- 400 15. Alexandrov K, Cascorbi I, Rojas M, Bouvier G, Kriek E, Bartsch H. CYP1A1 and GSTM1
401 genotypes affect benzo[a]pyrene DNA adducts in smokers' lung: comparison with
402 aromatic/hydrophobic adduct formation. *Carcinogenesis*. 2002;23(12):1969-77. doi:

- 1
2
3 403 10.1093/carcin/23.12.1969.
- 4 404 16. Samet JM. Radon and Lung Cancer. JNCI: Journal of the National Cancer Institute.
5 405 1989;81(10):745-58. doi: 10.1093/jnci/81.10.745.
- 6 406 17. Darby S, Hill D, Auvinen A, Barros-Dios JM, Baysson H, Bochicchio F, et al. Radon in
7 407 homes and risk of lung cancer: collaborative analysis of individual data from 13 European case-
8 408 control studies. BMJ. 2005;330(7485):223. doi: 10.1136/bmj.38308.477650.63.
- 9 409 18. Raaschou-Nielsen O, Andersen ZJ, Beelen R, Samoli E, Stafoggia M, Weinmayr G, et al.
10 410 Air pollution and lung cancer incidence in 17 European cohorts: prospective analyses from the
11 411 European Study of Cohorts for Air Pollution Effects (ESCAPE). The Lancet Oncology. 2013
12 412 2013/08/01/;14(9):813-22. doi: [https://doi.org/10.1016/S1470-2045\(13\)70279-1](https://doi.org/10.1016/S1470-2045(13)70279-1).
- 13 413 19. 2018 Summary-20190719. Retrieved August 26, 2022, from
14 414 [https://www.who.int/docs/default-source/wpro---documents/countries/china/2018-gats-china-](https://www.who.int/docs/default-source/wpro---documents/countries/china/2018-gats-china-factsheet-cn-en.pdf?sfvrsn=3f4e2da9_2)
15 415 [factsheet-cn-en.pdf?sfvrsn=3f4e2da9_2](https://www.who.int/docs/default-source/wpro---documents/countries/china/2018-gats-china-factsheet-cn-en.pdf?sfvrsn=3f4e2da9_2)
- 16 416 20. *Thematic household survey*. Retrieved August 26, 2022, from
17 417 https://www.censtatd.gov.hk/en/data/stat_report/product/B1130201/att/B11302702020XXXX
18 418 B0100.pdf
- 19 419 21. Abubakar II, Tillmann T, Banerjee A. Global, regional, and national age-sex specific all-
20 420 cause and cause-specific mortality for 240 causes of death, 1990-2013: a systematic analysis
21 421 for the Global Burden of Disease Study 2013. Lancet. 2015 Jan 10;385(9963):117-71.
- 22 422 22. Estimated alcohol consumption per capita in Hong Kong. Change4Health. (n.d.).
23 423 Retrieved December 1, 2022, from
24 424 https://www.change4health.gov.hk/en/alcohol_aware/figures/alcohol_consumption/index.htm
25 425 1
- 26 426 23. World Health Organization. Global status report on alcohol and health 2018. World
27 427 Health Organization; 2019 Feb 14.
- 28 428 24. Wild C. World cancer report 2014. Wild CP, Stewart BW, editors. Geneva, Switzerland:
29 429 World Health Organization; 2014.
- 30 430
- 31 431 25. Zhao S, Dong H, Qin J, Liu H, Li Y, Chen Y, et al. Breast cancer mortality in Chinese
32 432 women: does migrant status play a role? Annals of Epidemiology. 2019 2019/12/01/;40:28-
33 433 34.e2. doi: <https://doi.org/10.1016/j.annepidem.2019.10.006>.
- 34 434 26. Gomez SL, Yang J, Lin S-W, McCusker M, Sandler A, Cheng I, et al. Incidence trends of
35 435 lung cancer by immigration status among Chinese Americans. Cancer Epidemiol Biomarkers
36 436 Prev. 2015;24(8):1157-64. PMID: 25990553. doi: 10.1158/1055-9965.EPI-15-0123.
- 37 437 27. Hemminki K, Li X, Czene K. Cancer risks in first-generation immigrants to Sweden.
38 438 International Journal of Cancer. 2002 2002/05/10;99(2):218-28. doi:
39 439 <https://doi.org/10.1002/ijc.10322>.
- 40 440 28. Vanthomme K, Roskamp M, De Schutter H, Vandenneede H. Lung cancer incidence
41 441 differences in migrant men in Belgium, 2004–2013: histology-specific analyses. BMC Cancer.
42 442 2021 2021/03/30;21(1):328. doi: 10.1186/s12885-021-08038-6.
- 43 443 29. Schooling M, Leung GM, Janus ED, Ho SY, Hedley AJ, Lam TH. Childhood migration
44 444 and cardiovascular risk. International Journal of Epidemiology. 2004;33(6):1219-26. doi:
45 445 10.1093/ije/dyh221.
- 46 446 30. Leung JYY, Li AM, Leung GM, Schooling CM. Mode of delivery and childhood

- 1
2
3 447 hospitalizations for asthma and other wheezing disorders. *Clinical & Experimental Allergy*.
4 448 2015 2015/06/01;45(6):1109-17. doi: <https://doi.org/10.1111/cea.12548>.
5
6 449 31. Baker A, Bray I. Bayesian projections: what are the effects of excluding data from younger
7 450 age groups?. *American Journal of Epidemiology*. 2005 Oct 15;162(8):798-805.
8
9 451 32. Rosenberg PS, Anderson WF. Age-Period-Cohort Models in Cancer Surveillance Research:
10 452 Ready for Prime Time? APC Models. *Cancer Epidemiology, Biomarkers & Prevention*. 2011
11 453 Jul 1;20(7):1263-8.
12
13 454 33. Holford T. Analyzing the effects of age, period and cohort on incidence and mortality rates.
14 455 *Stat Meth Med Res*. 1992;1:317-37.
15
16 456 34. Brookmeyer R, Stroup DF, editors. *Monitoring the health of populations: statistical*
17 457 *principles and methods for public health surveillance*. Oxford University Press; 2004.
18
19 458 35. Yang Y, Land KC. *Age-period-cohort analysis: New models, methods, and empirical*
20 459 *applications*. Taylor & Francis; 2013.
21
22 460 36. Robertson C, Gandini S, Boyle P. Age-period-cohort models: a comparative study of
23 461 available methodologies. *Journal of clinical epidemiology*. 1999 Jun 1;52(6):569-83.
24
25 462 37. Riebler A, Held L. Projecting the future burden of cancer: Bayesian age-period-cohort
26 463 analysis with integrated nested Laplace approximations. *Biometrical Journal*. 2017
27 464 May;59(3):531-49.
28
29 465 38. Knoll M, Furkel J, Debus J, Abdollahi A, Karch A, Stock C. An R package for an integrated
30 466 evaluation of statistical approaches to cancer incidence projection. *BMC medical research*
31 467 *methodology*. 2020 Dec;20(1):1-1.
32
33 468 39. Ahmad OB, Boschi-Pinto C, Lopez AD, Murray CJ, Lozano R, Inoue M. Age
34 469 standardization of rates: a new WHO standard. Geneva: World Health Organization. 2001
35 470 Jan;9(10):1-4.
36
37 471 40. Sung H, Ferlay J, Siegel RL, Laversanne M, Soerjomataram I, Jemal A, Bray F. Global
38 472 cancer statistics 2020: GLOBOCAN estimates of incidence and mortality worldwide for 36
39 473 cancers in 185 countries. *CA: a cancer journal for clinicians*. 2021 May;71(3):209-49.
40
41 474 41. Mousavi SM, Fallah M, Sundquist K, Hemminki K. Age-and time-dependent changes in
42 475 cancer incidence among immigrants to Sweden: colorectal, lung, breast and prostate cancers.
43 476 *International journal of cancer*. 2012 Jul 15;131(2):E122-8.
44
45 477 42. National Cancer Institute. SEER stat fact sheets: liver and intrahepatic bile duct cancer.
46
47 478 43. Wu X, Chung VC, Hui EP, Ziea ET, Ng BF, Ho RS, Tsoi KK, Wong S, Wu JC.
48 479 Effectiveness of acupuncture and related therapies for palliative care of cancer: overview of
49 480 systematic reviews. *Scientific reports*. 2015 Nov 26;5(1):1-5.
50
51 481 44. Sung H, Rosenberg PS, Chen WQ, Hartman M, Lim WY, Chia KS, Wai-Kong Mang O,
52 482 Tse L, Anderson WF, Yang XR. The impact of breast cancer-specific birth cohort effects among
53 483 younger and older Chinese populations. *International journal of cancer*. 2016 Aug
54 484 1;139(3):527-34.
55
56 485 45. *The world economy volume 1: a millennial perspective, 2, Historical statistics*: Academic
57 486 *Foundation, Gurgaon, India (2007)*
58
59 487 46. Elias SG, Peeters PH, Grobbee DE, van Noord PA. The 1944-1945 Dutch famine and
60 488 subsequent overall cancer incidence. *Cancer Epidemiology Biomarkers & Prevention*. 2005
489 489 Aug;14(8):1981-5.
490 47. Chiu YL, Wang XR, Qiu H, Yu IT. Risk factors for lung cancer: a case-control study in

- 1
2
3 491 Hong Kong women. *Cancer Causes & Control*. 2010 May;21(5):777-85.
4 492 48. Li J, Lam AS, Yau ST, Yiu KK, Tsoi KK. Antihypertensive treatments and risks of lung
5 493 Cancer: A large population-based cohort study in Hong Kong. *BMC cancer*. 2021 Dec;21(1):1-
6 494 9.
7
8 495 49. Du J, Sun H, Sun Y, Du J, Cao W, Sun S. Assessment of age, period, and cohort effects of
9 496 lung cancer incidence in Hong Kong and projection up to 2030 based on changing
10 497 demographics. *American Journal of Cancer Research*. 2021;11(12):5902.
11
12 498 50. *Centre for Health Protection, Department of Health - Lung Cancer*. Centre for Health
13 499 Protection. Retrieved August 10, 2022, from
14 500 <https://www.chp.gov.hk/en/healthtopics/content/25/49.html>

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Figure 1. Parameter estimates of age (a), cohort (b) and period (c) effects based on an age-period-cohort model of male lung cancer mortality rates by immigrant groups: locals, immigrants stay in Hong Kong for more than 10 years and immigrants stay in Hong Kong for less than or equal to 10 years. Age effect was assessed by mortality (left axis). Cohort and period effects were assessed by relative risk (right axis), 95% confidence intervals are shown as shaded bands.

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Figure 2. Parameter estimates of age (a), cohort (b) and period (c) effects based on an age-period-cohort model of female lung cancer mortality rates by immigrant groups: locals, immigrants stay in Hong Kong for more than 10 years and immigrants stay in Hong Kong for less than or equal to 10 years. Age effect was assessed by mortality (left axis). Cohort and period effects were assessed by relative risk (right axis), 95% confidence intervals are shown as shaded bands.

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2 515
3 516 **Figure 3.** Projections of lung cancer mortality rates by gender and immigrant status from 2022 to 2030. Observations
4 517 are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of
5 518 red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical
6 519 dashed line indicates where prediction started.
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Figure 4. Projections of lung cancer mortality rates for the population younger than 60 by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.

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Figure 5. Projections of lung cancer mortality rates for the population older than or equal to 60 by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.

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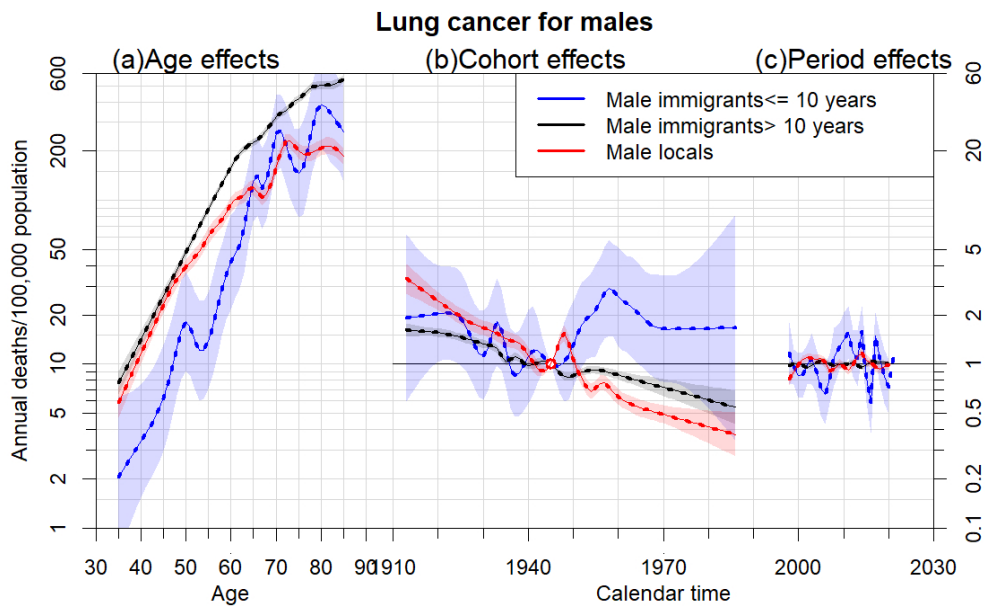


Figure 1. Parameter estimates of age (a), cohort (b) and period (c) effects based on an age-period-cohort model of male lung cancer mortality rates by immigrant groups: locals, immigrants stay in Hong Kong for more than 10 years and immigrants stay in Hong Kong for less than or equal to 10 years. Age effect was assessed by mortality (left axis). Cohort and period effects were assessed by relative risk (right axis), 95% confidence intervals are shown as shaded bands.

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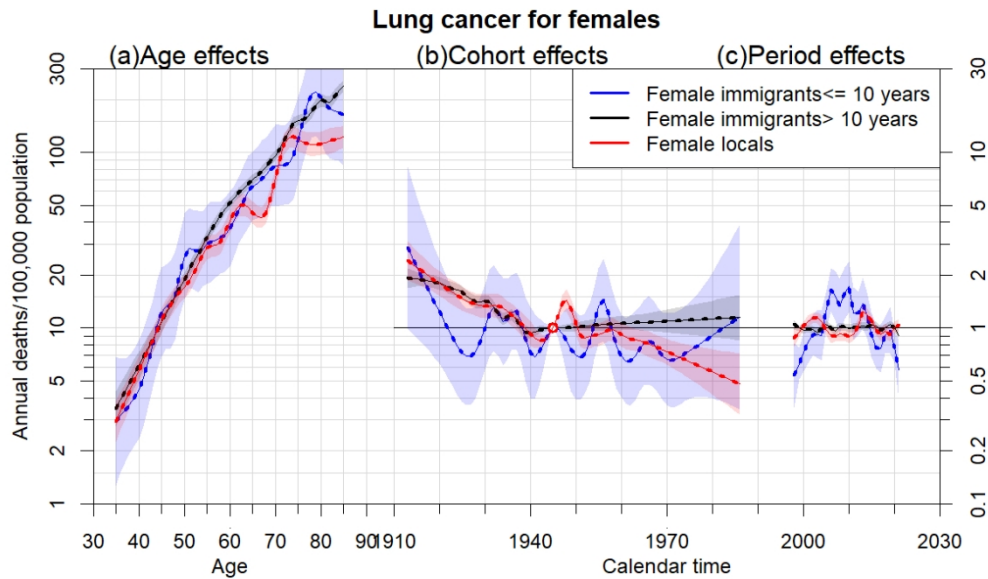


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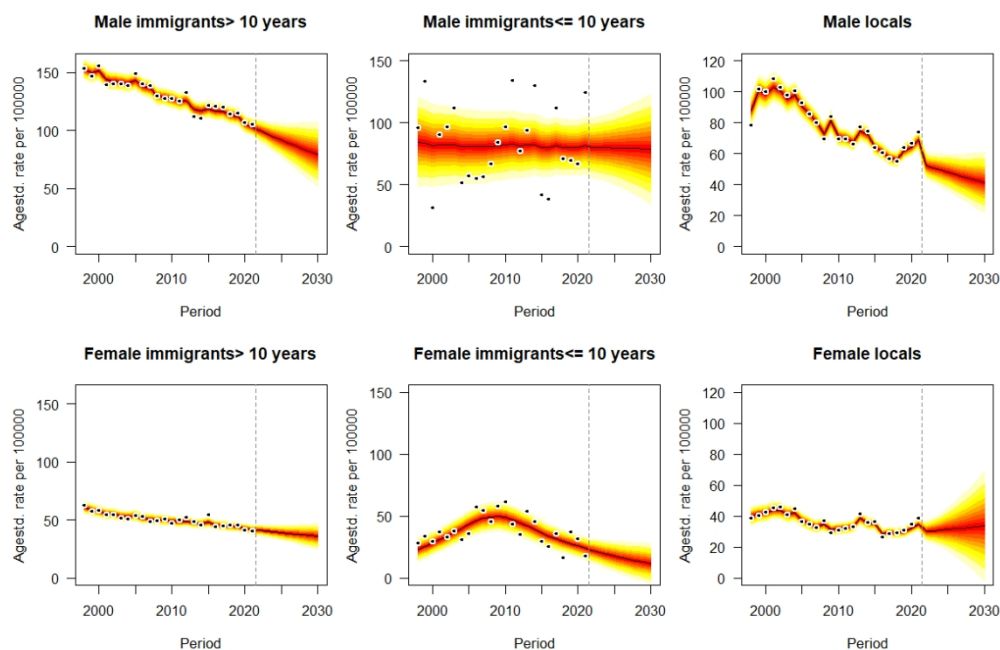


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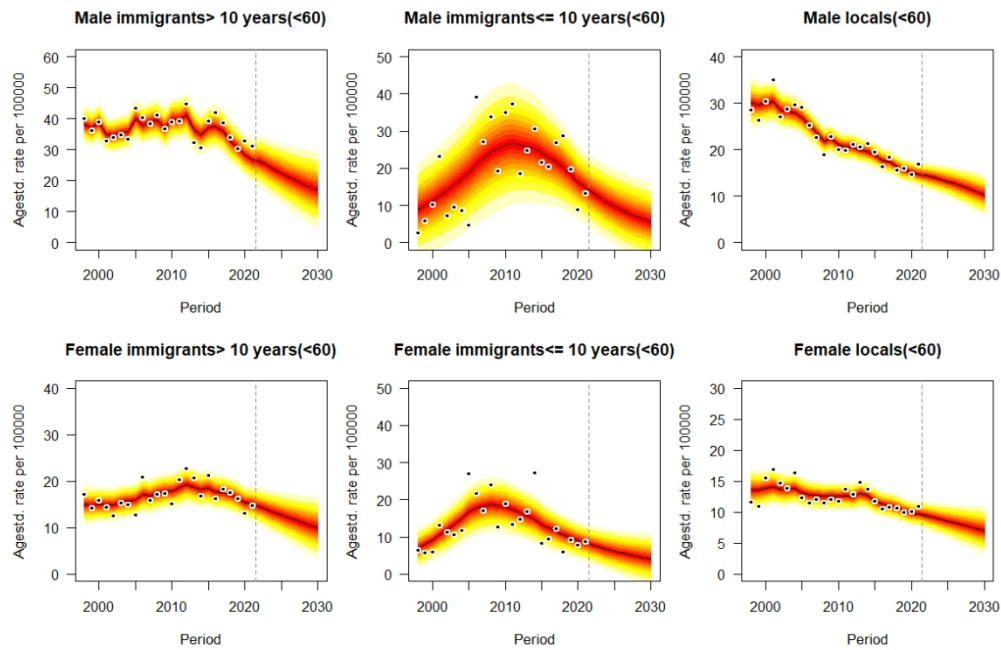


Figure 4. Projections of lung cancer mortality rates for the population younger than 60 by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.

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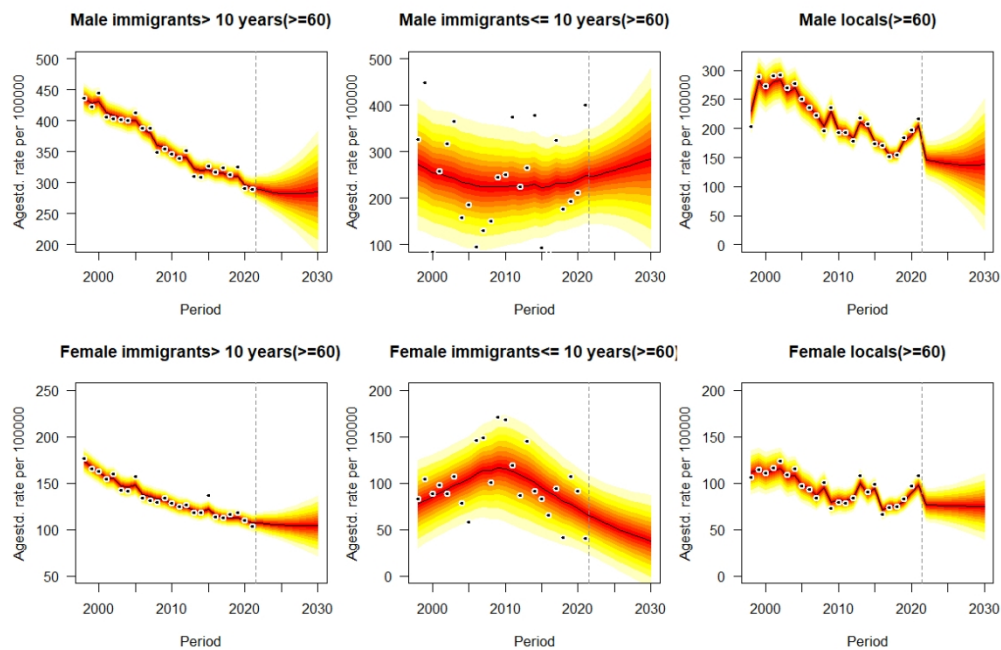


Figure 5. Projections of lung cancer mortality rates for the population older than or equal to 60 by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.

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Supplementary Material for

“An age-period-cohort analysis and projection of cancer mortality in

Hong Kong, 1998–2030”

APC Figures

eFigure 1(a) Colon cancer	3
eFigure 1(b) Liver cancer	4
eFigure 1(c) Pancreatic cancer	5
eFigure 1(d) Stomach cancer	6
eFigure 1(e) Prostate cancer	7

Projection Figures

Colon cancer	
eFigure 2(a)Projection (all ages)	8
eFigure 2(b)Projection (<60 years)	9
eFigure 2(c)Projection (≥ 60 years)	10
Liver cancer	
eFigure 3(a)Projection (all ages)	11
eFigure 3(b)Projection (<60 years)	12
eFigure 3(c)Projection (≥ 60 years)	13
Pancreatic cancer	
eFigure 4(a)Projection (all ages)	14
eFigure 4(b)Projection (<60 years)	15
eFigure 4(c)Projection (≥ 60 years)	16
Stomach cancer	
eFigure 5(a)Projection (all ages)	17
eFigure 5(b)Projection (<60 years)	18

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eFigure 5(c)Projection (≥ 60 years)..... 19

Prostate cancer

eFigure 6 Projection (all ages, < 60 years and ≥ 60 years)..... 20

Tables

eTable 1 Lung cancer..... 21

eTable 2 Colon cancer..... 22

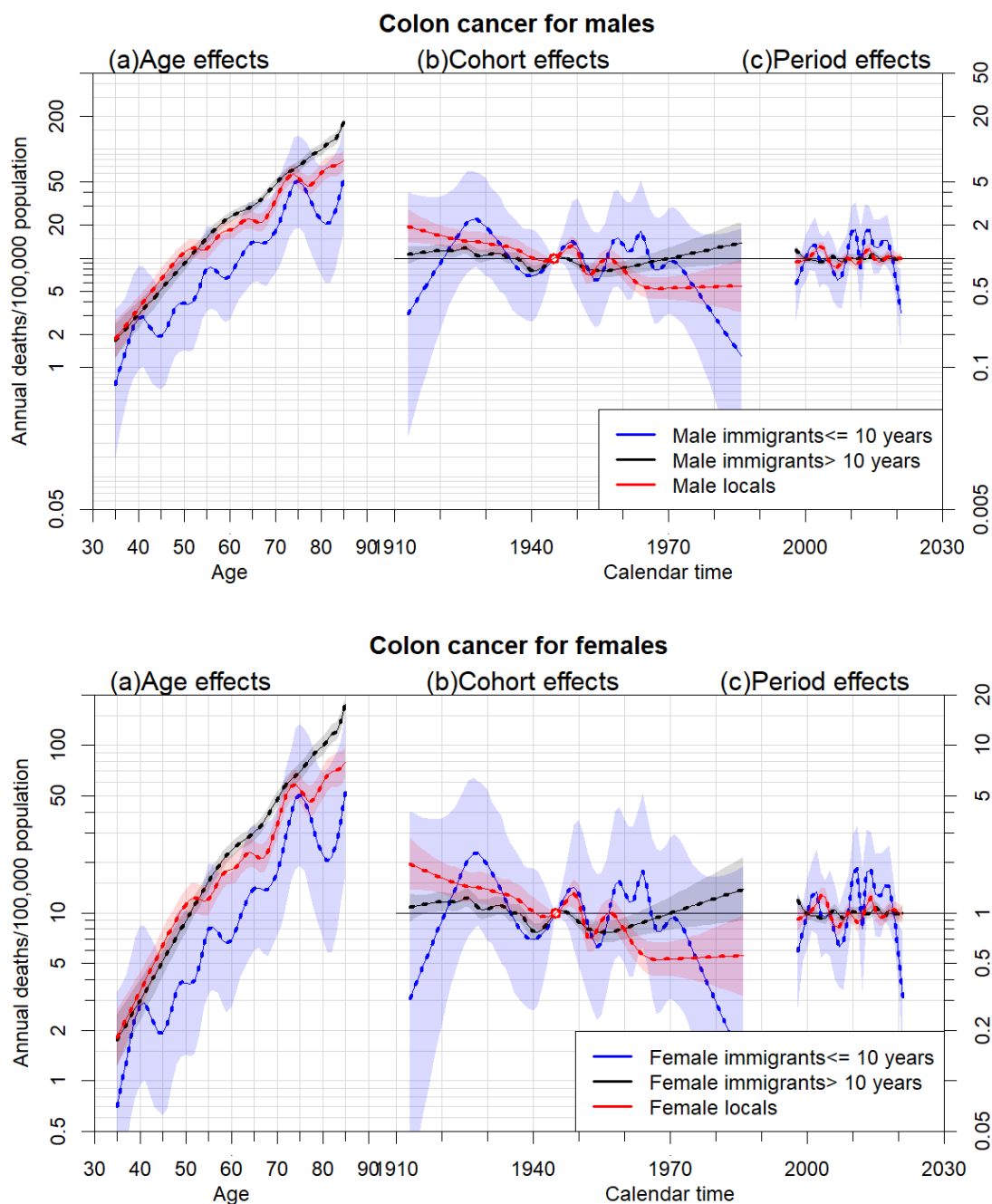
eTable 3 Liver cancer 23

eTable 4 Pancreatic cancer 24

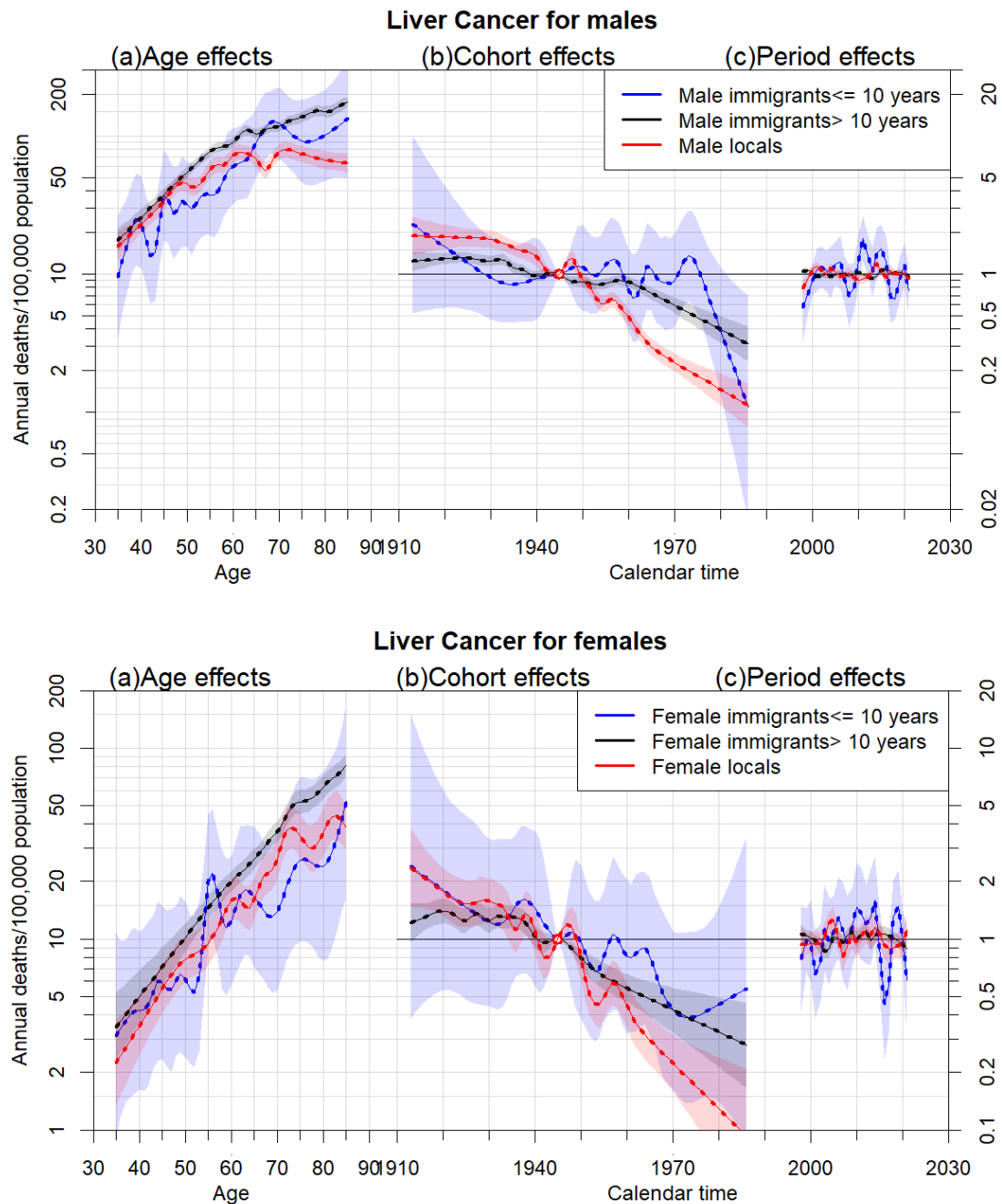
eTable 5 Stomach cancer 25

eTable 6 Prostate cancer 26

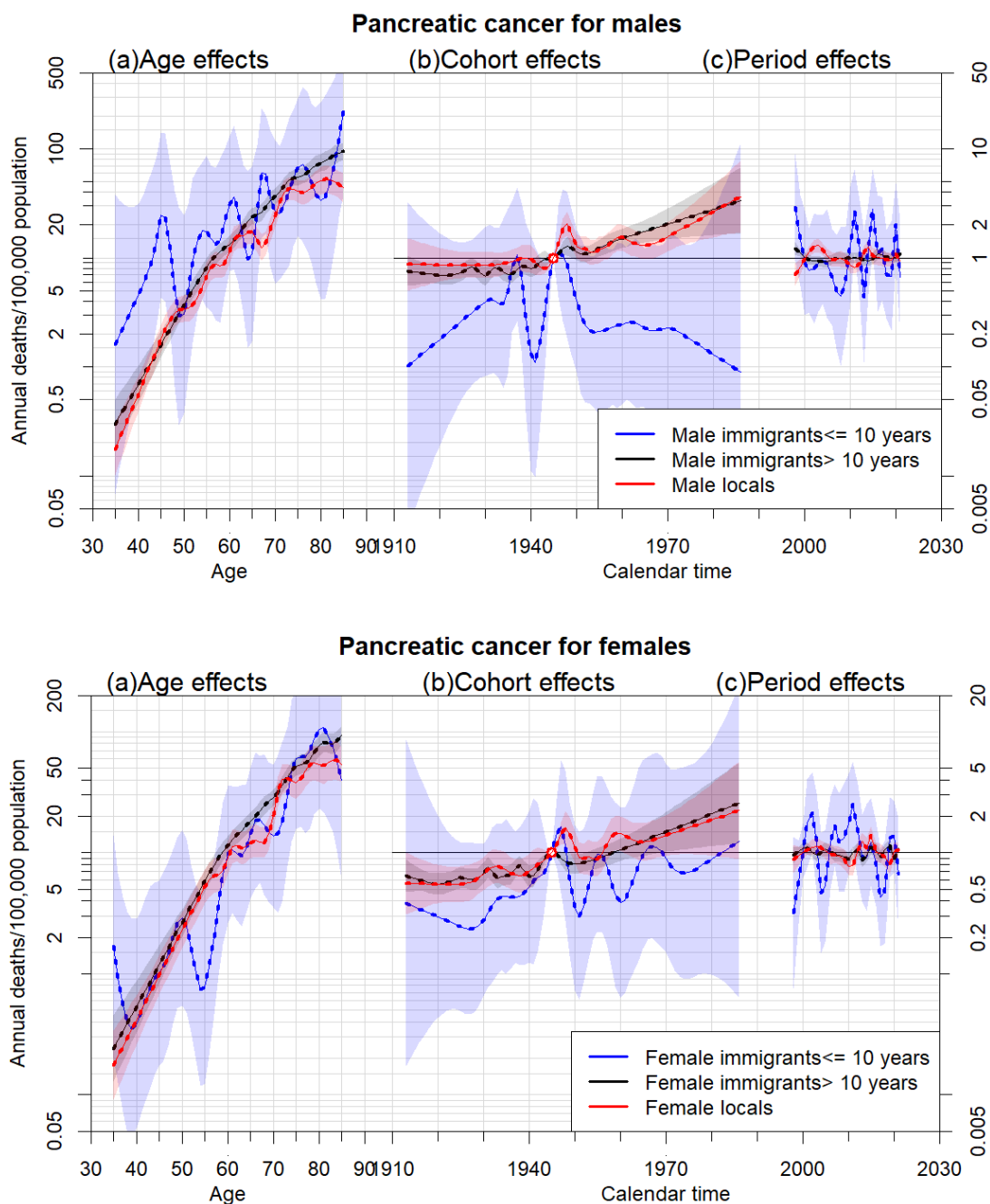
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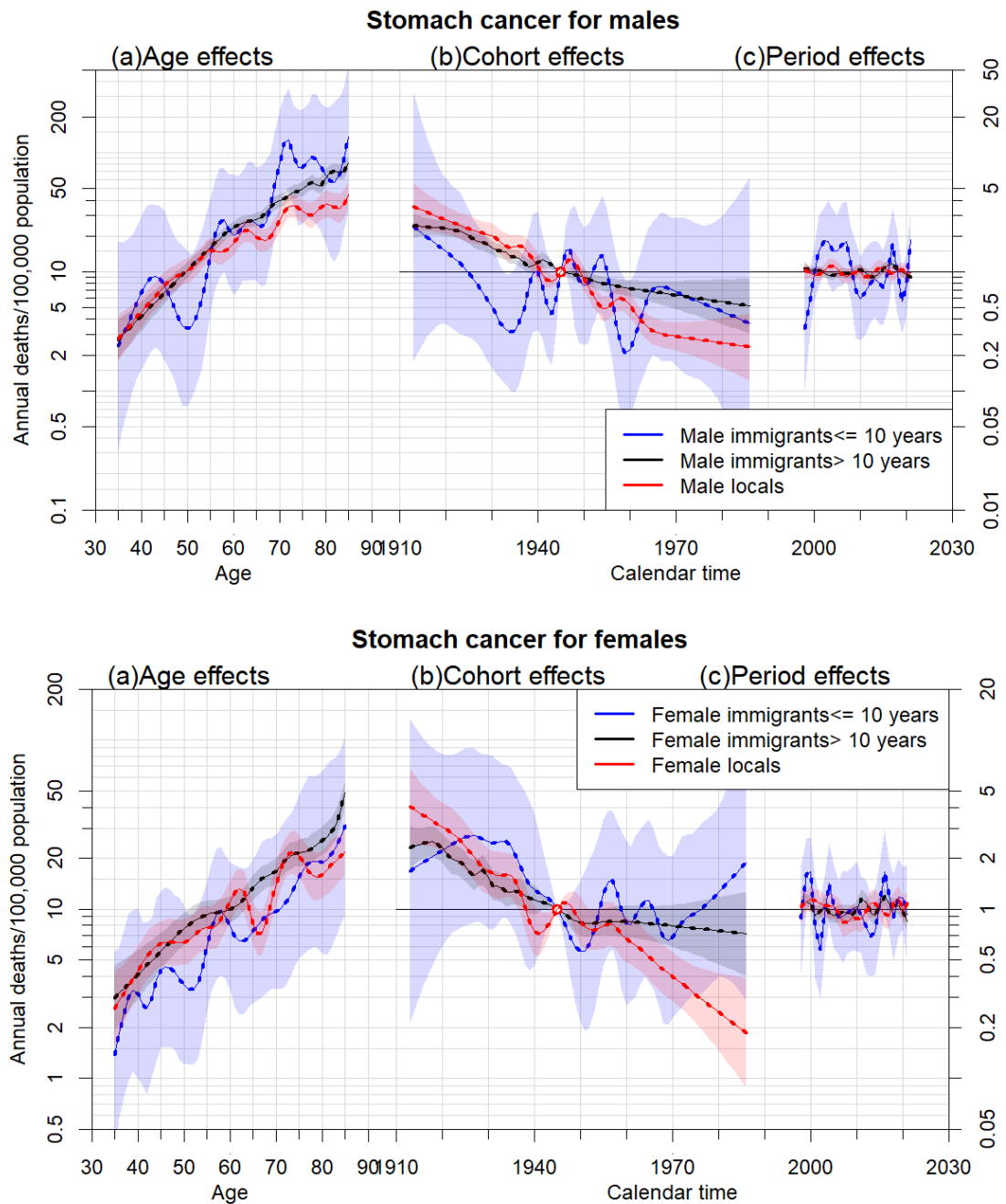
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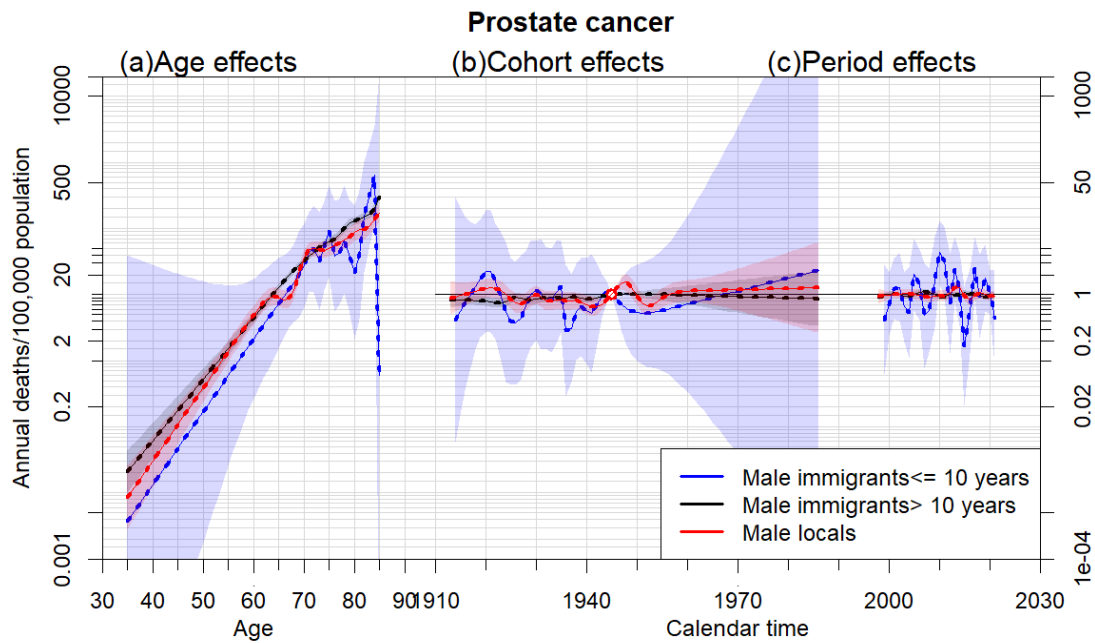
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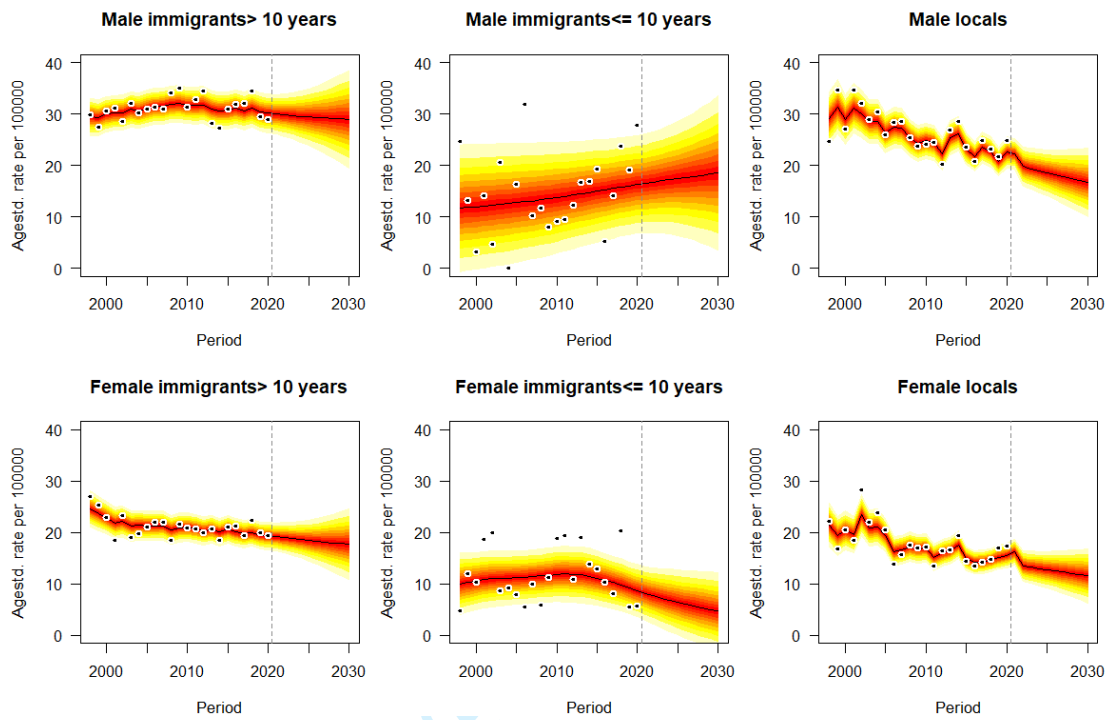
eFigure 1(c). Parameter estimates of age (a), cohort (b) and period (c) effects based on an age-period-cohort model of male and female pancreatic cancer mortality rates by immigrant groups: locals, immigrants stay in Hong Kong for more than 10 years and immigrants stay in Hong Kong for less than or equal to 10 years. Age effect was assessed by mortality (left axis). Cohort and period effects were assessed by relative risk (right axis), 95% confidence intervals are shown as shaded bands.



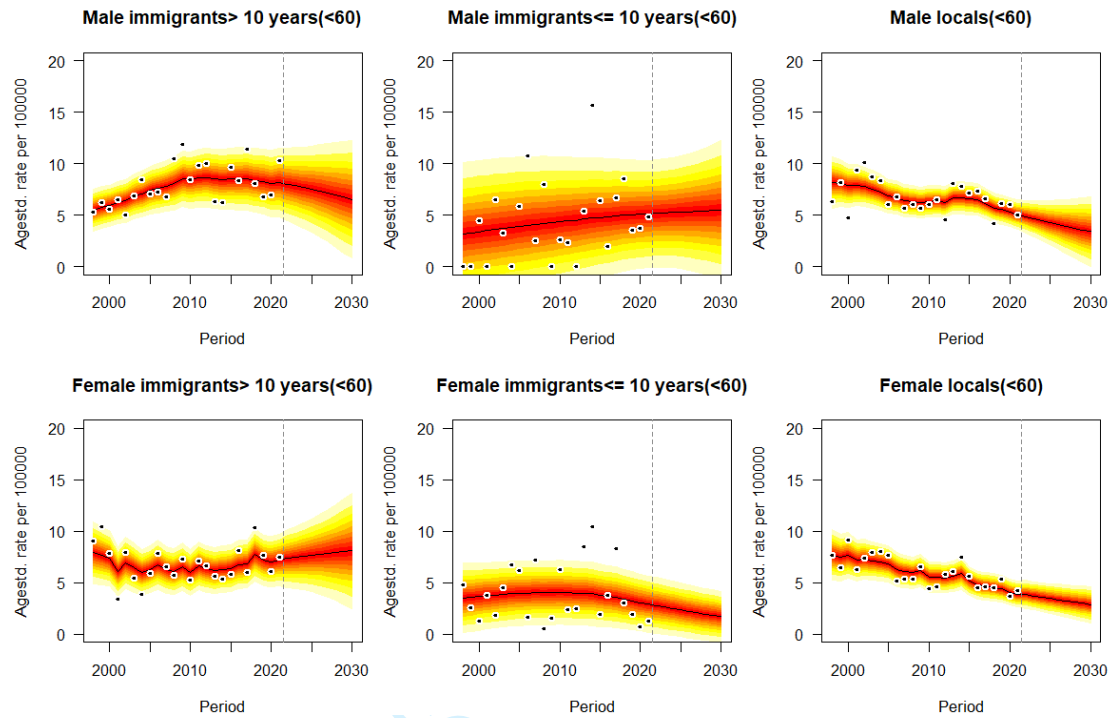
eFigure 1(d). Parameter estimates of age (a), cohort (b) and period (c) effects based on an age-period-cohort model of male and female stomach cancer mortality rates by immigrant groups: locals, immigrants stay in Hong Kong for more than 10 years and immigrants stay in Hong Kong for less than or equal to 10 years. Age effect was assessed by mortality (left axis). Cohort and period effects were assessed by relative risk (right axis), 95% confidence intervals are shown as shaded bands.



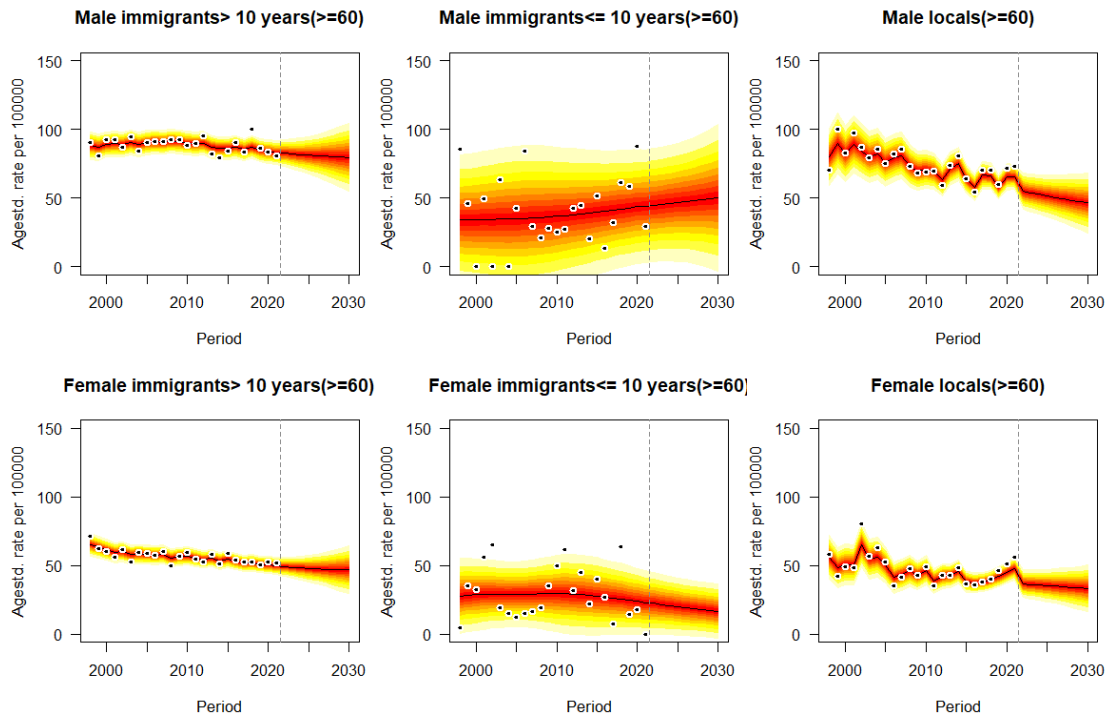
eFigure 1(e). Parameter estimates of age (a), cohort (b) and period (c) effects based on an age-period-cohort model of male prostate cancer mortality rates by immigrant groups: locals, immigrants stay in Hong Kong for more than 10 years and immigrants stay in Hong Kong for less than or equal to 10 years. Age effect was assessed by mortality (left axis). Cohort and period effects were assessed by relative risk (right axis), 95% confidence intervals are shown as shaded bands.



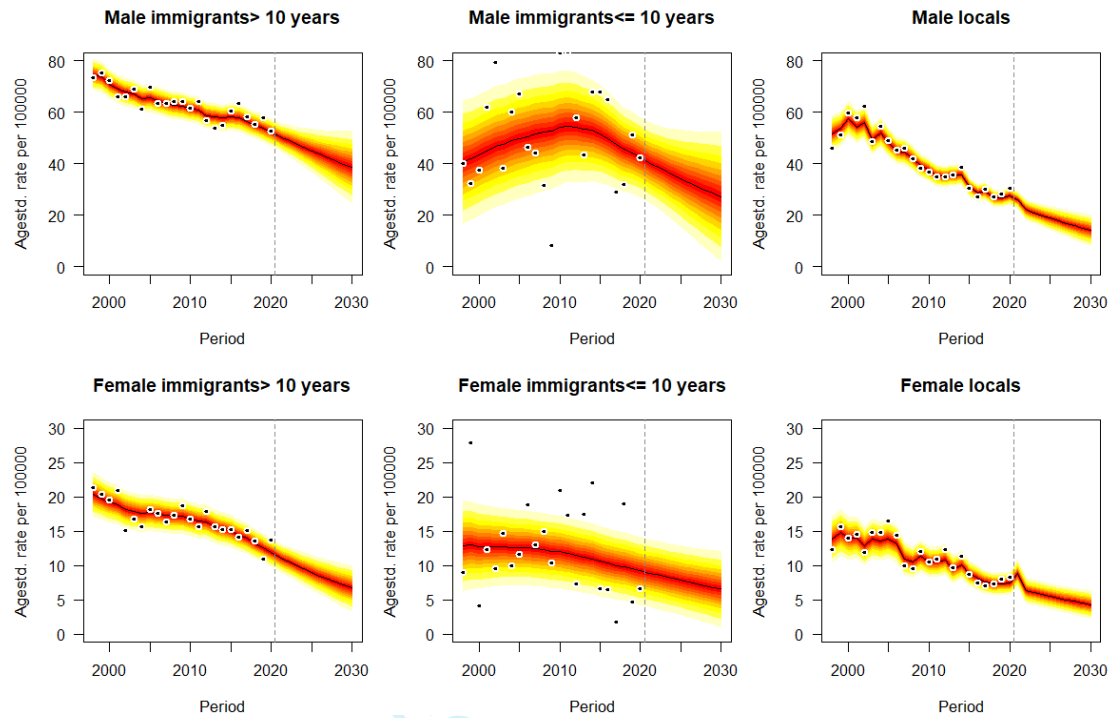
eFigure 2(a). Projections of colon cancer mortality rates by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



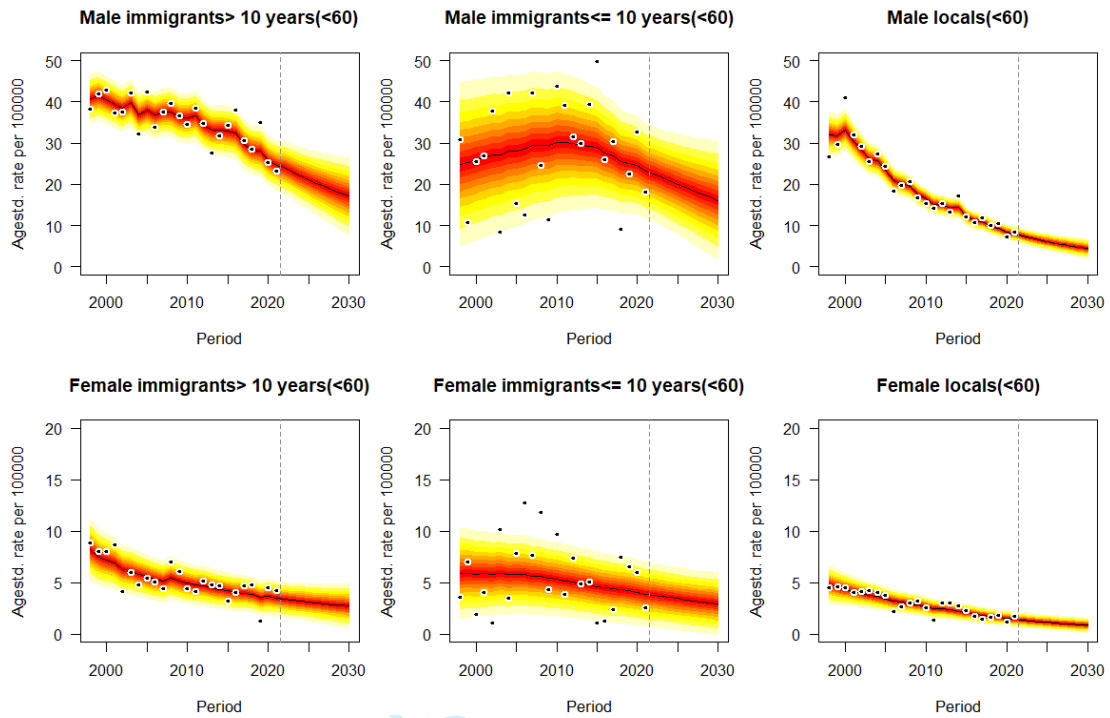
eFigure 2(b). Projections of colon cancer mortality rates for the population younger than 60 by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



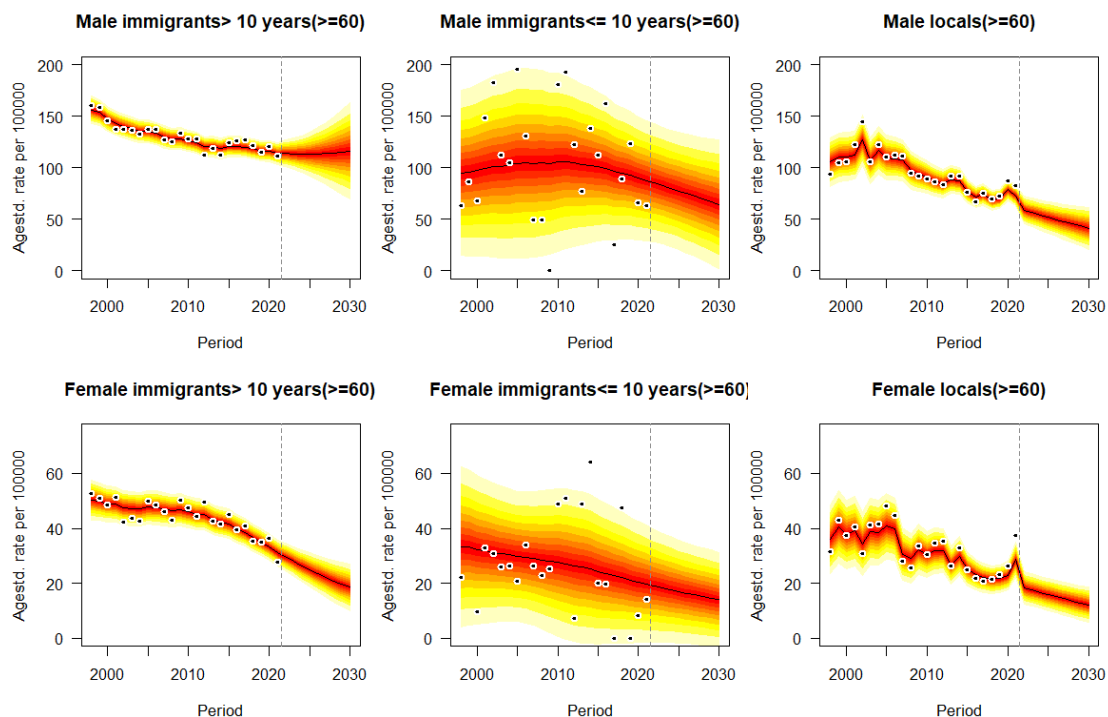
eFigure 2(c). Projections of colon cancer mortality rates for the population older than or equal to 60 by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



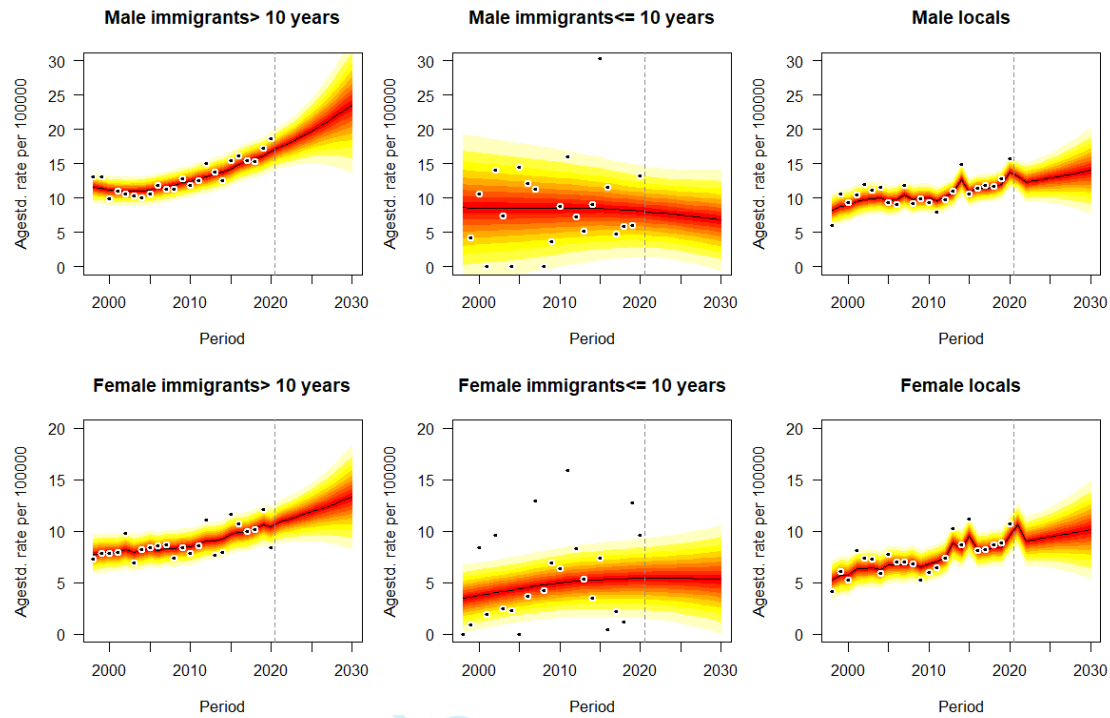
eFigure 3(a). Projections of liver cancer mortality rates by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



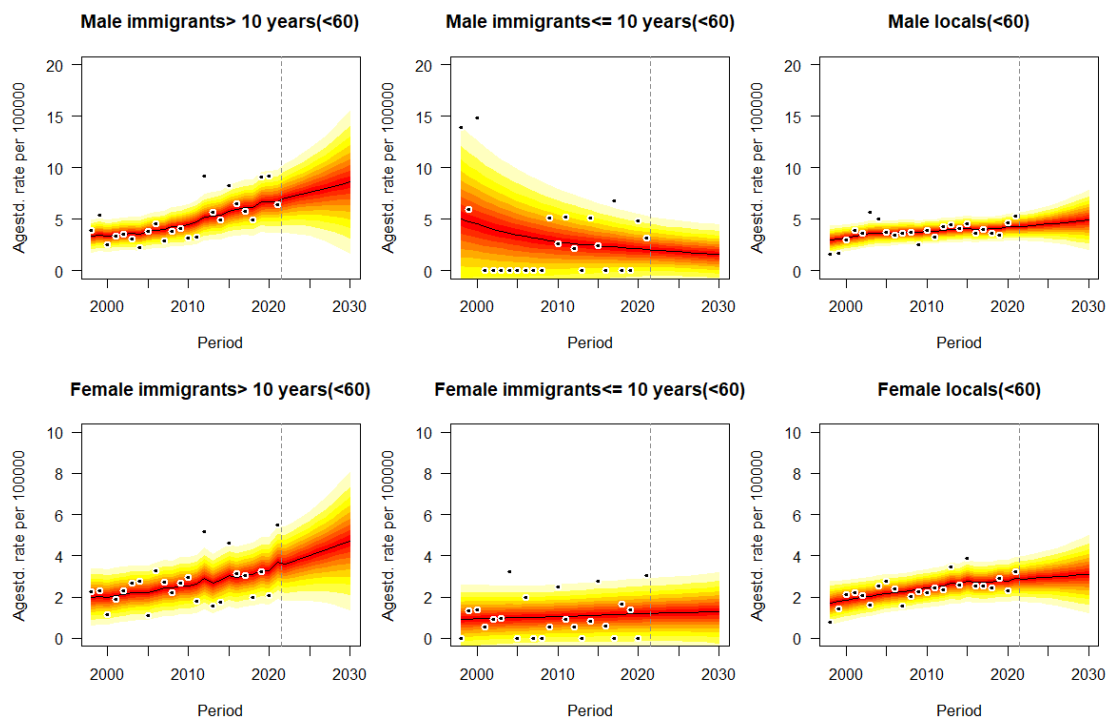
eFigure 3(b). Projections of liver cancer mortality rates for the population younger than 60 by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



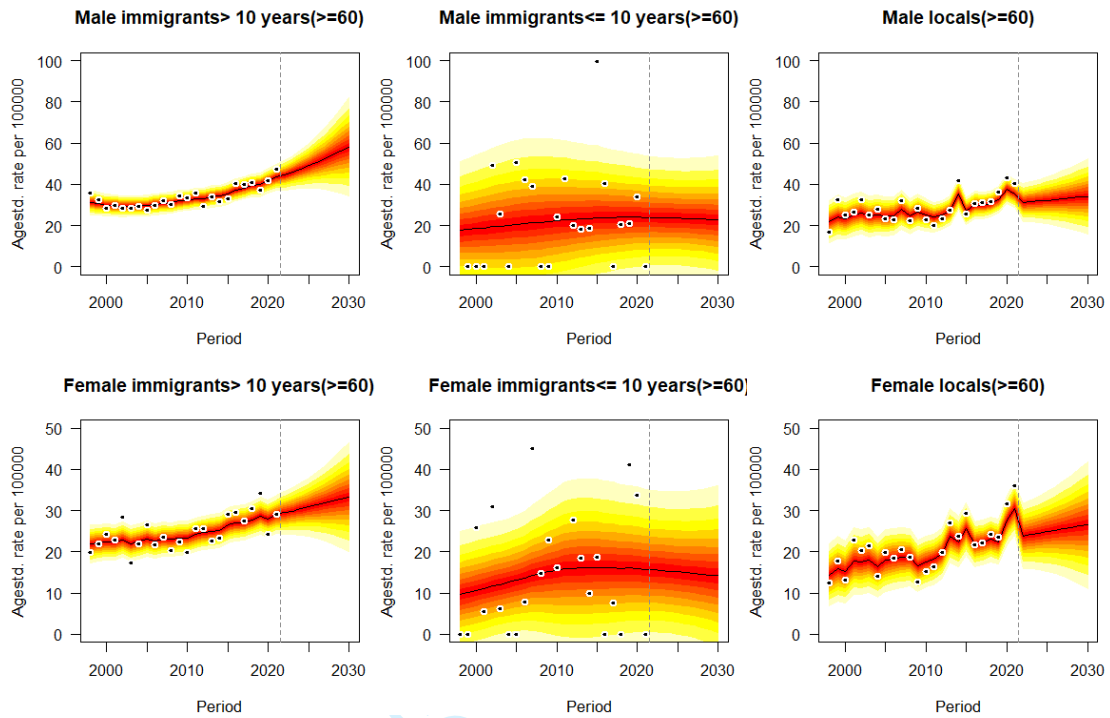
eFigure 3(c). Projections of liver cancer mortality rates for the population older than or equal to 60 by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



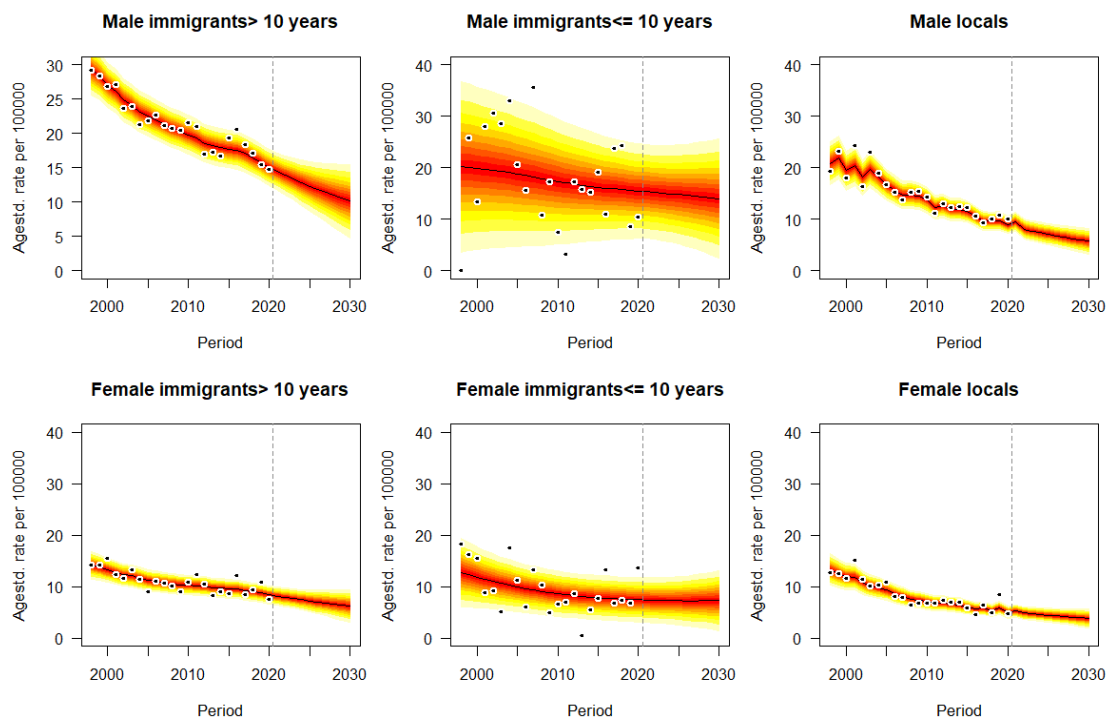
eFigure 4(a). Projections of pancreatic cancer mortality rates by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



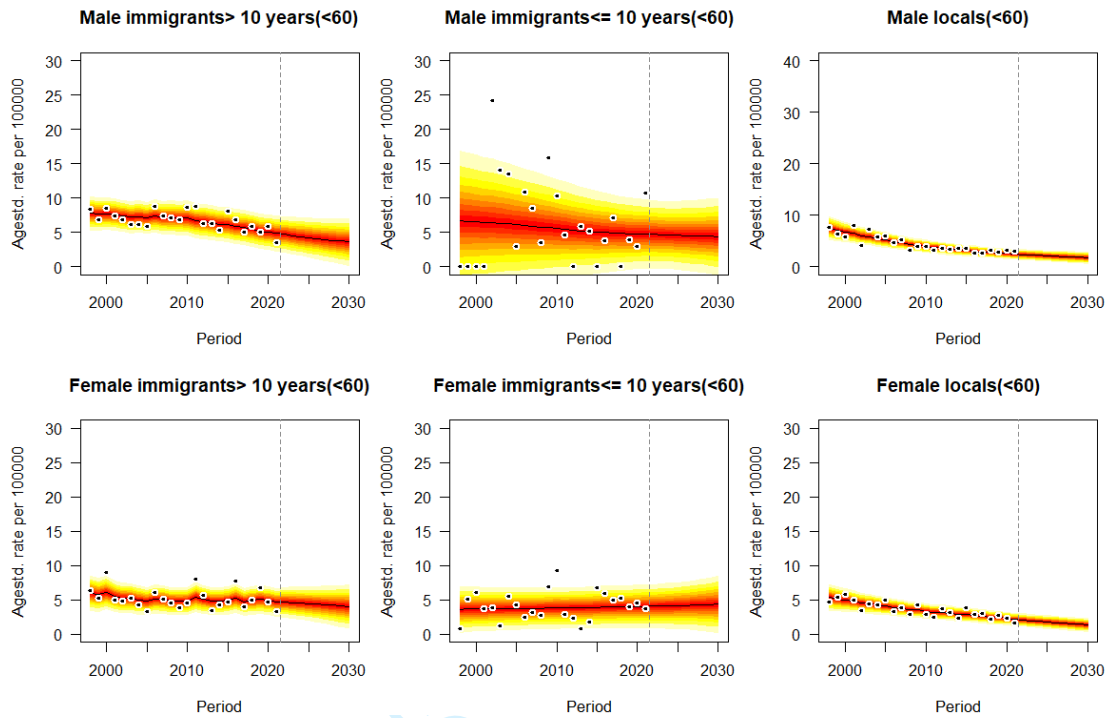
eFigure 4(b). Projections of pancreatic cancer mortality rates for the population younger than 60 by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



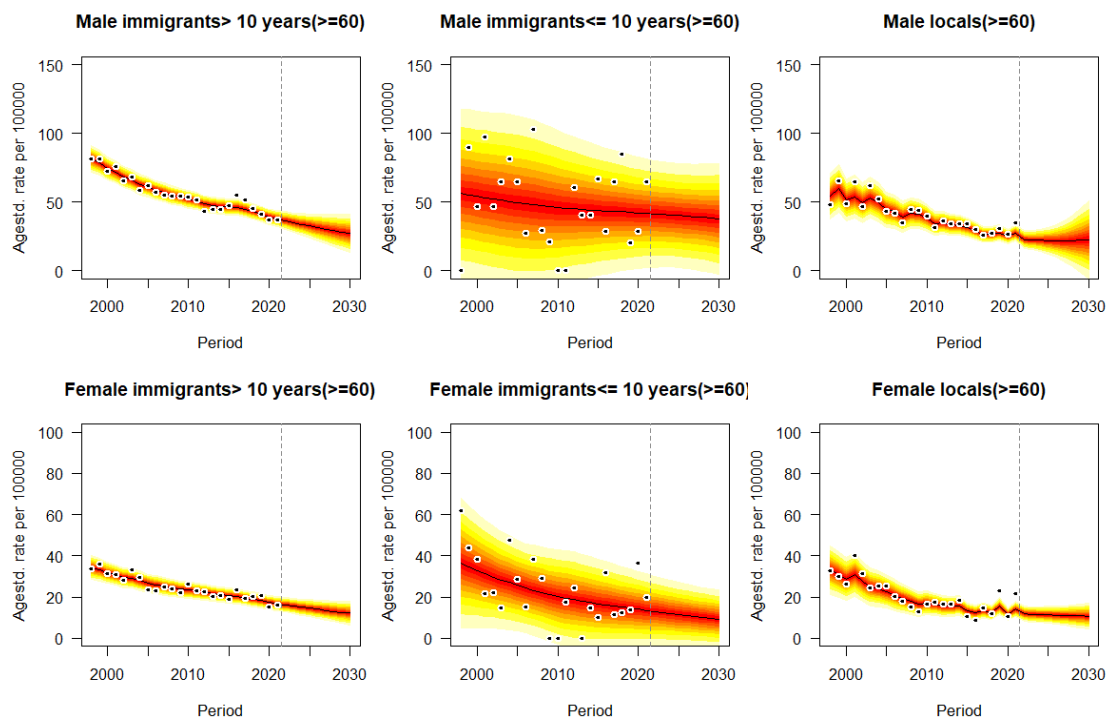
eFigure 4(c). Projections of pancreatic cancer mortality rates for the population older than or equal to 60 by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



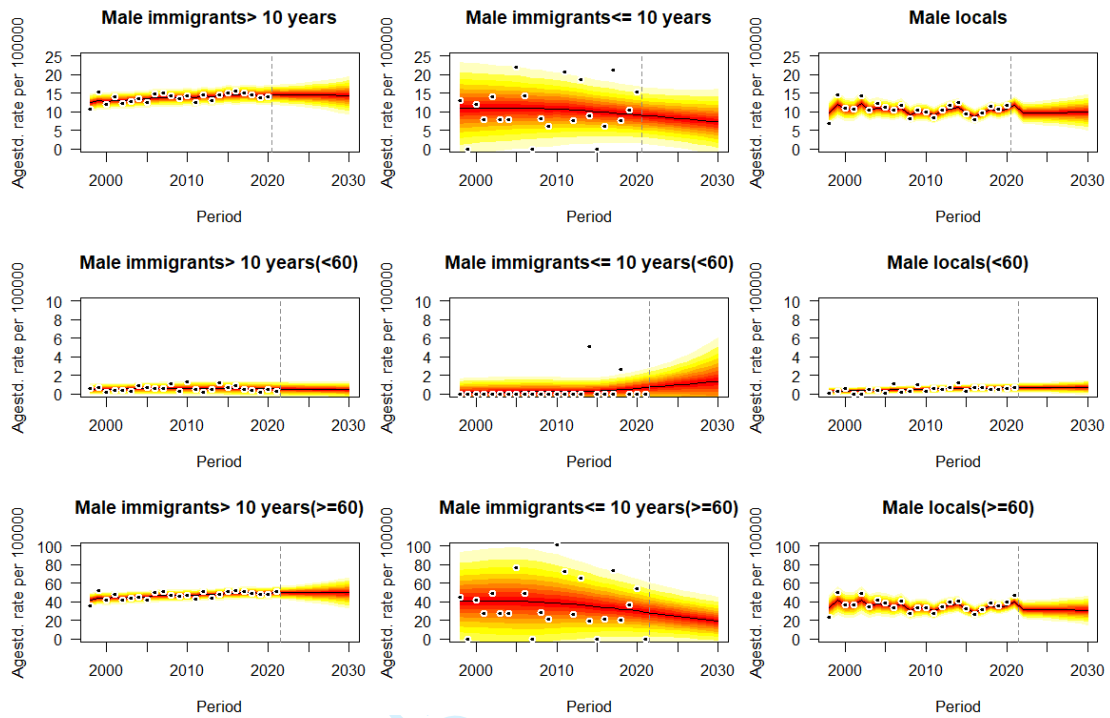
eFigure 5(a). Projections of stomach cancer mortality rates by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



eFigure 5(b). Projections of stomach cancer mortality rates for the population younger than 60 by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



eFigure 5(c). Projections of stomach cancer mortality rates for the population older than or equal to 60 by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



eFigure 6. Projections of prostate cancer mortality rates for males by immigrant status and age groups (less than, greater than or equal to 60 years old) from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.

Predictive mean of age-standardized mortality rates of lung cancer per 100,000 population										
Year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Female immigrants >10	41.80 (1.27)	41.34 (1.86)	40.58 (2.27)	39.87 (2.75)	39.19 (3.28)	38.53 (3.86)	37.89 (4.46)	37.26 (5.09)	36.65 (5.74)	36.04 (6.4)
Female immigrants ≤ 10	23.92 (4.00)	22.22 (4.67)	20.56 (5.38)	19.01 (6.10)	17.57 (6.80)	16.24 (7.45)	15.00 (8.04)	13.85 (8.56)	12.79 (9.01)	11.81 (9.39)
Female locals	34.67 (1.76)	30.22 (3.54)	30.63 (4.77)	31.05 (6.38)	31.48 (8.29)	31.9 (10.47)	32.32 (12.87)	32.73 (15.48)	33.15 (18.31)	33.55 (21.33)
Male immigrants >10	102.90 (2.43)	100.18 (4.18)	97.18 (5.33)	94.34 (6.72)	91.71 (8.24)	89.15 (9.84)	86.66 (11.47)	84.19 (13.11)	81.81 (14.74)	79.55 (16.37)
Male immigrants ≤10	81.26 (9.21)	79.90 (10.41)	79.81 (11.82)	79.72 (13.42)	79.62 (15.19)	79.50 (17.09)	79.32 (19.09)	79.08 (21.18)	78.78 (23.32)	78.41 (25.53)
Male locals	60.96 (2.82)	52.27 (4.86)	50.83 (5.39)	49.56 (6.13)	48.18 (6.97)	46.64 (7.84)	45.13 (8.76)	43.83 (9.76)	42.67 (10.8)	41.43 (11.8)
Female immigrants >10(<60y)	15.51 (1.12)	14.51 (1.50)	13.90 (1.76)	13.29 (2.04)	12.71 (2.33)	12.13 (2.62)	11.57 (2.91)	11.02 (3.18)	10.49 (3.43)	9.98 (3.68)
Female immigrants ≤ 10(<60y)	8.14 (1.91)	7.79 (1.95)	7.18(2.23)	6.62(2.53)	6.10(2.81)	5.63(3.08)	5.19(3.32)	4.79 (3.53)	4.42 (3.72)	4.09 (3.88)
Female locals(<60y)	10.25 (0.77)	9.48 (0.89)	9.17(1.02)	8.87(1.16)	8.57(1.32)	8.27(1.49)	7.97(1.65)	7.68 (1.82)	7.38 (1.98)	7.09 (2.13)
Male immigrants >10(<60y)	27.81 (2.10)	26.36 (3.58)	24.96 (3.94)	23.64 (4.35)	22.38 (4.79)	21.17 (5.23)	20.03 (5.67)	18.96 (6.10)	17.96 (6.51)	17.03 (6.90)
Male immigrants ≤ 10(<60y)	15.01 (2.98)	13.38 (3.71)	12.02 (4.17)	10.79 (4.59)	9.68 (4.95)	8.69 (5.24)	7.79 (5.46)	6.98 (5.61)	6.25 (5.69)	5.59 (5.72)
Male locals(<60y)	15.19 (0.78)	14.45 (1.15)	14.03 (1.29)	13.61 (1.46)	13.14 (1.64)	12.65 (1.82)	12.13 (2.01)	11.55 (2.17)	10.93 (2.31)	10.26 (2.43)
Female immigrants >10(≥ 60y)	108.85 (4.80)	107.21 (5.17)	106.26 (6.24)	105.52 (7.54)	104.94 (9.04)	104.51 (10.72)	104.21 (12.57)	104.07 (14.61)	104.06 (16.78)	104.16 (19.14)
Female immigrants ≤ 10(≥60y)	66.16 (13.25)	63.84 (15.72)	59.88 (17.50)	56.14 (19.31)	52.60 (21.03)	49.27 (22.66)	46.14 (24.16)	43.20 (25.52)	40.44 (26.74)	37.85 (27.81)
Female locals(≥60y)	77.33 (9.40)	76.53 (10.11)	76.22 (10.85)	75.94 (11.79)	75.69 (12.94)	75.49 (14.28)	75.32 (15.80)	75.19 (17.48)	75.10 (19.33)	75.03 (21.32)
Male immigrants >10(≥60y)	293.56 (9.13)	289.8 (11.7)	286.6 (15.19)	284.28 (19.51)	282.78 (24.49)	281.99 (30.07)	281.88 (36.31)	282.31 (43.15)	283.37 (50.66)	285.03 (58.86)
Male immigrants ≤ 10(≥60y)	244.88 (30.29)	247.01 (36.85)	251.24 (42.94)	255.62 (50.06)	260.14 (58.14)	264.82 (67.14)	269.61 (77.01)	274.52 (87.75)	279.55 (99.34)	284.69 (111.81)
Male locals(≥60y)	150.75 (16.22)	146.29 (18.46)	143.54 (20.58)	141.84 (23.97)	140.07 (28.24)	138.14 (33.39)	136.65 (39.82)	136.49 (47.87)	137.24 (57.47)	138.26 (68.52)

eTable 1. Predictive means and standard deviations (in brackets) of age-standardized mortality rates of lung cancer per 100,000 population for each gender, age group (less than, greater or equal to 60 years old) and immigrant status from 2022 to 2030. Reported means and standard deviations (in brackets) of age-standardized mortality rates in 2021 are also listed.

Predictive mean of age-standardized mortality rates of colon cancer per 100,000 population										
Year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Female immigrants >10	20.03 (0.95)	18.95 (1.13)	18.77 (1.37)	18.59 (1.66)	18.42 (1.98)	18.27 (2.33)	18.12 (2.71)	17.98 (3.11)	17.85 (3.53)	17.73 (3.96)
Female immigrants ≤ 10	8.11 (2.19)	7.70 (2.51)	7.25 (2.81)	6.82 (3.11)	6.42 (3.37)	6.03 (3.61)	5.67 (3.83)	5.33 (4.01)	5.01 (4.17)	4.71 (4.31)
Female locals	13.77 (1.30)	13.47 (1.61)	13.24 (1.72)	13.01 (1.87)	12.77 (2.04)	12.53 (2.24)	12.29 (2.46)	12.06 (2.68)	11.82 (2.92)	11.59 (3.16)
Male immigrants >10	31.22 (1.28)	29.82 (1.46)	29.66 (1.79)	29.52 (2.19)	29.41 (2.63)	29.30 (3.11)	29.21 (3.64)	29.14 (4.19)	29.06 (4.78)	28.98 (5.39)
Male immigrants ≤10	15.47 (2.14)	16.77 (3.77)	17.02 (4.18)	17.23 (4.64)	17.45 (5.14)	17.67 (5.69)	17.88 (6.27)	18.09 (6.91)	18.31 (7.56)	18.50 (8.26)
Male locals	21.28 (1.38)	19.81 (2.07)	19.39 (2.22)	18.97 (2.42)	18.57 (2.61)	18.18 (2.85)	17.81 (3.12)	17.43 (3.40)	17.06 (3.71)	16.71 (4.03)
Female immigrants >10(<60y)	7.09 (0.99)	7.36 (1.12)	7.46 (1.28)	7.56 (1.46)	7.65 (1.68)	7.74 (1.92)	7.83 (2.19)	7.92 (2.48)	8.01 (2.79)	8.09 (3.13)
Female immigrants ≤ 10(<60y)	3.11 (0.67)	2.82 (0.86)	2.65 (0.91)	2.51 (0.97)	2.36 (1.02)	2.22 (1.07)	2.08 (1.11)	1.95 (1.14)	1.83 (1.18)	1.72 (1.22)
Female locals(<60y)	4.10 (0.41)	3.87 (0.50)	3.73 (0.54)	3.61 (0.59)	3.47 (0.65)	3.34 (0.70)	3.22 (0.76)	3.11 (0.82)	2.99 (0.88)	2.88 (0.94)
Male immigrants >10(<60y)	8.29 (0.91)	7.98 (1.17)	7.85 (1.38)	7.71 (1.60)	7.54 (1.83)	7.36 (2.08)	7.17(2.32)	6.97(2.57)	6.76(2.81)	6.55(3.05)
Male immigrants ≤ 10(<60y)	5.03 (1.44)	5.18 (1.58)	5.22 (1.75)	5.26 (1.93)	5.30 (2.14)	5.34 (2.36)	5.38(2.59)	5.43(2.84)	5.47(3.11)	5.51(3.38)
Male locals(<60y)	5.14 (0.43)	4.88 (0.63)	4.66 (0.79)	4.46 (0.96)	4.26 (1.13)	4.08 (1.31)	3.91(1.48)	3.73(1.65)	3.57(1.82)	3.42(1.97)
Female immigrants >10(≥60y)	52.16 (2.59)	49.21 (2.99)	48.70 (3.56)	48.26 (4.26)	47.87 (5.05)	47.54 (5.94)	47.26 (6.90)	47.05 (7.94)	46.91 (9.06)	46.81 (10.26)
Female immigrants ≤ 10(≥60y)	24.01 (5.83)	22.44 (6.56)	21.69 (6.96)	20.95 (7.38)	20.23 (7.80)	19.52 (8.23)	18.84 (8.66)	18.17 (9.08)	17.51 (9.49)	16.86 (9.90)
Female locals(≥60y)	37.42 (5.31)	36.69 (5.74)	36.29 (6.06)	35.87 (6.46)	35.46 (6.95)	35.04 (7.5)	34.61 (8.12)	34.19 (8.79)	33.77 (9.51)	33.34 (10.27)
Male immigrants >10(≥60y)	84.17 (3.55)	82.72 (4.09)	82.16 (4.95)	81.64 (5.97)	81.19 (7.12)	80.81 (8.39)	80.47 (9.77)	80.15 (11.24)	79.85 (12.81)	79.56 (14.45)
Male immigrants ≤ 10(≥60y)	43.25 (11.07)	44.93 (13.09)	45.62 (14.52)	46.30 (16.09)	46.96 (17.80)	47.61 (19.64)	48.25 (21.62)	48.88 (23.73)	49.51 (25.97)	50.13 (28.34)
Male locals(≥60y)	55.79 (6.86)	54.89 (7.65)	53.75 (8.03)	52.63 (8.52)	51.54 (9.12)	50.47 (9.8)	49.43 (10.55)	48.42 (11.37)	47.42 (12.25)	46.44 (13.16)

eTable 2. Predictive means and standard deviations (in brackets) of age-standardized mortality rates of colon cancer per 100,000 population for each gender, age group (less than, greater or equal to 60 years old) and immigrant status from 2022 to 2030. Reported means and standard deviations (in brackets) of age-standardized mortality rates in 2021 are also listed.

Predictive mean of age-standardized mortality rates of liver cancer per 100,000 population										
Year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Female immigrants >10	11.34 (0.66)	10.68 (0.71)	10.09 (0.85)	9.54 (1.01)	9.01 (1.16)	8.50 (1.31)	8.02(1.45)	7.57(1.59)	7.14(1.72)	6.74(1.83)
Female immigrants ≤10	9.15 (1.55)	8.66 (1.82)	8.38 (1.95)	8.11 (2.08)	7.84 (2.22)	7.58 (2.36)	7.32(2.49)	7.07(2.63)	6.82(2.76)	6.58(2.88)
Female locals	6.72 (0.69)	6.36 (0.88)	6.08 (0.90)	5.81 (0.93)	5.53 (0.97)	5.26 (1.01)	5.01(1.06)	4.77(1.11)	4.53(1.15)	4.3(1.21)
Male immigrants >10	52.17 (1.78)	49.22 (2.36)	47.76 (2.93)	46.35 (3.59)	45.01 (4.31)	43.67 (5.05)	42.37 (5.81)	41.1(6.56)	39.89 (7.33)	38.71 (8.08)
Male immigrants ≤10	42.33 (5.87)	39.03 (6.49)	37.39 (7.47)	35.81 (8.51)	34.26 (9.58)	32.76 (10.63)	31.31 (11.65)	29.91 (12.62)	28.56 (13.54)	27.25 (14.40)
Male locals	24.22 (1.77)	22.16 (2.09)	21.02 (2.22)	19.91 (2.39)	18.85 (2.58)	17.83 (2.79)	16.85 (3.03)	15.92 (3.21)	15.03 (3.40)	14.18 (3.59)
Female immigrants >10(<60y)	3.62 (0.45)	3.39 (0.52)	3.29 (0.57)	3.20 (0.63)	3.12 (0.69)	3.04 (0.75)	2.96(0.82)	2.89(0.89)	2.82(0.96)	2.75(1.03)
Female immigrants ≤10(<60y)	4.10 (0.79)	3.81 (0.91)	3.69 (0.96)	3.57 (1.02)	3.46 (1.08)	3.36 (1.15)	3.25(1.22)	3.15(1.29)	3.06(1.36)	2.97(1.43)
Female locals(<60y)	1.50 (0.13)	1.37 (0.2)	1.29 (0.21)	1.22 (0.23)	1.16 (0.24)	1.10 (0.26)	1.04(0.27)	0.99(0.29)	0.94(0.30)	0.89(0.31)
Male immigrants >10(<60y)	26.32 (2.11)	24.04 (2.35)	23.02 (2.63)	22.05 (2.94)	21.13 (3.27)	20.25 (3.61)	19.41 (3.95)	18.62 (4.30)	17.86 (4.64)	17.14 (4.98)
Male immigrants ≤10(<60y)	25.52 (2.99)	22.56 (3.96)	21.71 (4.44)	20.87 (4.94)	20.04 (5.45)	19.22 (5.95)	18.42 (6.45)	17.63 (6.91)	16.86 (7.36)	16.11 (7.78)
Male locals(<60y)	8.25 (0.69)	7.47 (0.74)	6.97 (0.79)	6.52 (0.86)	6.11 (0.93)	5.73 (1.01)	5.38(1.08)	5.04(1.15)	4.73(1.21)	4.44(1.27)
Female immigrants >10(≥60y)	33.67 (1.88)	29.63 (2.01)	27.99 (2.36)	26.42 (2.75)	24.92 (3.14)	23.49 (3.52)	22.13 (3.88)	20.85 (4.23)	19.64 (4.55)	18.50 (4.85)
Female immigrants ≤10(≥60y)	21.72 (5.11)	19.08 (5.81)	18.38 (6.14)	17.71 (6.48)	17.03 (6.83)	16.39 (7.16)	15.76 (7.49)	15.16 (7.80)	14.57 (8.11)	14.01 (8.39)
Female locals(≥60y)	20.63 (3.03)	18.41 (3.23)	17.55 (3.26)	16.72 (3.32)	15.91 (3.40)	15.11 (3.49)	14.34 (3.59)	13.59 (3.69)	12.87 (3.81)	12.17 (3.93)
Male immigrants >10(≥60y)	115.39 (4.54)	113.96 (5.95)	113.43 (7.65)	113.17 (9.70)	113.16 (12.04)	113.37 (14.66)	113.79 (17.56)	114.39 (20.73)	115.19 (24.18)	116.17 (27.91)
Male immigrants ≤10(≥60y)	88.61 (15.58)	85.14 (18.85)	82.59 (20.6)	80.02 (22.44)	77.42 (24.34)	74.83 (26.24)	72.23 (28.12)	69.64 (29.94)	67.07 (31.70)	64.52 (33.38)
Male locals(≥60y)	62.88 (5.97)	58.95 (7.91)	56.51 (8.20)	54.14 (8.61)	51.84 (9.12)	49.61 (9.70)	47.46 (10.33)	45.38 (11.01)	43.38 (11.68)	41.45 (12.36)

eTable 3. Predictive means and standard deviations (in brackets) of age-standardized mortality rates of liver cancer per 100,000 population for each gender, age group (less than, greater or equal to 60 years old) and immigrant status from 2022 to 2030. Reported means and standard deviations (in brackets) of age-standardized mortality rates in 2021 are also listed.

Predictive mean of age-standardized mortality rates of pancreatic cancer per 100,000 population										
Year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Female immigrants >10	10.89 (0.62)	11.11 (0.75)	11.36 (0.91)	11.61 (1.09)	11.87 (1.31)	12.14 (1.56)	12.42 (1.84)	12.71 (2.15)	13.01 (2.48)	13.3(2.85)
Female immigrants ≤ 10	5.51 (1.44)	5.44 (1.56)	5.44 (1.69)	5.43(1.84)	5.42(1.99)	5.41(2.15)	5.39(2.32)	5.36(2.49)	5.34(2.66)	5.31(2.84)
Female locals	8.79 (1.10)	9.01 (1.22)	9.15 (1.34)	9.29(1.48)	9.43(1.64)	9.57(1.83)	9.71(2.05)	9.85(2.28)	9.99(2.54)	10.14 (2.83)
Male immigrants >10	16.30 (0.98)	17.87 (1.19)	18.48 (1.49)	19.11 (1.87)	19.78 (2.32)	20.47 (2.83)	21.18 (3.42)	21.92 (4.07)	22.69 (4.81)	23.49 (5.61)
Male immigrants ≤ 10	8.10 (2.02)	7.87 (2.37)	7.76 (2.53)	7.64(2.70)	7.51(2.87)	7.38(3.05)	7.24(3.23)	7.09(3.41)	6.95(3.58)	6.81(3.75)
Male locals	11.97 (1.26)	12.29 (1.49)	12.49 (1.64)	12.69 (1.83)	12.91 (2.06)	13.11 (2.33)	13.33 (2.63)	13.55 (2.97)	13.78 (3.34)	14.02 (3.74)
Female immigrants >10(<60y)	3.47 (0.33)	3.62 (0.57)	3.74 (0.66)	3.87(0.77)	4.01(0.89)	4.14(1.02)	4.28(1.18)	4.42(1.34)	4.57(1.53)	4.72(1.73)
Female immigrants ≤ 10(<60y)	1.12 (0.33)	1.21 (0.48)	1.22 (0.52)	1.23(0.56)	1.24(0.61)	1.25(0.66)	1.26(0.71)	1.26(0.77)	1.27(0.83)	1.28(0.89)
Female locals(<60y)	2.76 (0.27)	2.88 (0.36)	2.91 (0.41)	2.93(0.48)	2.96(0.55)	2.99(0.63)	3.02(0.71)	3.04(0.81)	3.07(0.90)	3.10(1.01)
Male immigrants >10(<60y)	6.88 (0.98)	7.05 (1.11)	7.24 (1.32)	7.43(1.56)	7.62(1.84)	7.82(2.16)	8.01(2.50)	8.21(2.88)	8.40(3.30)	8.61(3.75)
Male immigrants ≤ 10(<60y)	2.20 (0.71)	2.01 (0.85)	1.95 (0.91)	1.9(0.94)	1.84(0.99)	1.79(1.04)	1.74(1.09)	1.69(1.14)	1.64(1.19)	1.60(1.24)
Male locals(<60y)	4.16 (0.35)	4.33 (0.48)	4.41 (0.57)	4.46(0.68)	4.53(0.81)	4.61(0.94)	4.69(1.09)	4.77(1.26)	4.85(1.44)	4.93(1.63)
Female immigrants >10(≥60y)	28.58 (1.83)	29.45 (2.11)	29.91 (2.54)	30.38 (3.06)	30.85 (3.66)	31.33 (4.33)	31.81 (5.08)	32.29 (5.91)	32.78 (6.79)	33.27 (7.74)
Female immigrants ≤ 10(≥60y)	16.79 (5.29)	15.65 (6.08)	15.49 (6.71)	15.33 (7.36)	15.16 (8.03)	14.97 (8.73)	14.79 (9.43)	14.59 (10.14)	14.39 (10.86)	14.19 (11.58)
Female locals(≥60y)	22.80 (4.23)	23.85 (4.46)	24.21 (4.81)	24.56 (5.23)	24.91 (5.73)	25.25 (6.30)	25.58 (6.95)	25.90 (7.67)	26.22 (8.47)	26.54 (9.34)
Male immigrants >10(≥60y)	42.70 (2.55)	44.36 (3.02)	45.85 (3.76)	47.41 (4.69)	49.04 (5.78)	50.73 (7.05)	52.48 (8.50)	54.28 (10.13)	56.16 (11.95)	58.11 (13.98)
Male immigrants ≤ 10(≥60y)	24.68 (8.21)	23.96 (9.01)	23.87 (9.74)	23.75 (10.52)	23.61 (11.33)	23.45 (12.17)	23.28 (13.04)	23.09 (13.93)	22.89 (14.83)	22.68 (15.75)
Male locals(≥60y)	30.10 (4.68)	31.17 (5.22)	31.55 (5.63)	31.93 (6.14)	32.30 (6.75)	32.66 (7.45)	33.01 (8.23)	33.35 (9.11)	33.69 (10.08)	34.03 (11.12)

eTable 4. Predictive means and standard deviations (in brackets) of age-standardized mortality rates of pancreatic cancer per 100,000 population for each gender, age group (less than, greater or equal to 60 years old) and immigrant status from 2022 to 2030. Reported means and standard deviations (in brackets) of age-standardized mortality rates in 2021 are also listed.

Predictive mean of age-standardized mortality rates of stomach cancer per 100,000 population										
Year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Female immigrants >10	8.20 (0.55)	7.95 (0.62)	7.71 (0.74)	7.47 (0.87)	7.25 (1.01)	7.03 (1.15)	6.83 (1.29)	6.62 (1.43)	6.43 (1.57)	6.24 (1.71)
Female immigrants ≤ 10	7.51 (1.44)	7.36 (1.56)	7.33 (1.69)	7.30 (1.85)	7.28 (2.01)	7.27 (2.20)	7.27 (2.40)	7.28 (2.61)	7.31 (2.84)	7.33 (3.09)
Female locals	5.26 (0.40)	4.91 (0.52)	4.75 (0.57)	4.61 (0.63)	4.47 (0.71)	4.34 (0.77)	4.21 (0.84)	4.08 (0.91)	3.95 (0.99)	3.83 (1.06)
Male immigrants >10	15.22 (0.64)	13.89 (0.97)	13.34(1.21)	12.81 (1.46)	12.31 (1.73)	11.83 (1.99)	11.38 (2.26)	10.95 (2.51)	10.54 (2.76)	10.15 (3.01)
Male immigrants ≤10	15.83 (3.04)	15.21 (3.38)	15.07 (3.67)	14.93 (3.98)	14.79 (4.31)	14.64 (4.65)	14.51 (5.02)	14.35 (5.39)	14.19 (5.78)	14.03 (6.17)
Male locals	8.14 (0.89)	8.07 (0.99)	7.73 (1.03)	7.41(1.07)	7.10 (1.13)	6.81 (1.19)	6.51 (1.26)	6.23 (1.33)	5.97 (1.39)	5.71 (1.46)
Female immigrants >10(<60y)	4.81 (0.56)	4.69 (0.79)	4.62 (0.87)	4.55 (0.96)	4.47 (1.07)	4.39 (1.17)	4.31 (1.29)	4.22 (1.41)	4.13 (1.52)	4.03 (1.64)
Female immigrants ≤ 10(<60y)	3.89 (0.80)	4.08 (0.93)	4.10 (1.03)	4.13 (1.14)	4.17 (1.27)	4.21 (1.41)	4.24 (1.55)	4.28 (1.70)	4.32 (1.87)	4.36 (2.05)
Female locals(<60y)	2.28 (0.21)	2.08 (0.27)	1.98 (0.29)	1.88 (0.32)	1.79 (0.35)	1.71 (0.37)	1.61 (0.41)	1.53 (0.43)	1.44 (0.45)	1.37 (0.47)
Male immigrants >10(<60y)	4.94 (0.57)	4.71 (0.79)	4.55 (0.89)	4.41 (0.99)	4.25 (1.10)	4.12 (1.21)	3.98 (1.32)	3.86 (1.43)	3.74 (1.54)	3.63 (1.65)
Male immigrants ≤ 10(<60y)	4.81 (1.31)	4.70 (1.42)	4.66 (1.55)	4.63 (1.69)	4.59 (1.83)	4.55 (1.99)	4.52 (2.15)	4.48 (2.32)	4.44 (2.50)	4.41 (2.68)
Male locals(<60y)	2.48 (0.21)	2.37 (0.29)	2.28 (0.32)	2.21 (0.35)	2.12 (0.38)	2.04 (0.42)	1.97 (0.45)	1.91 (0.49)	1.83 (0.52)	1.77(0.55)
Female immigrants >10(≥60y)	17.80 (1.04)	16.23 (1.26)	15.65 (1.47)	15.08 (1.70)	14.55 (1.94)	14.03 (2.18)	13.54 (2.43)	13.07 (2.68)	12.62 (2.92)	12.19 (3.16)
Female immigrants ≤ 10(≥60y)	14.72 (4.29)	13.01 (4.83)	12.52 (5.11)	12.03 (5.37)	11.55 (5.63)	11.08 (5.88)	10.63 (6.12)	10.19 (6.35)	9.76(6.56)	9.34 (6.75)
Female locals(≥60y)	12.20 (1.66)	11.86 (1.84)	11.67 (1.98)	11.49 (2.15)	11.33 (2.35)	11.18 (2.58)	11.04 (2.84)	10.91 (3.11)	10.79(3.4)	10.68 (3.71)
Male immigrants >10(≥ 60y)	37.23 (2.29)	36.59 (2.56)	35.17(3.18)	33.82 (3.86)	32.55 (4.57)	31.34 (5.28)	30.19 (6.01)	29.08 (6.70)	28.02 (7.40)	27.01 (8.07)
Male immigrants ≤ 10(≥60y)	42.30 (10.88)	41.43 (11.78)	41.03 (12.71)	40.61 (13.70)	40.17 (14.75)	39.71 (15.85)	39.24 (16.99)	38.75 (18.16)	38.23 (19.35)	37.71 (20.57)
Male locals(≥60y)	23.04 (3.29)	22.69 (3.56)	22.37(4.07)	22.16(4.84)	21.89 (5.86)	21.61 (7.22)	21.52 (9.02)	21.74 (11.29)	22.17 (14.03)	22.73 (17.28)

eTable 5. Predictive means and standard deviations (in brackets) of age-standardized mortality rates of stomach cancer per 100,000 population for each gender, age group (less than, greater or equal to 60 years old) and immigrant status from 2022 to 2030. Reported means and standard deviations (in brackets) of age-standardized mortality rates in 2021 are also listed.

Predictive mean of age-standardized mortality rates of prostate cancer per 100,000 population										
Year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Male immigrants >10	14.81 (0.61)	14.59 (0.79)	14.57 (0.96)	14.56 (1.15)	14.54 (1.37)	14.51 (1.61)	14.48 (1.86)	14.45 (2.13)	14.42 (2.42)	14.38 (2.72)
Male immigrants ≤10	9.03 (2.95)	8.78 (3.11)	8.58 (3.29)	8.39 (3.49)	8.19(3.69)	8.10(3.89)	7.82(4.11)	7.63(4.31)	7.45(4.51)	7.27(4.72)
Male locals	9.54 (1.40)	9.66 (1.57)	9.67 (1.66)	9.69 (1.77)	9.72(1.91)	9.75(2.06)	9.78(2.23)	9.82(2.43)	9.86(2.64)	9.9(2.88)
Male immigrants >10(<60y)	0.57 (0.12)	0.52 (0.17)	0.51 (0.19)	0.50 (0.21)	0.49(0.22)	0.48(0.24)	0.47(0.25)	0.46(0.27)	0.45(0.29)	0.44(0.31)
Male immigrants ≤10(<60y)	0.65 (0.59)	0.73 (0.77)	0.81 (0.93)	0.87 (1.10)	0.94(1.31)	1.01(1.51)	1.09(1.75)	1.16(2.02)	1.24(2.32)	1.33(2.64)
Male locals(<60y)	0.63 (0.12)	0.66 (0.14)	0.66 (0.16)	0.66 (0.19)	0.67(0.21)	0.67(0.24)	0.67(0.27)	0.68(0.31)	0.68(0.33)	0.69(0.37)
Male immigrants >10(≥60y)	49.43 (2.59)	49.61 (2.73)	49.63 (3.29)	49.64 (3.94)	49.64 (4.68)	49.64 (5.51)	49.63 (6.38)	49.62 (7.32)	49.61 (8.32)	49.58(9.37)
Male immigrants ≤10(≥60y)	28.29 (9.15)	27.66 (9.78)	26.53 (10.21)	25.4 (10.63)	24.28 (11.03)	23.16 (11.41)	22.07 (11.76)	21.01 (12.09)	19.96 (12.38)	18.95(12.63)
Male locals(≥60y)	31.57 (5.17)	31.48 (5.49)	31.40 (5.76)	31.32 (6.09)	31.24 (6.48)	31.15 (6.94)	31.06 (7.44)	30.96 (8.01)	30.86 (8.61)	30.74(9.26)

eTable 6. Predictive means and standard deviations (in brackets) of age-standardized mortality rates of prostate cancer per 100,000 population for each age group (less than, greater or equal to 60 years old) and immigrant status from 2022 to 2030. Reported means and standard deviations (in brackets) of age-standardized mortality rates in 2021 are also listed.

Reporting checklist for cohort study.

Based on the STROBE cohort guidelines.

Instructions to authors

Complete this checklist by entering the page numbers from your manuscript where readers will find each of the items listed below.

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			Page Number
Title and abstract			
Title	#1a	Indicate the study's design with a commonly used term in the title or the abstract	1
Abstract	#1b	Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background / rationale	#2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	#3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	#4	Present key elements of study design early in the paper	5
Setting	#5	Describe the setting, locations, and relevant dates, including periods	5

1			of recruitment, exposure, follow-up, and data collection	
2	Eligibility criteria	#6a	Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up.	5
3				
4				
5				
6	Eligibility criteria	#6b	For matched studies, give matching criteria and number of exposed and unexposed	n/a
7				
8				
9				
10	Variables	#7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
11				
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15	Data sources / measurement	#8	For each variable of interest give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group. Give information separately for for exposed and unexposed groups if applicable.	5
16				
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22	Bias	#9	Describe any efforts to address potential sources of bias	5
23				
24	Study size	#10	Explain how the study size was arrived at	5
25				
26				
27	Quantitative variables	#11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why	5
28				
29				
30				
31	Statistical methods	#12a	Describe all statistical methods, including those used to control for confounding	
32				
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34	5			
35				
36				
37	Statistical methods	#12b	Describe any methods used to examine subgroups and interactions	5
38				
39				
40				
41	Statistical methods	#12c	Explain how missing data were addressed	5
42				
43				
44	Statistical methods	#12d	If applicable, explain how loss to follow-up was addressed	n/a
45				
46				
47				
48	Statistical methods	#12e	Describe any sensitivity analyses	
49				
50				
51				
52	n/a			
53				
54	Results			
55				
56	Participants	#13a	Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible,	n/a
57				
58				
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included in the study, completing follow-up, and analysed. Give information separately for for exposed and unexposed groups if applicable.

1			
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3			
4			
5	Participants	#13b	Give reasons for non-participation at each stage 5
6			
7	Participants	#13c	Consider use of a flow diagram
8			
9	n/a		
10			
11			
12	Descriptive data	#14a	Give characteristics of study participants (eg demographic, clinical, 5
13			social) and information on exposures and potential confounders. Give
14			information separately for exposed and unexposed groups if
15			applicable.
16			
17			
18			
19	Descriptive data	#14b	Indicate number of participants with missing data for each variable of
20			interest
21			
22			
23	n/a		
24			
25	Descriptive data	#14c	Summarise follow-up time (eg, average and total amount)
26			
27			
28	n/a		
29			
30	Outcome data	#15	Report numbers of outcome events or summary measures over time.
31			Give information separately for exposed and unexposed groups if
32			applicable.
33			
34			
35	n/a		
36			
37			
38	Main results	#16a	Give unadjusted estimates and, if applicable, confounder-adjusted 6
39			estimates and their precision (eg, 95% confidence interval). Make
40			clear which confounders were adjusted for and why they were
41			included
42			
43			
44	Main results	#16b	Report category boundaries when continuous variables were n/a
45			categorized
46			
47			
48	Main results	#16c	If relevant, consider translating estimates of relative risk into absolute
49			risk for a meaningful time period
50			
51			
52	n/a		
53			
54			
55	Other analyses	#17	Report other analyses done—eg analyses of subgroups and 7
56			interactions, and sensitivity analyses
57			

Discussion

1	Key results	#18	Summarise key results with reference to study objectives	8
2				
3	Limitations	#19	Discuss limitations of the study, taking into account sources of	10
4			potential bias or imprecision. Discuss both direction and magnitude of	
5			any potential bias.	
6				
7				
8	Interpretation	#20	Give a cautious overall interpretation considering objectives,	8
9			limitations, multiplicity of analyses, results from similar studies, and	
10			other relevant evidence.	
11				
12				
13	Generalisability	#21	Discuss the generalisability (external validity) of the study results	9
14				
15				
16	Other			
17	Information			
18				
19				
20	Funding	#22	Give the source of funding and the role of the funders for the present	11
21			study and, if applicable, for the original study on which the present	
22			article is based	
23				
24				

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BMJ Open

An age-period-cohort analysis and projection of cancer mortality in Hong Kong, 1998–2030

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An age-period-cohort analysis and projection of cancer mortality in Hong Kong, 1998–2030

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Word count: 3379

24 Abstract

25 **Objectives:** To explore the relationship between immigration groups and cancer mortality, this
26 study aimed to explore age, period, birth cohort effects and effects across genders and
27 immigration groups on mortality rates of lung, pancreatic, colon, liver, prostate and stomach
28 cancers and their projections.

30 **Design, Setting, and Participants:** Death registry data in Hong Kong between 1998 and 2021,
31 which were stratified by age, sex and immigration status. Immigration status was classified into
32 three groups: locals born in Hong Kong, long-stay immigrants and short-stay immigrants.

34 **Methods:** Age-period-cohort analysis was used to examine age, period, and birth cohort effects
35 for genders and immigration groups from 1998 to 2021. Bayesian age-period-cohort models
36 were applied to predict the mortality rates from 2022 to 2030.

38 **Results:** Short-stay immigrants revealed pronounced fluctuations of mortality rates by age and
39 of relative risks by cohort and period effects for six types of cancers than those of long-stay
40 immigrants and locals. Immigrants for each type of cancer and gender will be at a higher
41 mortality risk than locals, as men will be at a higher risk of mortality from cancers than women
42 in the future (excluding prostate cancer). After 2021, decreasing trends ($p < 0.05$) or plateau
43 ($p > 0.05$) of forecasting mortality rates of cancers occur for all immigration groups, except for
44 increasing trends for short-stay male immigrants with colon cancer ($p < 0.05$, Avg +0.30
45 deaths/100,000 per annum from 15.47 to 18.50 deaths/100,000) and long-stay male immigrants
46 with pancreatic cancer ($p < 0.05$, Avg +0.72 deaths/100,000 per annum from 16.30 to 23.49
47 deaths/100,000).

49 **Conclusions:** Findings underscore the effect of gender and immigration status in Hong Kong
50 on mortality risks of cancers that immigrants for each type of cancer and gender will be at a
51 higher mortality risk than locals.

53 **Keywords:** Age-period-cohort analysis, immigration, mortality, lung cancer, pancreatic cancer,
54 colon cancer, liver cancer, prostate cancer, stomach cancer

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55 **Strengths and limitations of this study**

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57 • This study provides new evidence regarding the relationship between immigration status
58 and cancer mortality, given the effects of age, period, birth cohort and their predictions.

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60 • The non-identifiability problem has not been interpreted in APC models

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62 • The future perspective of cancer therapies and techniques have not been considered.

For peer review only

64 Introduction

65 Several migration waves from mainland China to Hong Kong have occurred over the past
66 century. These migration waves included a large-scale migration inflow from 1945 to 1950 (the
67 Chinese Civil War) and a few small-scale inflows in the 1950s, 1970s, and 1990s [1-3]. In 2016,
68 immigrants from mainland China formed approximately 38% of the population of Hong Kong.
69 These inflows have led to a growing interest in research on the disparity of health conditions
70 between the locals and immigrants.

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72 Cancer has been one of the most common causes of death, as an estimated 19.3 million new
73 cancer cases and 9.9 million new cancer-associated deaths occurred worldwide in 2020 [4]. In
74 Hong Kong, lung cancer is one of the most common causes of cancer deaths [5, 6]. Previous
75 studies suggested that the primary cause of lung cancer is cigarette smoking [7-11]. Genetic
76 factors, asbestos, radon gas, second-hand smoke, and other forms of air pollution have been
77 proven to influence the risk of lung cancer [12-18]. The overall daily smoking rate in mainland
78 China was approximately 23.2% in 2018 [19], whereas the daily smoking rate in Hong Kong
79 was only 10.2% in 2019 [20]. The leading causes of liver cancer include viral infection,
80 drinking of alcohol and polluted water and food supplies which are also culprits for colon,
81 stomach and pancreatic cancer [21]. Alcohol consumption per capita in Hong Kong has reached
82 2.37 liters in 2021 [22], compared to 7.0 liters of per capita consumption of alcohol in mainland
83 China in 2018 [23]. As approximately 99% of prostate cancer cases occur after age 50, factors
84 of prostate cancer have been regarded as old age, race, family history and the diet of red meat
85 consumption [24]. In addition to these risk factors, studies have suggested that cancer mortality
86 rates vary depending on migrant status [25-28]. According to data from the Census and
87 Statistics Department of Hong Kong, approximately 81% of immigrants in Hong Kong
88 immigrated from mainland China, Macau, and Taiwan. Immigrants from mainland China
89 account for the bulk of this population. Previous studies have shown that child immigrants in
90 Hong Kong tend to suffer from a higher risk of wheezing disorders and cardiovascular diseases,
91 and immigrant women have higher age-specific mortality rates of breast cancer than locally-
92 born women in Hong Kong [29, 30]. However, to date, few studies have investigated the effect
93 of length of stay in Hong Kong and birthplace on the risk of other types of cancer.

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95 In this study, we compared the mortality rates of lung, pancreatic, colon, liver, prostate and
96 stomach cancers between locally born residents in Hong Kong and immigrants from mainland
97 China. Both populations are widely considered as ethnically homogeneous with similar cultures.
98 Nevertheless, due to different early life experiences, immigrants are exposed to more various
99 social economy and lifestyles than locals. Therefore, it's constructive to ascertain whether
100 immigrants from mainland China have a different mortality pattern of cancers from locals to

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4 101 verify the significance of migration status for this health outcome. As Age-period-cohort (APC)
5 102 analysis plays a vital role in studying time-specific phenomena in epidemiology, in this study,
6 103 to evaluate the effect of immigration on cancer mortality in the past and future, we developed
7 104 APC models specified by sex and migrant status to assess the effects of age, period, birth cohort,
8 105 and of the length of stay in Hong Kong on the mortality risks of cancers. Additionally, we
9 106 explore the projection of mortality rates for the locally born population and immigrants in Hong
10 107 Kong who were younger or older than 60 using a predictive model, taking into account age,
11 108 period, and birth cohort effects as well.
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18 110 **Methods**

19 111 *Data*

20 112 We obtained the death registry data in Hong Kong between 1998 and 2021 from the Census
21 113 and Statistics Department of Hong Kong, as the data in 2022 has not been available up to now.
22 114 The data was extracted from a routine census held by the Hong Kong government as subjective
23 115 errors caused by resampling can be neglected. The population data were stratified by age, sex,
24 116 immigration status, and length of stay in Hong Kong. We retrieved six types of cancer cases
25 117 from the death registry data using ICD codes, such as ICD-9 code 162 and ICD-10 codes
26 118 C34.0–C34.3, C348, and C349 for lung cancer. To assure comparability among
27 119 registries, deaths from the age group of 35–85 years were selected, since cases younger than 35
28 120 and older than 85 were relatively trivial for lack of statistical interpretability [31]. Immigration
29 121 status was classified into three groups: locals born in Hong Kong, immigrants who have lived
30 122 in Hong Kong for >10 years before death defined as long-stay immigrants, and immigrants who
31 123 have lived in Hong Kong for ≤10 years before death defined as short-stay immigrants. Notably,
32 124 much focus was placed on immigrants from mainland China, because approximately 81% of
33 125 immigrants in Hong Kong came from mainland China, Macau, and Taiwan based on the data
34 126 from the Census and Statistics Department of Hong Kong. Moreover, few cases recorded from
35 127 Macau and Taiwan are statistically insignificant in the analysis. Demographics and population
36 128 projections from 2022 to 2030 were retrieved from the Census and Statistics Department of
37 129 Hong Kong and estimated with cubic smoothing spline as the prerequisite of the predictive
38 130 model. Codes for APC and BAPC analysis are available in the GitHub repository
39 131 (<https://github.com/kshz2164313/APC-population-projections-for-immigration-HK>).
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54 134 *Statistical analysis*

55 135 We modeled cancer mortality rates in Hong Kong using APC analysis based on log-linear
56 136 Poisson regression models. The model aimed to disentangle age, period, and cohort effects of
57 137 time-varying phenomena simultaneously [32, 33], given that
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$$\log(E_{ij}) = \alpha_i + \beta_j + \gamma_k + \mu + \log(\theta_{ij}) \quad (1)$$

where E_{ij} denotes expected mortality; α_i , β_j , and γ_k denote age, period, and cohort effect, respectively, for $i = 1, \dots, I$, $j = 1, \dots, J$, $k = 1, \dots, K$ with $k = I - i + j$. $\log(\theta_{ij})$ is the offset. We mainly focused on the contributions of sex and immigration status due to the non-identifiability problem that the effects of these three components are collinear with each other (denoted as period – age = cohort) [34]. Birth cohort effect and period effect were assessed with relative risks to evaluate the effect of three components. The median year of birth among cases was regarded as the reference cohort [35,36]. Since death cases aged at 35–85 years between 1998 and 2021 were selected, the range of birth cohort from 1913 to 1986 covered observations and further projections until 2030. The second and penultimate period effects were constrained to the reference for period. For sex and immigration status, maximum likelihood framework was applied to estimate the relative risks and 95% confidence intervals (CIs) by age groups, calendar period, and birth cohort.

Several projection approaches for future cancer mortality have been developed, but a Bayesian age-period-cohort (BAPC) model built upon integrated nested Laplace approximations (INLA) [37] yields relatively higher coverage and better performance for all evaluated parameter combinations [38]. To prevent some sampling problems caused by Markov chain Monte Carlo (MCMC), this MCMC-free BAPC approach was applied to predict future cancer mortality within a fully Bayesian inference setting and provide outputs of interest simply, such as projected age-standardized and age-specific rates. Convergence checks are not necessary for this technique [37]. The projections of age-standardized cancer mortality rates for each sex, age group (younger or older than 60 years) and migrant status, taking into account age, period, and birth cohort effects, were performed based on the weights of population age groups from the WHO World Standard population [39], with 95% prediction intervals. Mann-Kendall trend test was applied to verify the projection trend. Friedman's Two-Way Analysis of Variance was applied to test interactions between gender and immigration groups for each year.

All analyses were performed via R version 4.2.1 (R Core Team, R Foundation for Statistical Computing, Vienna, Austria, 2013, <http://www.R-project.org/>). The APC models were established using the Epi package, and the projections based on Bayesian APC models were performed with the BAPC package.

Patient and Public Involvement

None.

Results

Figure 1 & 2 and eFigure 1(a-e) in **Supplementary Material** illustrate the estimates of age

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4 178 (assessed by cancer mortality), cohort and period effects (assessed by relative risk) based on
5 179 APC models among three migrant groups for men and women with six types of cancers,
6 180 respectively. All the mortality rates for each gender and immigration status exhibit notable
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8 181 increasing trends with age. Age, cohort and period effects of six types of cancer for immigrants
9 182 who stayed in Hong Kong for ≤ 10 years revealed relatively more pronounced fluctuations and
10 183 deviations from those effects in the other two immigration groups. Significant increasing trends
11 184 of age effect occurred in all types of cancer, regardless of gender and immigration status. For
12 185 example, while relatively insignificant differences in lung cancer mortality rates by
13 186 immigration status among females have performed, male immigrants who remained in Hong
14 187 Kong for > 10 years had higher lung cancer mortality rates at ages above 50 years and those
15 188 who arrived ≤ 10 years had lower lung cancer mortality at ages below 62 years compared to
16 189 local men Figure 1. In addition to compatible dynamics of period effect for locals and long-stay
17 190 immigrants, similar changes of relative risks by birth cohort for locals and long-stay immigrants
18 191 in lung, colon, liver and stomach cancers occurred before 1945, whereas significant differences
19 192 of relative risks by birth cohort between these two immigration groups occurred after 1960
20 193 (Figure 1 & eFigure 1(a,b,d)). Locals and long-stay immigrants in pancreatic and prostate
21 194 cancer perform almost similar changes of relative risks by birth cohort effects all the time
22 195 (eFigure 1(c,e)). Short-stay immigrants who have stayed in Hong Kong for ≤ 10 years had more
23 196 fluctuating relative risks affected by period effects before 2020 than those for locals and long-
24 197 stay immigrants. Lack of young cases, especially young short-stay immigrants, of prostate
25 198 cancer leads to significant deviations and variances in age and cohort effects.

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36 200 Figure 3-5, eFigure 2-6 in **Supplementary Material** illustrate the age-standardized mortality
37 201 rates of six types of cancer from 1998 to 2021 and their projections by sex, immigrant status
38 202 and age groups from 2022 to 2030, taking into account age, period, and birth cohort effects.
39 203 Means and standard deviations of predictive mortality rates are shown in eTable 1-6 in
40 204 **Supplementary Material**. For all ages projection (Figure 2 & eFigure 2-6), as men will be at
41 205 higher risk of mortality rates of cancers (excluding prostate cancer) than women in the future
42 206 for all three age groups (all ages, young and older than 60 years) and approximately significant
43 207 interactions between gender and immigration groups emerge for each type of cancer in each
44 208 year ($p < 0.05$), given the projected trends, immigrants for each gender, especially who have
45 209 stayed in Hong Kong for > 10 years will suffer from higher mortality rates of cancer in each
46 210 year than locals. Monotone decreasing trends or plateau of forecasting occur for both genders
47 211 and all immigration groups in cancers, except for increasing trends for male immigrants who
48 212 have stayed in Hong Kong for ≤ 10 years with colon cancer ($p < 0.05$, Avg +0.30 deaths/100,000
49 213 per annum) from 15.47 deaths/100,000 (95% CI: 11.28, 19.66) in 2021 to 18.50 deaths/100,000
50 214 (95% CI: 2.31, 34.69) in 2030, and male immigrants who have stayed in Hong Kong for > 10
51 215 years with pancreatic cancer ($p < 0.05$, Avg +0.72 deaths/100,000 per annum) from 16.30

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3 216 deaths/100,000 (95% CI: 14.38,17.26) in 2021 to 23.49 deaths/100,000 (95% CI: 12.49, 34.49)
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5 217 in 2030. Most of predictive trends for younger cases (<60 years) and older cases (\geq 60 years)
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7 218 reach a consensus with those for all ages population, except for two phenomena: 1.) mortality
8 219 rates of lung cancer for men immigrants \leq 10 that insignificant trend for all ages ($p > 0.05$) vs.
9 220 decline for younger cases ($p < 0.05$) vs. increase for older cases ($p < 0.05$); 2.) mortality rates
10 221 of liver cancer for men immigrants >10 that decline for all ages ($p < 0.05$) vs. decline for
11 222 younger cases ($p < 0.05$) vs. insignificant trend for older cases ($p > 0.05$). Some particular cases
12 223 occur in the projection of prostate cancer that young long-stay male immigrants (0.44
13 224 deaths/100,000, 95% CI: 0, 1.05) aged less than 60 will be at lower mortality rate than locals
14 225 (0.69 deaths/100,000, 95% CI: 0, 1.42) in 2030 (eTable 6). Compared with other cancers and
15 226 immigration groups, male immigrants who have stayed in Hong Kong for >10 years with lung
16 227 cancer would perform the most significant decline in predictive mean from 102.90 (95% CI:
17 228 98.14, 107.66) to 79.55 (95% CI: 47.46, 111.64) deaths per 100,000 population (Avg -2.34
18 229 deaths/100,000 per annum) (eTable 1), while the same immigration group with pancreatic
19 230 cancer would indicate the most significant uptrend in each year of 16.30 (95% CI: 14.38,17.26)
20 231 and 23.49 (95% CI: 12.49, 34.49) deaths per 100,000 population in 2021 and 2030, respectively
21 232 (Avg +0.72 deaths/100,000 per annum) (eTable 4).

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236 Discussion

237 Early detection of cancer is positive and instructive for increasing chances of cure. Nevertheless,
238 238 the high mortality rate of cancer results from late diagnosis among most patients after
239 239 progression to more advanced or severe stages. Individuals at high risk of cancer, such as
240 240 smokers, alcoholics or those who are frequently exposed to susceptible circumstances, should
241 241 be screened for early detections to increase opportunities for cure [40]. Therefore, the
242 242 differences in mortality rates among immigration groups are synonymous with detection means,
243 243 therapies, and social history in disparate periods and areas.

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245 While the changes in mortality rates by age for long-stay immigrants reached approximate
246 246 harmony with those for locals, the changes in mortality rates by age for short-stay immigrants
247 247 revealed clear differences with those for the other two populations. The group of long-stay
248 248 immigrants had a higher risk of death from lung, colon and liver cancers than the other two
249 249 immigration groups after the age of 60 years. Short-stay male immigrants were less likely to
250 250 die from lung cancer before the age of 65 years. The contrast in age effects among the
251 251 immigration groups was partially consistent with studies [25, 41] that highlighted the age
252 252 effects for locals and immigrants on breast cancer mortality in Hong Kong and lung cancer

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3 253 incidence in Sweden, as they both showed similar trends and magnitudes between locals and
4 254 immigrants before the age of 60 years. They are also compatible with the results in [42] that
5 255 diagnosis of liver cancer is the most frequent among populations at 55 to 65 years old.
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7 256 According to these trends, young individuals, especially new young immigrant men, who
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9 257 have benefited from all-rounded development in mainland China and Hong Kong, are more
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11 258 likely to seek early detection and be treated for cancers using more advanced treatments [43].
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13 259 Differences in birth cohort effects among immigrant groups partially comply with the
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15 260 interpretation above.

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18 262 We observed significant trends of cohort effects among locals and immigrants. These findings
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20 263 are partially consistent but subtly different from previous findings, regarding the effect of
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22 264 immigration status on cancers. Zhao et al. [25] described multiple peaks of cohort effects on
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24 265 breast cancer mortality between locals and immigrants in Hong Kong, as well as a significant
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26 266 decline in cohort effects after 1950. In contrast, Sung et al. [44] investigated the difference in
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28 267 breast cancer incidence between Chinese Americans and non-Hispanic whites in the U.S. and
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30 268 emphasized that Chinese Americans were at lower risk of breast cancer than non-Hispanic
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32 269 whites born in the same year. Here, we interpret the cohort-driven trends resulting from the
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34 270 intricacy of social history and lifestyle. Compared to a relatively stable social development in
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36 271 Hong Kong, representing downward trends of relative risks for locals, wars and social
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38 272 instability in mainland China resulted in several immigration waves from mainland China to
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40 273 Hong Kong before 1950. Additionally, remarkable increasing trends were recorded for new
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42 274 immigrants after 1950, which corresponded to the economic downturn after wars and famine
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44 275 between 1959 and 1961 during their youth [45]. The increasing trends for new immigrants
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46 276 and similar trends for locals and long-stay immigrants were consistent with the finding that
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48 277 nutrient deficiency contributes to a higher risk of severe mortality rates of cancers [46].
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50 278 Furthermore, we speculate that these trends, especially those for locals and long-stay
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52 279 immigrants, are most likely attributed to social development and personal behaviors, such as
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54 280 daily habits, occupational history, different diagnoses and treatments, and domestic
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56 281 environmental exposures. Notably, short-stay immigrants suffered from a lower risk of death
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58 282 from colon cancer for all ages (eFigure 1a in **Supplementary Material**). As locals and
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60 283 immigrants in Hong Kong transitioned to more westernized lifestyles, higher consumption of
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285 meat was associated with a higher risk of these types of cancer, whereas consumption of
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287 vegetables had a strong protective effect against pancreatic cancer, and moderate
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289 consumption of coffee appeared to be beneficial against lung cancer [47,48]. Further studies
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on potential risk factors are required.

289 Short-stay immigrants had more fluctuating and non-stationary but inconspicuous relative
290 risks by period effects before 2021 than locals and long-stay immigrants. Cumulatively, an

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4 291 arch pattern and fluctuating curve depicting period effects externally resulted in an arch
5 292 pattern of age-standardized mortality rates for short-stay immigrant women and irregular rates
6 293 for short-stay immigrant men before 2021. The external performance of different period
7 294 effects on mortality rates could be most likely attributed to the higher effect of different
8 295 lifestyles and social development on new immigrants than on long-stay immigrants and locals
9 296 in Hong Kong. For the age-standardized mortality rates and projections, consistent with
10 297 previous findings [49,50], we predict that the mortality rates of cancer in Hong Kong after
11 298 2021 will continue to decline or remain relatively stable, consistent with the trends before
12 299 2020, except for male immigrants who have stayed in Hong Kong for ≤ 10 years with colon
13 300 cancer and male immigrants who have stayed in Hong Kong for >10 years with pancreatic
14 301 cancer. Men will be at higher risk of mortality rates of cancer than women, regardless of
15 302 immigration status. They are also compatible with the results in [4] that men suffer from a
16 303 higher risk of these types of cancer than women, excluding prostate cancer. Furthermore, new
17 304 immigrant women will be at lower risk than local women, even though long-stay immigrants
18 305 will suffer from higher mortality rates than locals in the future. Potential interpretations could
19 306 be consistent with those for birth cohort effects, as age and period effects are considered as
20 307 confounders of cohort effect.
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309 In the past few decades, spurred by an increasing burden of high incidence and mortality rates
310 of cancer, several studies focused on the inherent identification dilemma of three effects in the
311 APC model. Further, complicated population distribution and immigration status in Hong
312 Kong, one of the areas with the highest population density and migration frequency in the
313 world, have intricate causes and inherent dynamics of cancer and other diseases. To our
314 knowledge, few studies have assessed the relationship between immigration status and cancer
315 mortality. Therefore, this study is original to examine the effect of the length of stay in Hong
316 Kong and origins of previous residence on cancer deaths, which is instructive for further
317 immigration policy-making and targeted strategies of disease detection and intervention.
318 However, this study had several limitations. Given the non-identifiability problem in age-
319 period-cohort models, we could only depict trends and variations among different
320 immigration and sex groups, as illustrated in figures, and insufficiently perform the estimates
321 of the contributions of three effects or subgroups to mortality rates. Furthermore, we adopted
322 a cubic smoothing spline to estimate populations of immigrants and locals due to the large
323 proportion of unspecified immigration status from official demographic projections. A few
324 acceptable cases resulted in a limited type of cancer so that some common cancers, such as
325 the ovary and cervix, were discarded. Since the issue of quantification, the future perspective
326 of cancer therapies and techniques have not been considered in the model of projection.

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4 **329 Conclusion**

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6 330 We conclude that immigrants, especially short-stay immigrants, had more pronounced
7 331 fluctuations of mortality rates by age and of relative risks by cohort and period effects for six
8 332 types of cancers than those of long-stay immigrants and locals. Men will be at a higher risk of
9 333 mortality rates of six types of cancer than women in the future. Male immigrants who have
10 334 stayed in Hong Kong for ≤ 10 years with colon cancer and male immigrants who have stayed
11 335 in Hong Kong for > 10 years with pancreatic cancer would perform significant uptrend in the
12 336 future, while other immigration groups for each type of cancer would continue to decline or
13 337 remain relatively stable. Immigrants for each gender in Hong Kong would suffer from higher
14 338 mortality risks of cancers than locals in the future.
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4 339 **Declaration**

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6 340 **Ethical approval and consent to participate**

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8 341 Ethical approval and consent to participate are not applicable. This study does not involve
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10 342 human participants. Data was obtained from the Census and Statistics Department of Hong
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12 343 Kong.

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14 344 **Consent for publication**

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16 345 Not applicable.

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19 346 **Data Availability Statement**

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21 347 Data are available upon reasonable request.

22
23 348 **Author contributions**

24 349 **Yanji Zhao:** Methodology, Formal analysis, Data Curation, Writing - Original Draft,
25 350 Visualization

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27 351 **Zian Zhuang:** Methodology, Formal analysis, Data Curation, Writing - Review & Editing

28 352 **Lin Yang:** Validation, Writing - Review & Editing

29 353 **Daihai He:** Conceptualization, Writing - Review & Editing, Supervision

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36
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38
39 358 **Conflict of interest**

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41 359 None declared.

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45 361 None.

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364 References

- 365
- 366 1. Fan S-C. The population projection of Hong Kong. *Southeast Asian Journal of Social Science*.
367 1974;2(1/2):105-17.
- 368 2. Department CaS. Hong Kong Statistics 1947-1967 (Report).
369 https://www.statistics.gov.hk/pub/hist/1961_1970/B10100031967AN67E0100.pdf,
370 Accessed 4th May 2019.
- 371 3. Department CaS. Demographic Trends in Hong Kong 1981-2011 (Report).
372 <http://www.statistics.gov.hk/pub/B1120017032012XXXXB0100.pdf>, Accessed 4th May 2019.
- 373 4. Sung H, Ferlay J, Siegel RL, Laversanne M, Soerjomataram I, Jemal A, et al. Global Cancer
374 Statistics 2020: GLOBOCAN Estimates of Incidence and Mortality Worldwide for 36 Cancers
375 in 185 Countries. *CA: A Cancer Journal for Clinicians*. 2021 2021/05/01;71(3):209-49. doi:
376 <https://doi.org/10.3322/caac.21660>.
- 377 5. Wang XR, Chiu YL, Qiu H, Au JSK, Yu ITS. The roles of smoking and cooking emissions
378 in lung cancer risk among Chinese women in Hong Kong. *Annals of Oncology*. 2009
379 2009/04/01;20(4):746-51. doi: <https://doi.org/10.1093/annonc/mdn699>.
- 380 6. Chiu Y-L, Wang X-R, Qiu H, Yu IT-S. Risk factors for lung cancer: a case-control study in
381 Hong Kong women. *Cancer Causes & Control*. 2010 2010/05/01;21(5):777-85. doi:
382 10.1007/s10552-010-9506-9.
- 383 7. Office on S, Health. Publications and Reports of the Surgeon General. Women and
384 Smoking: A Report of the Surgeon General. Atlanta (GA): Centers for Disease Control and
385 Prevention (US); 2001.
- 386 8. Escobedo LG, Peddicord JP. Smoking prevalence in US birth cohorts: the influence of gender
387 and education. *American Journal of Public Health*. 1996 1996/02/01;86(2):231-6. doi:
388 10.2105/AJPH.86.2.231.
- 389 9. Husten CG, Shelton DM, Chrismon JH, Lin YC, Mowery P, Powell FA. Cigarette smoking
390 and smoking cessation among older adults: United States, 1965-94. *Tobacco Control*.
391 1997;6(3):175. doi: 10.1136/tc.6.3.175.
- 392 10. Bolego C, Poli A, Paoletti R. Smoking and gender. *Cardiovascular Research*.
393 2002;53(3):568-76. doi: 10.1016/S0008-6363(01)00520-X.
- 394 11. Doll R, Hill AB. The mortality of doctors in relation to their smoking habits; a preliminary
395 report. *Br Med J*. 1954;1(4877):1451-5. PMID: 13160495. doi: 10.1136/bmj.1.4877.1451.
- 396 12. Ramada Rodilla JM, Calvo Cerrada B, Serra Pujadas C, Delclos GL, Benavides FG. Fiber
397 burden and asbestos-related diseases: an umbrella review. *Gaceta Sanitaria*. 2021 2021/06/11/.
398 doi: <https://doi.org/10.1016/j.gaceta.2021.04.001>.
- 399 13. Collishaw NE, Kirkbride J, Wigle DT. Tobacco smoke in the workplace: an occupational
400 health hazard. *Can Med Assoc J*. 1984;131(10):1199-204. PMID: 6498670.
- 401 14. Dresler CM, Fratelli C, Babb J, Everley L, Evans AA, Clapper ML. Gender differences in
402 genetic susceptibility for lung cancer. *Lung Cancer*. 2000 2000/12/01;30(3):153-60. doi:
403 [https://doi.org/10.1016/S0169-5002\(00\)00163-X](https://doi.org/10.1016/S0169-5002(00)00163-X).
- 404 15. Alexandrov K, Cascorbi I, Rojas M, Bouvier G, Kriek E, Bartsch H. CYP1A1 and GSTM1
405 genotypes affect benzo[a]pyrene DNA adducts in smokers' lung: comparison with
406 aromatic/hydrophobic adduct formation. *Carcinogenesis*. 2002;23(12):1969-77. doi:

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3 407 10.1093/carcin/23.12.1969.
- 4 408 16. Samet JM. Radon and Lung Cancer. JNCI: Journal of the National Cancer Institute.
5 409 1989;81(10):745-58. doi: 10.1093/jnci/81.10.745.
- 6 410 17. Darby S, Hill D, Auvinen A, Barros-Dios JM, Baysson H, Bochicchio F, et al. Radon in
7 411 homes and risk of lung cancer: collaborative analysis of individual data from 13 European case-
8 412 control studies. BMJ. 2005;330(7485):223. doi: 10.1136/bmj.38308.477650.63.
- 9 413 18. Raaschou-Nielsen O, Andersen ZJ, Beelen R, Samoli E, Stafoggia M, Weinmayr G, et al.
10 414 Air pollution and lung cancer incidence in 17 European cohorts: prospective analyses from the
11 415 European Study of Cohorts for Air Pollution Effects (ESCAPE). The Lancet Oncology. 2013
12 416 2013/08/01/;14(9):813-22. doi: [https://doi.org/10.1016/S1470-2045\(13\)70279-1](https://doi.org/10.1016/S1470-2045(13)70279-1).
- 13 417 19. 2018 Summary-20190719. Retrieved August 26, 2022, from
14 418 [https://www.who.int/docs/default-source/wpro---documents/countries/china/2018-gats-china-](https://www.who.int/docs/default-source/wpro---documents/countries/china/2018-gats-china-factsheet-cn-en.pdf?sfvrsn=3f4e2da9_2)
15 419 [factsheet-cn-en.pdf?sfvrsn=3f4e2da9_2](https://www.who.int/docs/default-source/wpro---documents/countries/china/2018-gats-china-factsheet-cn-en.pdf?sfvrsn=3f4e2da9_2)
- 16 420 20. *Thematic household survey*. Retrieved August 26, 2022, from
17 421 https://www.censtatd.gov.hk/en/data/stat_report/product/B1130201/att/B11302702020XXXX
18 422 [B0100.pdf](https://www.censtatd.gov.hk/en/data/stat_report/product/B1130201/att/B11302702020XXXX)
- 19 423 21. Abubakar II, Tillmann T, Banerjee A. Global, regional, and national age-sex specific all-
20 424 cause and cause-specific mortality for 240 causes of death, 1990-2013: a systematic analysis
21 425 for the Global Burden of Disease Study 2013. Lancet. 2015 Jan 10;385(9963):117-71.
- 22 426 22. Estimated alcohol consumption per capita in Hong Kong. Change4Health. (n.d.).
23 427 Retrieved December 1, 2022, from
24 428 https://www.change4health.gov.hk/en/alcohol_aware/figures/alcohol_consumption/index.htm
25 429 1
- 26 430 23. World Health Organization. Global status report on alcohol and health 2018. World
27 431 Health Organization; 2019 Feb 14.
- 28 432 24. Wild C. World cancer report 2014. Wild CP, Stewart BW, editors. Geneva, Switzerland:
29 433 World Health Organization; 2014.
- 30 434
- 31 435 25. Zhao S, Dong H, Qin J, Liu H, Li Y, Chen Y, et al. Breast cancer mortality in Chinese
32 436 women: does migrant status play a role? Annals of Epidemiology. 2019 2019/12/01/;40:28-
33 437 34.e2. doi: <https://doi.org/10.1016/j.annepidem.2019.10.006>.
- 34 438 26. Gomez SL, Yang J, Lin S-W, McCusker M, Sandler A, Cheng I, et al. Incidence trends of
35 439 lung cancer by immigration status among Chinese Americans. Cancer Epidemiol Biomarkers
36 440 Prev. 2015;24(8):1157-64. PMID: 25990553. doi: 10.1158/1055-9965.EPI-15-0123.
- 37 441 27. Hemminki K, Li X, Czene K. Cancer risks in first-generation immigrants to Sweden.
38 442 International Journal of Cancer. 2002 2002/05/10;99(2):218-28. doi:
39 443 <https://doi.org/10.1002/ijc.10322>.
- 40 444 28. Vanthomme K, Roskamp M, De Schutter H, Vandenneede H. Lung cancer incidence
41 445 differences in migrant men in Belgium, 2004–2013: histology-specific analyses. BMC Cancer.
42 446 2021 2021/03/30;21(1):328. doi: 10.1186/s12885-021-08038-6.
- 43 447 29. Schooling M, Leung GM, Janus ED, Ho SY, Hedley AJ, Lam TH. Childhood migration
44 448 and cardiovascular risk. International Journal of Epidemiology. 2004;33(6):1219-26. doi:
45 449 10.1093/ije/dyh221.
- 46 450 30. Leung JYY, Li AM, Leung GM, Schooling CM. Mode of delivery and childhood

- 1
2
3 451 hospitalizations for asthma and other wheezing disorders. *Clinical & Experimental Allergy*.
4 452 2015 2015/06/01;45(6):1109-17. doi: <https://doi.org/10.1111/cea.12548>.
5
6 453 31. Baker A, Bray I. Bayesian projections: what are the effects of excluding data from younger
7 454 age groups?. *American Journal of Epidemiology*. 2005 Oct 15;162(8):798-805.
8
9 455 32. Rosenberg PS, Anderson WF. Age-Period-Cohort Models in Cancer Surveillance Research:
10 456 Ready for Prime Time? APC Models. *Cancer Epidemiology, Biomarkers & Prevention*. 2011
11 457 Jul 1;20(7):1263-8.
12
13 458 33. Holford T. Analyzing the effects of age, period and cohort on incidence and mortality rates.
14 459 *Stat Meth Med Res*. 1992;1:317-37.
15
16 460 34. Brookmeyer R, Stroup DF, editors. *Monitoring the health of populations: statistical*
17 461 *principles and methods for public health surveillance*. Oxford University Press; 2004.
18 462 35. Yang Y, Land KC. *Age-period-cohort analysis: New models, methods, and empirical*
19 463 *applications*. Taylor & Francis; 2013.
20 464 36. Robertson C, Gandini S, Boyle P. Age-period-cohort models: a comparative study of
21 465 available methodologies. *Journal of clinical epidemiology*. 1999 Jun 1;52(6):569-83.
22
23 466 37. Riebler A, Held L. Projecting the future burden of cancer: Bayesian age-period-cohort
24 467 analysis with integrated nested Laplace approximations. *Biometrical Journal*. 2017
25 468 May;59(3):531-49.
26
27 469 38. Knoll M, Furkel J, Debus J, Abdollahi A, Karch A, Stock C. An R package for an integrated
28 470 evaluation of statistical approaches to cancer incidence projection. *BMC medical research*
29 471 *methodology*. 2020 Dec;20(1):1-1.
30
31 472 39. Ahmad OB, Boschi-Pinto C, Lopez AD, Murray CJ, Lozano R, Inoue M. Age
32 473 standardization of rates: a new WHO standard. Geneva: World Health Organization. 2001
33 474 Jan;9(10):1-4.
34
35 475 40. Sung H, Ferlay J, Siegel RL, Laversanne M, Soerjomataram I, Jemal A, Bray F. Global
36 476 cancer statistics 2020: GLOBOCAN estimates of incidence and mortality worldwide for 36
37 477 cancers in 185 countries. *CA: a cancer journal for clinicians*. 2021 May;71(3):209-49.
38
39 478 41. Mousavi SM, Fallah M, Sundquist K, Hemminki K. Age-and time-dependent changes in
40 479 cancer incidence among immigrants to Sweden: colorectal, lung, breast and prostate cancers.
41 480 *International journal of cancer*. 2012 Jul 15;131(2):E122-8.
42
43 481 42. National Cancer Institute. SEER stat fact sheets: liver and intrahepatic bile duct cancer.
44 482 43. Wu X, Chung VC, Hui EP, Ziea ET, Ng BF, Ho RS, Tsoi KK, Wong S, Wu JC.
45 483 Effectiveness of acupuncture and related therapies for palliative care of cancer: overview of
46 484 systematic reviews. *Scientific reports*. 2015 Nov 26;5(1):1-5.
47
48 485 44. Sung H, Rosenberg PS, Chen WQ, Hartman M, Lim WY, Chia KS, Wai-Kong Mang O,
49 486 Tse L, Anderson WF, Yang XR. The impact of breast cancer-specific birth cohort effects among
50 487 younger and older Chinese populations. *International journal of cancer*. 2016 Aug
51 488 1;139(3):527-34.
52
53 489 45. *The world economy volume 1: a millennial perspective, 2, Historical statistics*: Academic
54 490 *Foundation, Gurgaon, India (2007)*
55
56 491 46. Elias SG, Peeters PH, Grobbee DE, van Noord PA. The 1944-1945 Dutch famine and
57 492 subsequent overall cancer incidence. *Cancer Epidemiology Biomarkers & Prevention*. 2005
58 493 Aug;14(8):1981-5.
59
60 494 47. Chiu YL, Wang XR, Qiu H, Yu IT. Risk factors for lung cancer: a case-control study in

- 1
2
3 495 Hong Kong women. *Cancer Causes & Control*. 2010 May;21(5):777-85.
4 496 48. Li J, Lam AS, Yau ST, Yiu KK, Tsoi KK. Antihypertensive treatments and risks of lung
5 497 Cancer: A large population-based cohort study in Hong Kong. *BMC cancer*. 2021 Dec;21(1):1-
6 498 9.
7
8 499 49. Du J, Sun H, Sun Y, Du J, Cao W, Sun S. Assessment of age, period, and cohort effects of
9 500 lung cancer incidence in Hong Kong and projection up to 2030 based on changing
10 501 demographics. *American Journal of Cancer Research*. 2021;11(12):5902.
11 502 50. *Centre for Health Protection, Department of Health - Lung Cancer*. Centre for Health
12 503 Protection. Retrieved August 10, 2022, from
13 504 <https://www.chp.gov.hk/en/healthtopics/content/25/49.html>

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Figure 1. Parameter estimates of age (a), cohort (b) and period (c) effects based on an age-period-cohort model of male lung cancer mortality rates by immigrant groups: locals, immigrants stay in Hong Kong for more than 10 years and immigrants stay in Hong Kong for less than or equal to 10 years. Age effect was assessed by mortality (left axis). Cohort and period effects were assessed by relative risk (right axis), 95% confidence intervals are shown as shaded bands.

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Figure 2. Parameter estimates of age (a), cohort (b) and period (c) effects based on an age-period-cohort model of female lung cancer mortality rates by immigrant groups: locals, immigrants stay in Hong Kong for more than 10 years and immigrants stay in Hong Kong for less than or equal to 10 years. Age effect was assessed by mortality (left axis). Cohort and period effects were assessed by relative risk (right axis), 95% confidence intervals are shown as shaded bands.

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2 519
3 520 **Figure 3.** Projections of lung cancer mortality rates by gender and immigrant status from 2022 to 2030. Observations
4 521 are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of
5 522 red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical
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Figure 4. Projections of lung cancer mortality rates for the population younger than 60 by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.

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Figure 5. Projections of lung cancer mortality rates for the population older than or equal to 60 by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.

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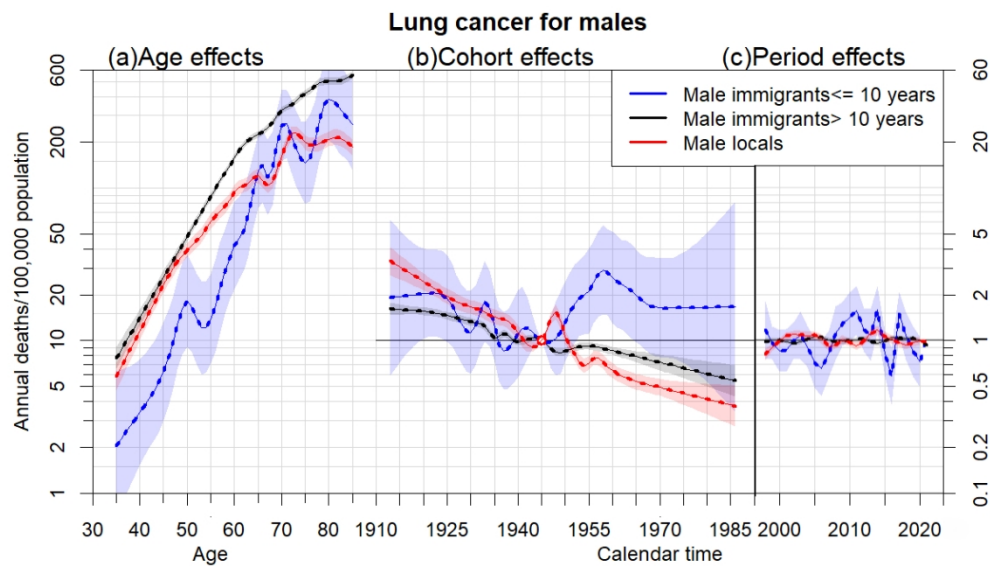


Figure 1. Parameter estimates of age (a), cohort (b) and period (c) effects based on an age-period-cohort model of male lung cancer mortality rates by immigrant groups: locals, immigrants stay in Hong Kong for more than 10 years and immigrants stay in Hong Kong for less than or equal to 10 years. Age effect was assessed by mortality (left axis). Cohort and period effects were assessed by relative risk (right axis), 95% confidence intervals are shown as shaded bands.

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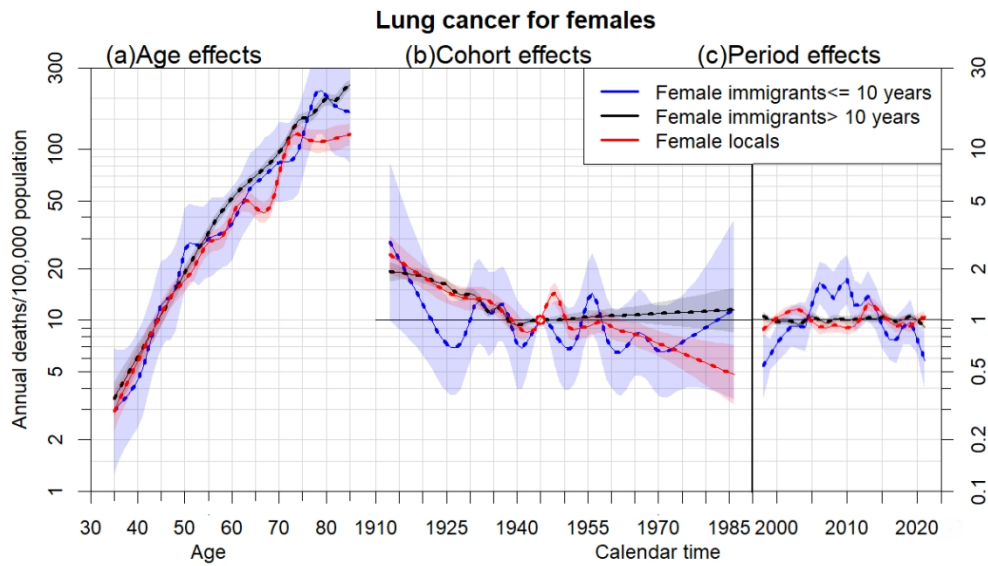


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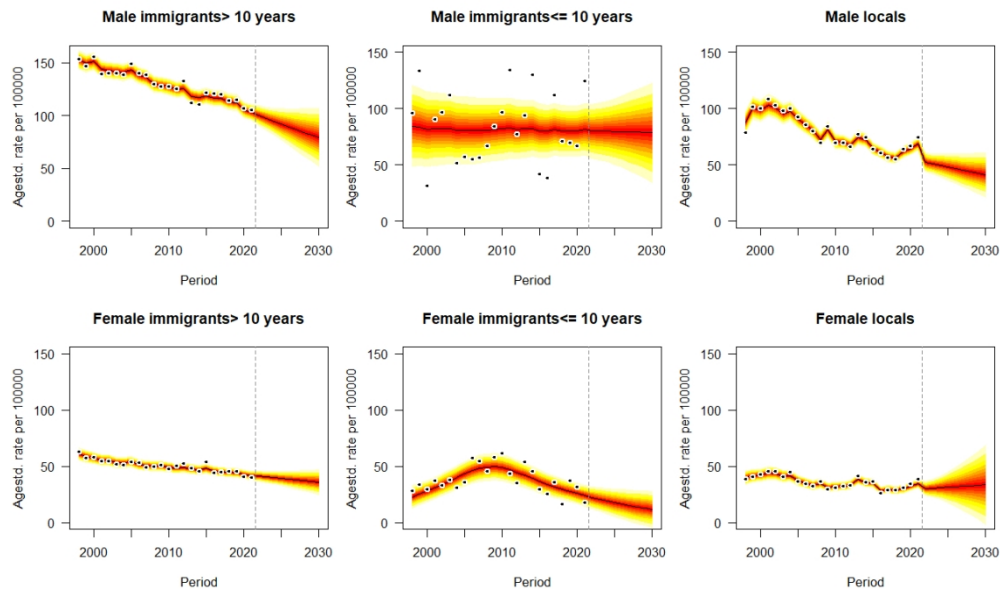


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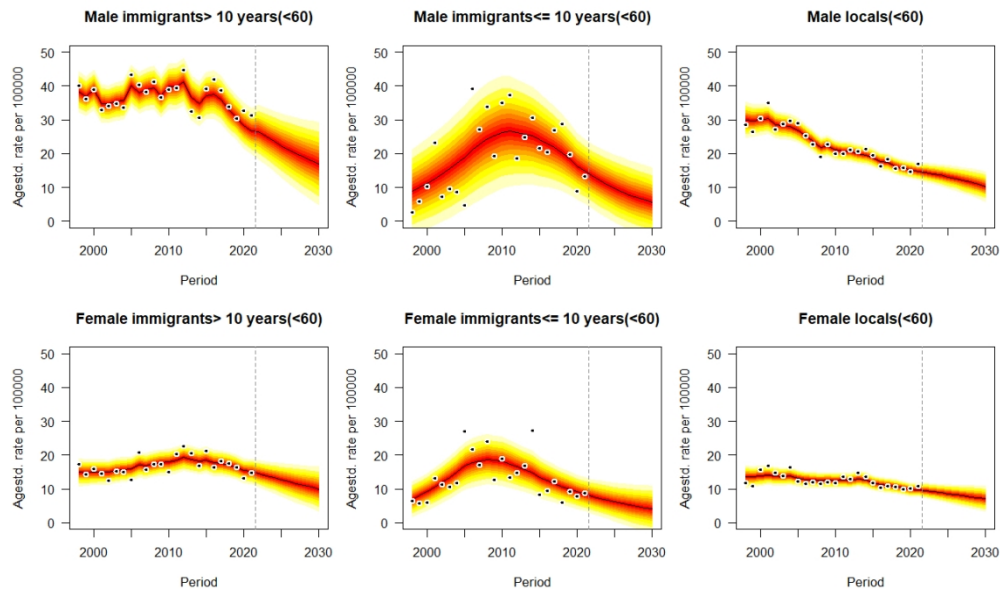


Figure 4. Projections of lung cancer mortality rates for the population younger than 60 by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.

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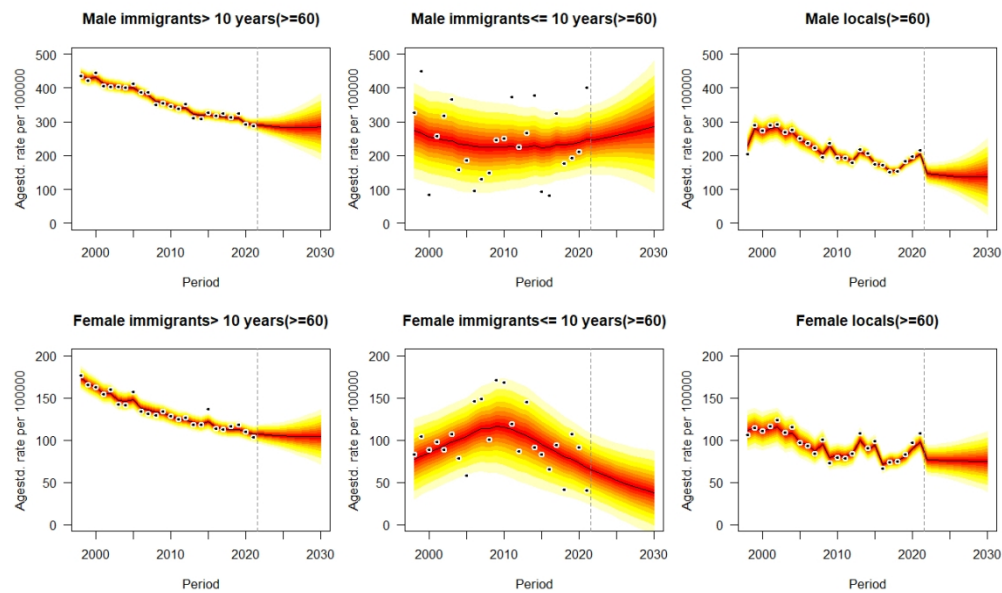


Figure 5. Projections of lung cancer mortality rates for the population older than or equal to 60 by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.

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Supplementary Material for

“An age-period-cohort analysis and projection of cancer mortality in

Hong Kong, 1998–2030”

APC Figures

eFigure 1(a) Colon cancer	3
eFigure 1(b) Liver cancer	4
eFigure 1(c) Pancreatic cancer	5
eFigure 1(d) Stomach cancer	6
eFigure 1(e) Prostate cancer	7

Projection Figures

Colon cancer	
eFigure 2(a)Projection (all ages)	8
eFigure 2(b)Projection (<60 years)	9
eFigure 2(c)Projection (\geq 60 years)	10
Liver cancer	
eFigure 3(a)Projection (all ages)	11
eFigure 3(b)Projection (<60 years)	12
eFigure 3(c)Projection (\geq 60 years)	13
Pancreatic cancer	
eFigure 4(a)Projection (all ages)	14
eFigure 4(b)Projection (<60 years)	15
eFigure 4(c)Projection (\geq 60 years)	16
Stomach cancer	
eFigure 5(a)Projection (all ages)	17
eFigure 5(b)Projection (<60 years)	18

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eFigure 5(c)Projection (≥ 60 years)..... 19

Prostate cancer

eFigure 6 Projection (all ages, <60 years and ≥ 60 years)..... 20

Tables

eTable 1 Lung cancer..... 21

eTable 2 Colon cancer..... 22

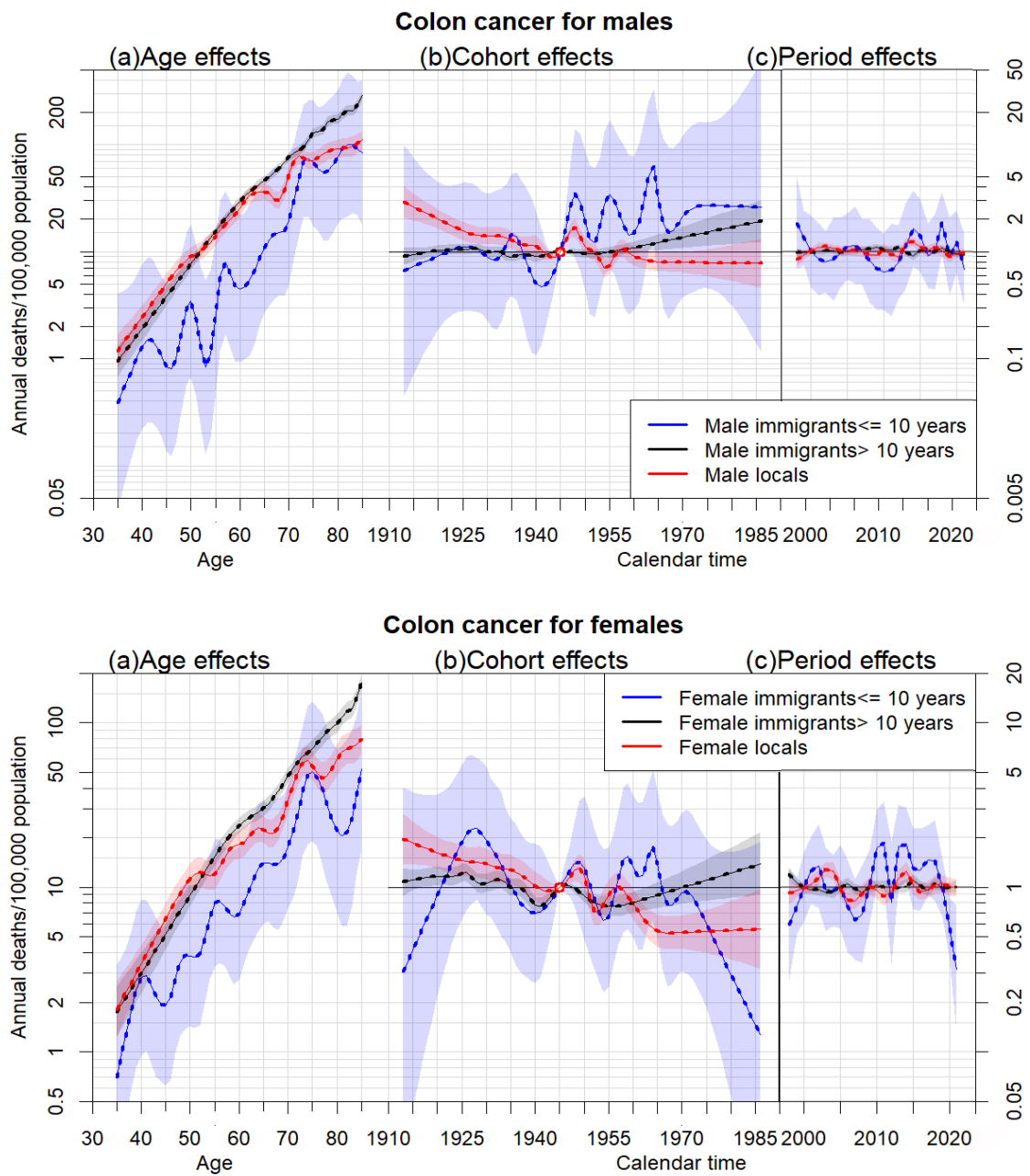
eTable 3 Liver cancer 23

eTable 4 Pancreatic cancer 24

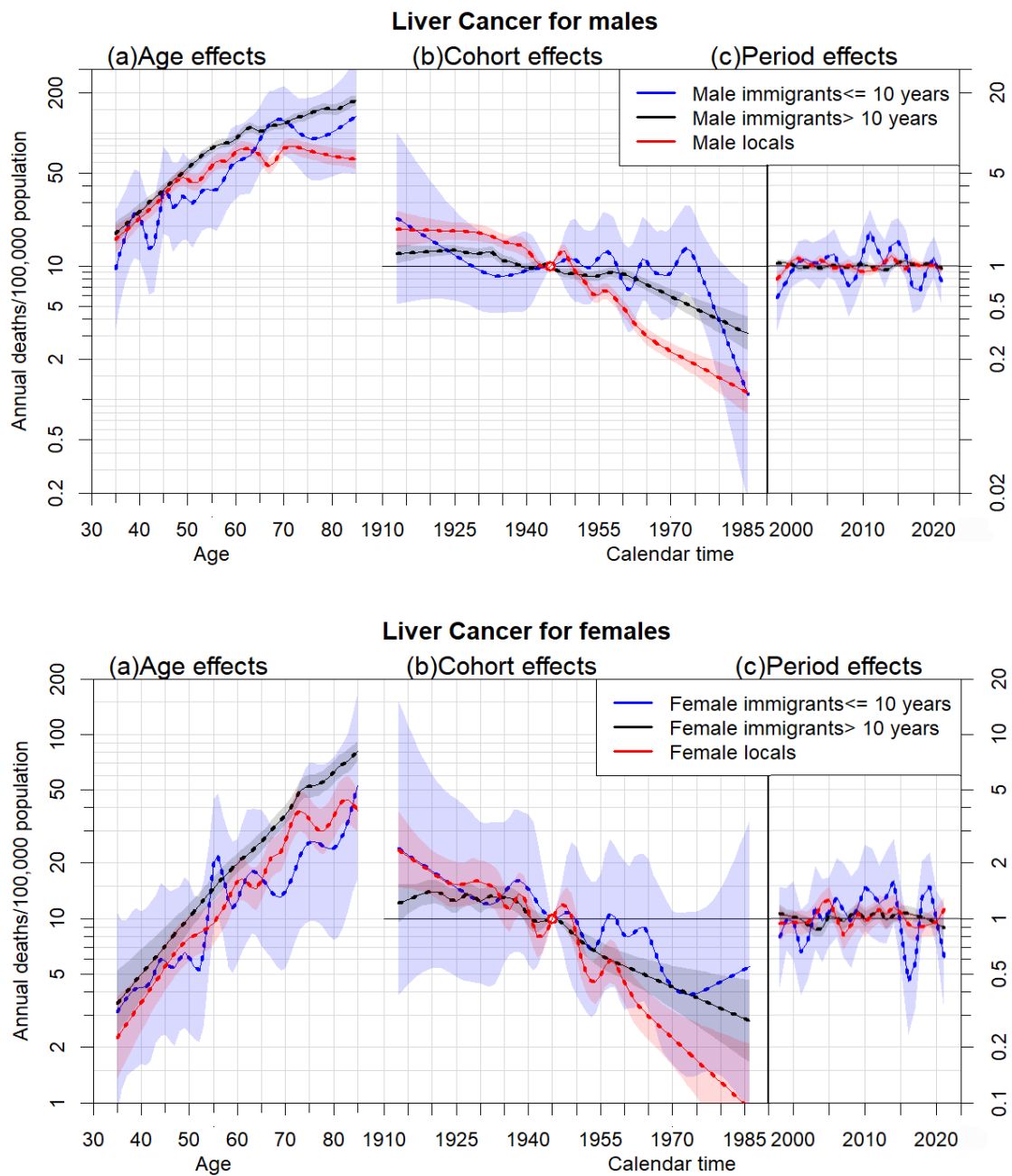
eTable 5 Stomach cancer 25

eTable 6 Prostate cancer 26

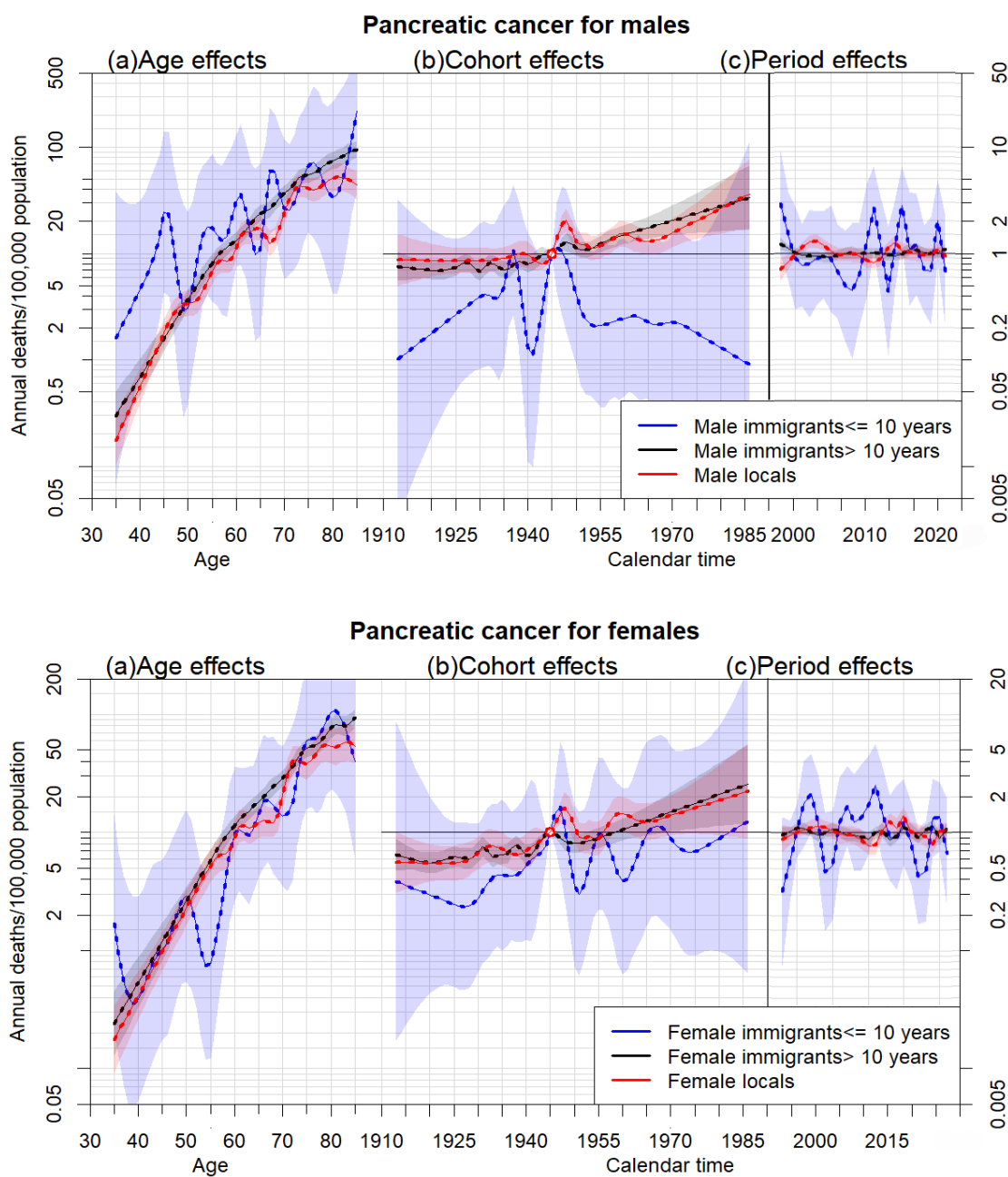
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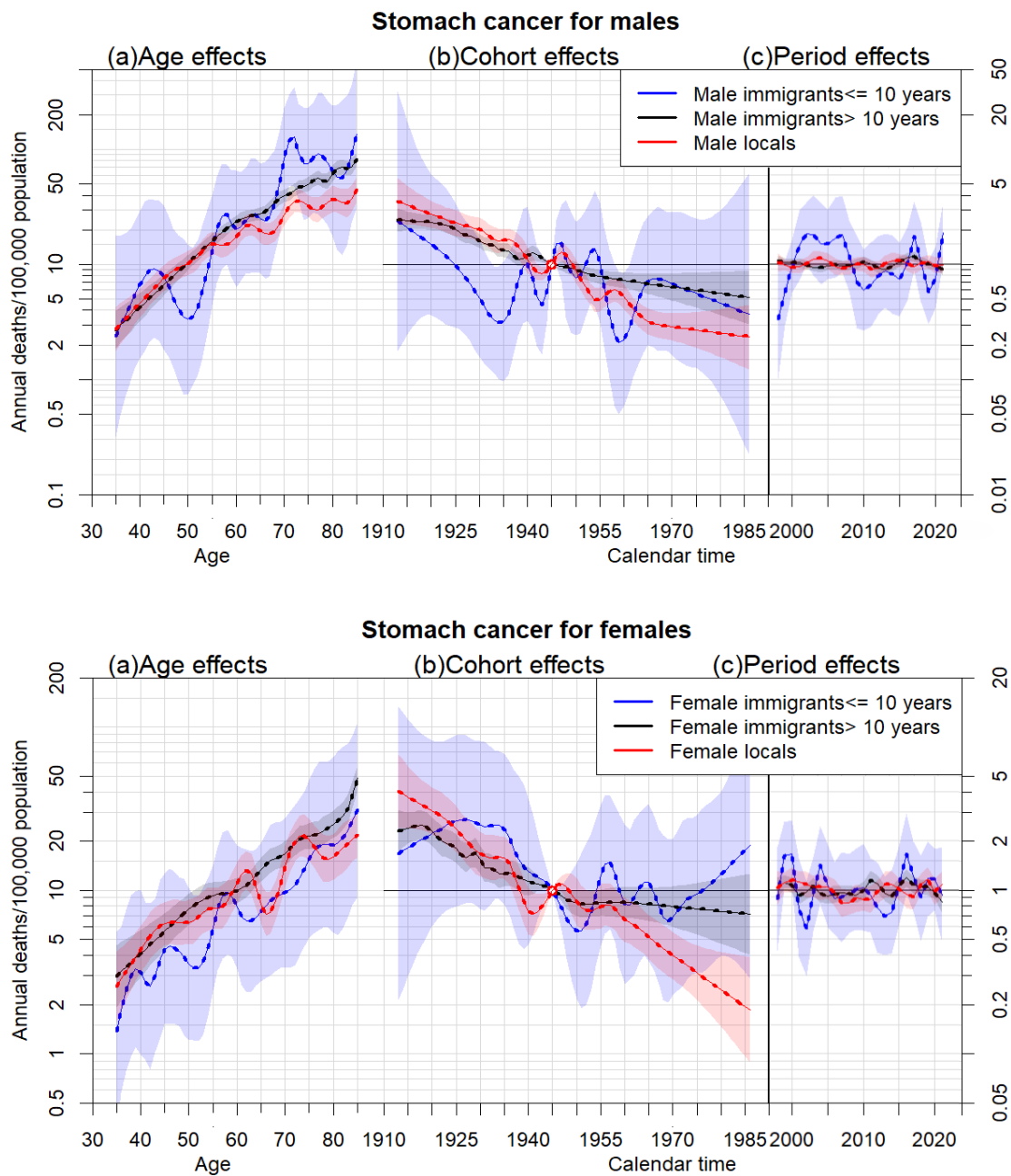
eFigure 1(a). Parameter estimates of age (a), cohort (b) and period (c) effects based on an age-period-cohort model of male and female colon cancer mortality rates by immigrant groups: locals, immigrants stay in Hong Kong for more than 10 years and immigrants stay in Hong Kong for less than or equal to 10 years. Age effect was assessed by mortality (left axis). Cohort and period effects were assessed by relative risk (right axis), 95% confidence intervals are shown as shaded bands.



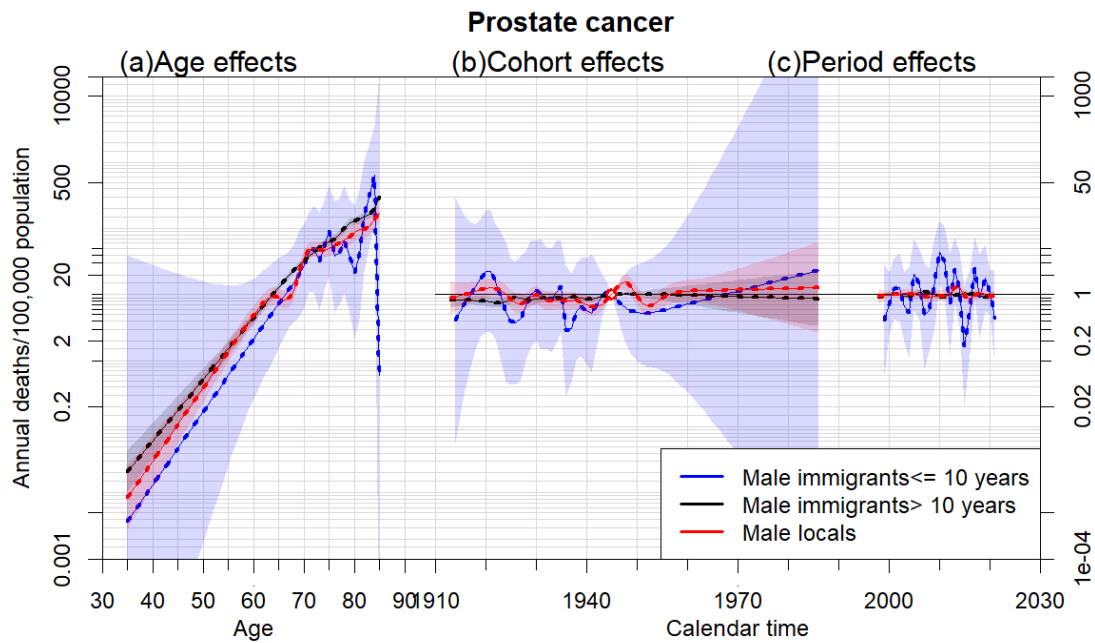
eFigure 1(b). Parameter estimates of age (a), cohort (b) and period (c) effects based on an age-period-cohort model of male and female liver cancer mortality rates by immigrant groups: locals, immigrants stay in Hong Kong for more than 10 years and immigrants stay in Hong Kong for less than or equal to 10 years. Age effect was assessed by mortality (left axis). Cohort and period effects were assessed by relative risk (right axis), 95% confidence intervals are shown as shaded bands.



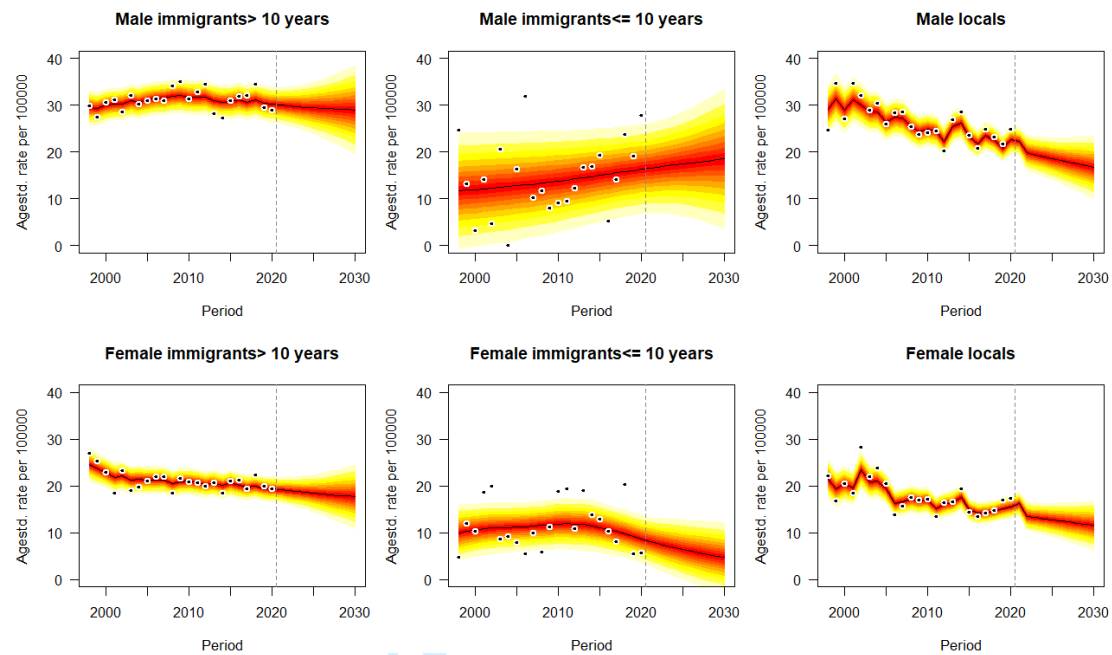
eFigure 1(c). Parameter estimates of age (a), cohort (b) and period (c) effects based on an age-period-cohort model of male and female pancreatic cancer mortality rates by immigrant groups: locals, immigrants stay in Hong Kong for more than 10 years and immigrants stay in Hong Kong for less than or equal to 10 years. Age effect was assessed by mortality (left axis). Cohort and period effects were assessed by relative risk (right axis), 95% confidence intervals are shown as shaded bands.



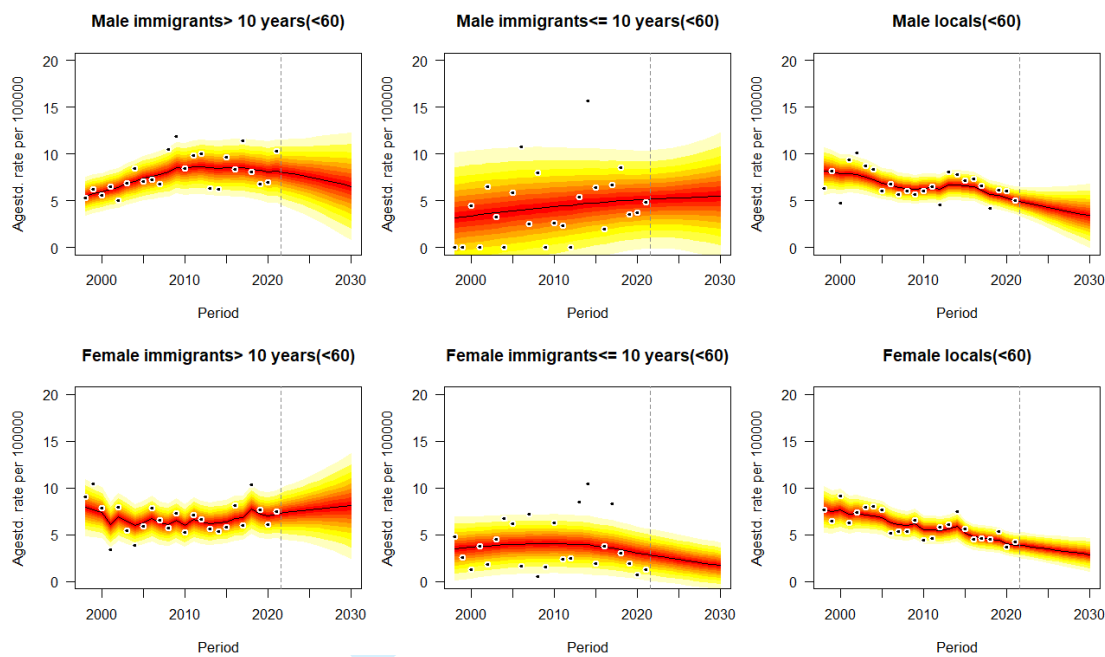
eFigure 1(d). Parameter estimates of age (a), cohort (b) and period (c) effects based on an age-period-cohort model of male and female stomach cancer mortality rates by immigrant groups: locals, immigrants stay in Hong Kong for more than 10 years and immigrants stay in Hong Kong for less than or equal to 10 years. Age effect was assessed by mortality (left axis). Cohort and period effects were assessed by relative risk (right axis), 95% confidence intervals are shown as shaded bands.



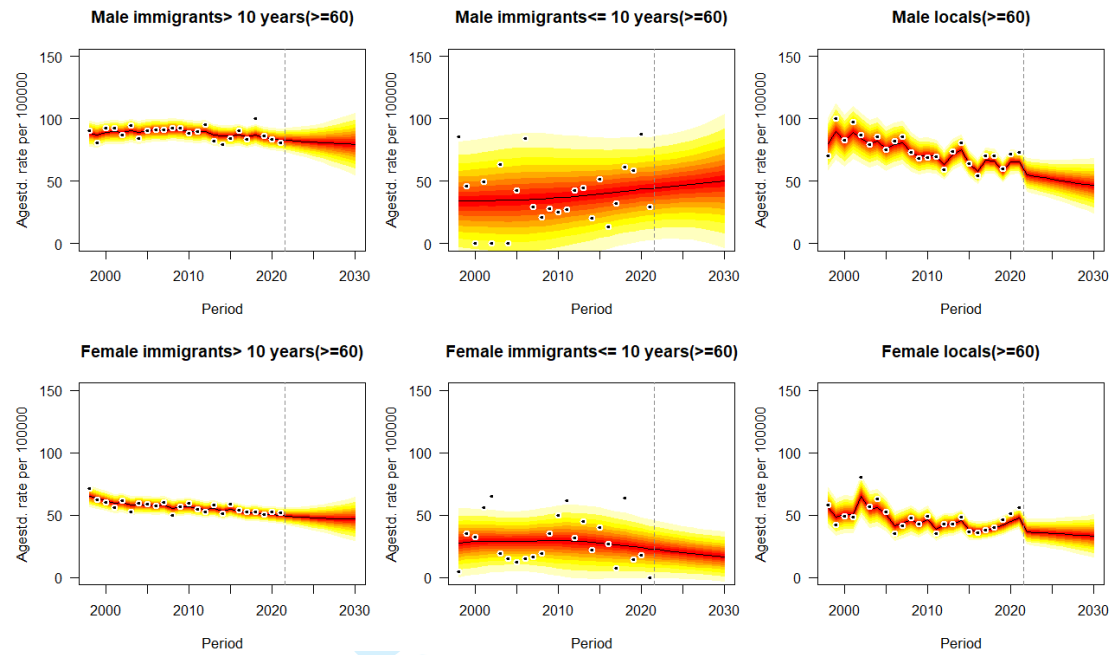
eFigure 1(e). Parameter estimates of age (a), cohort (b) and period (c) effects based on an age-period-cohort model of male prostate cancer mortality rates by immigrant groups: locals, immigrants stay in Hong Kong for more than 10 years and immigrants stay in Hong Kong for less than or equal to 10 years. Age effect was assessed by mortality (left axis). Cohort and period effects were assessed by relative risk (right axis), 95% confidence intervals are shown as shaded bands.



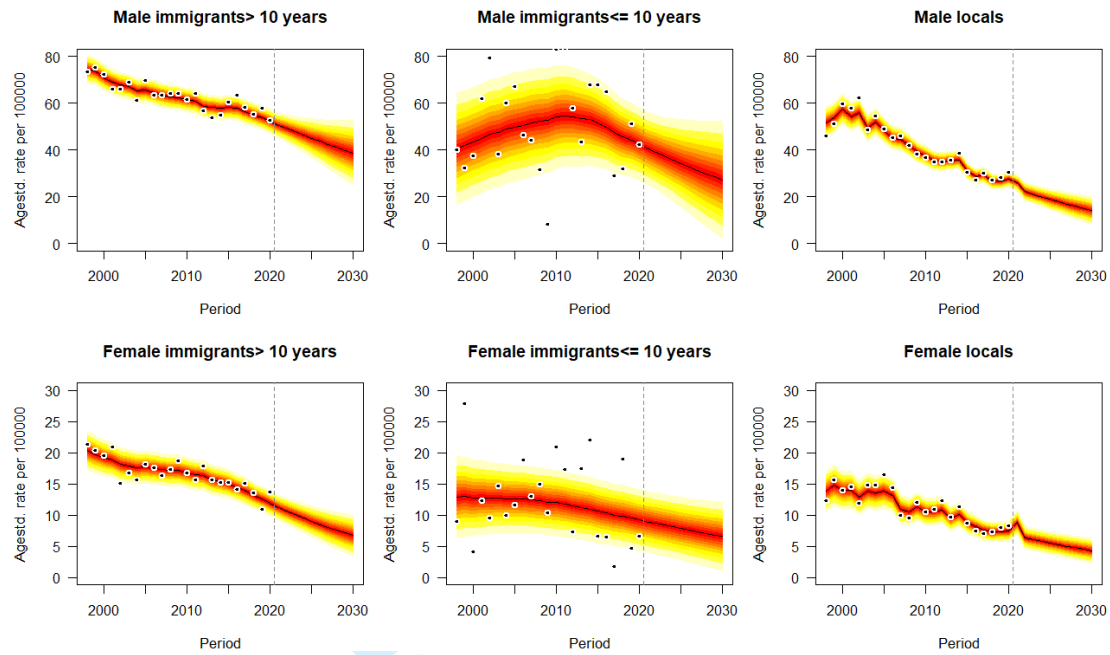
eFigure 2(a). Projections of colon cancer mortality rates by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



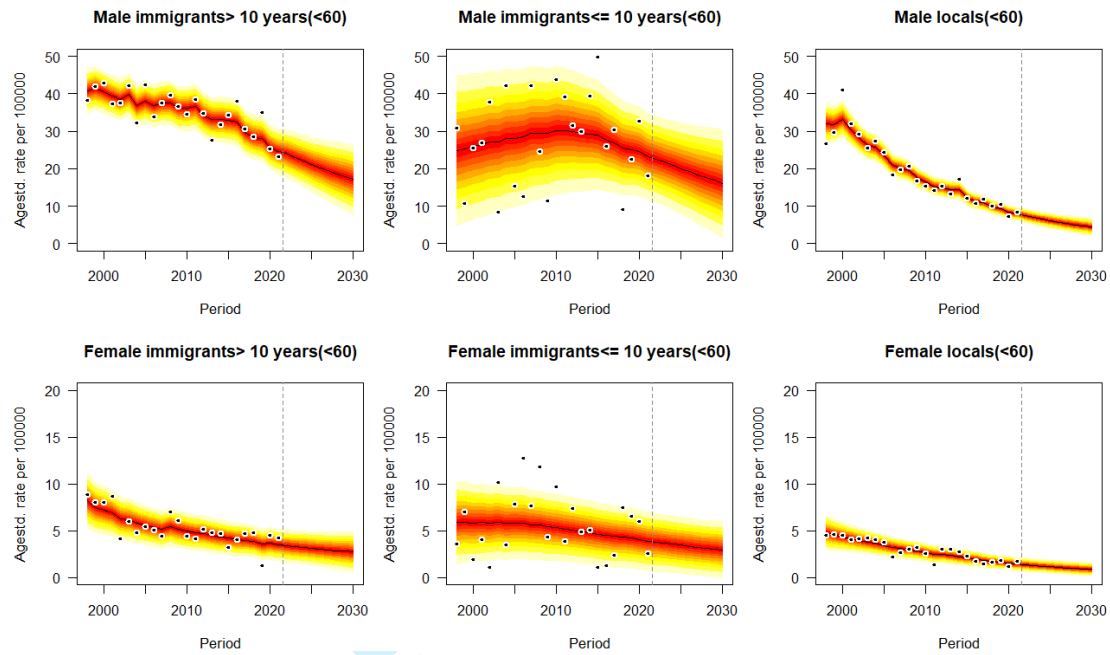
eFigure 2(b). Projections of colon cancer mortality rates for the population younger than 60 by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



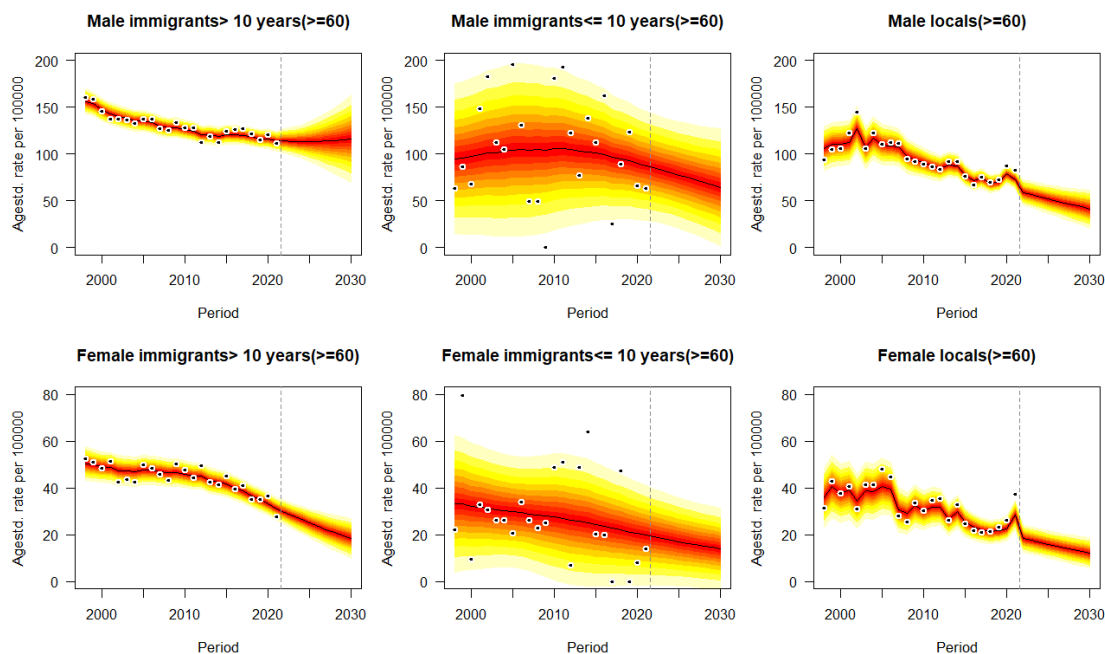
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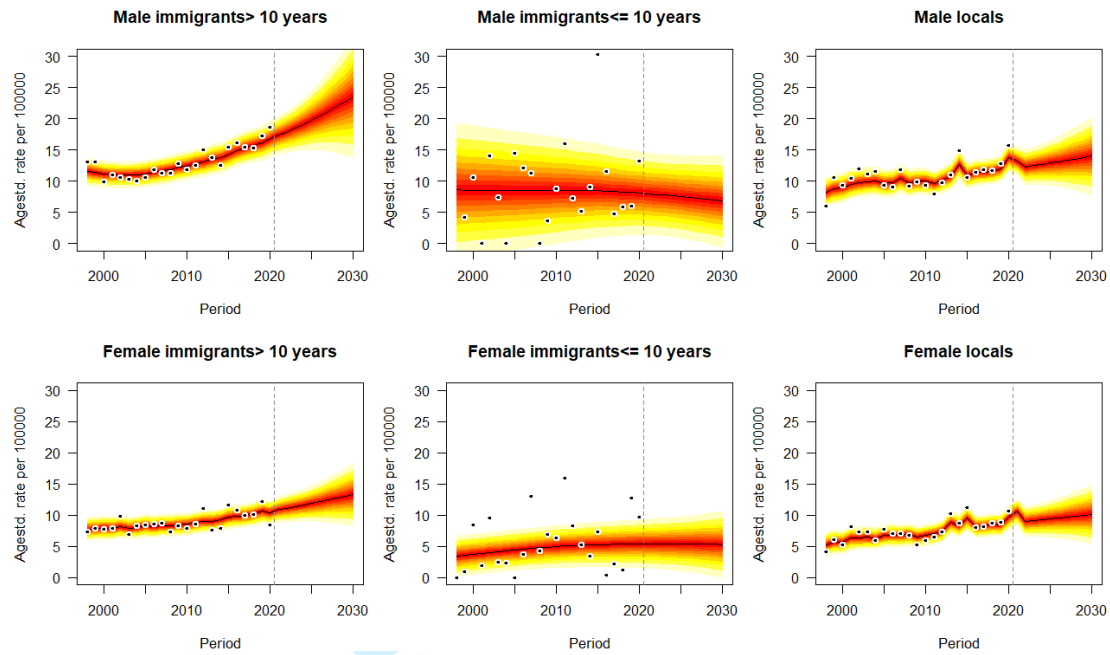
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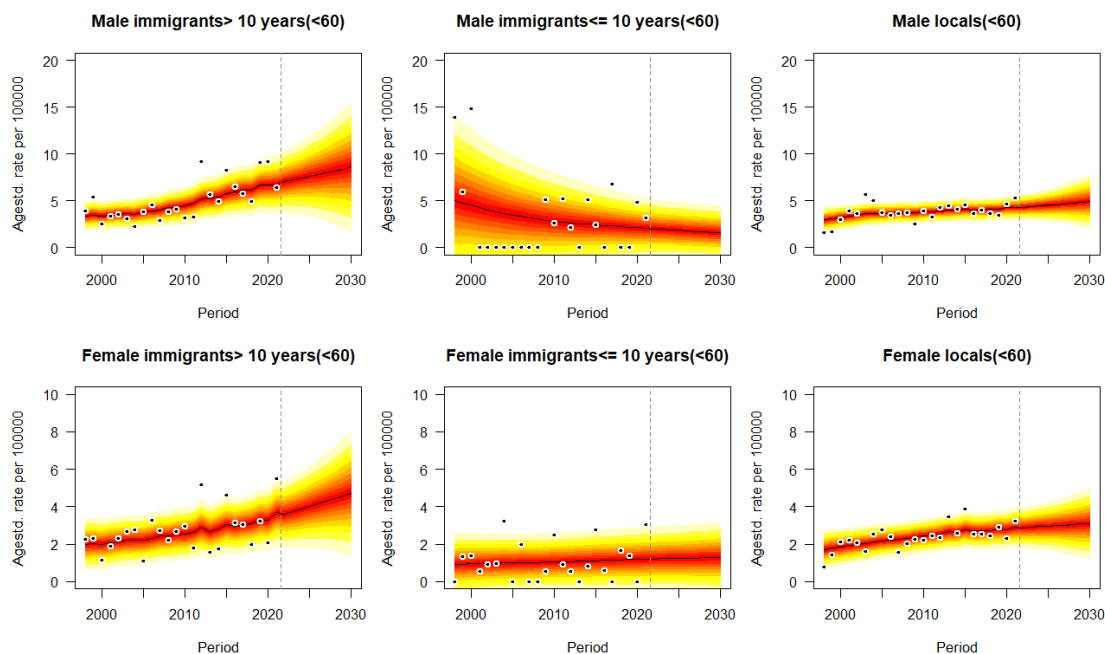
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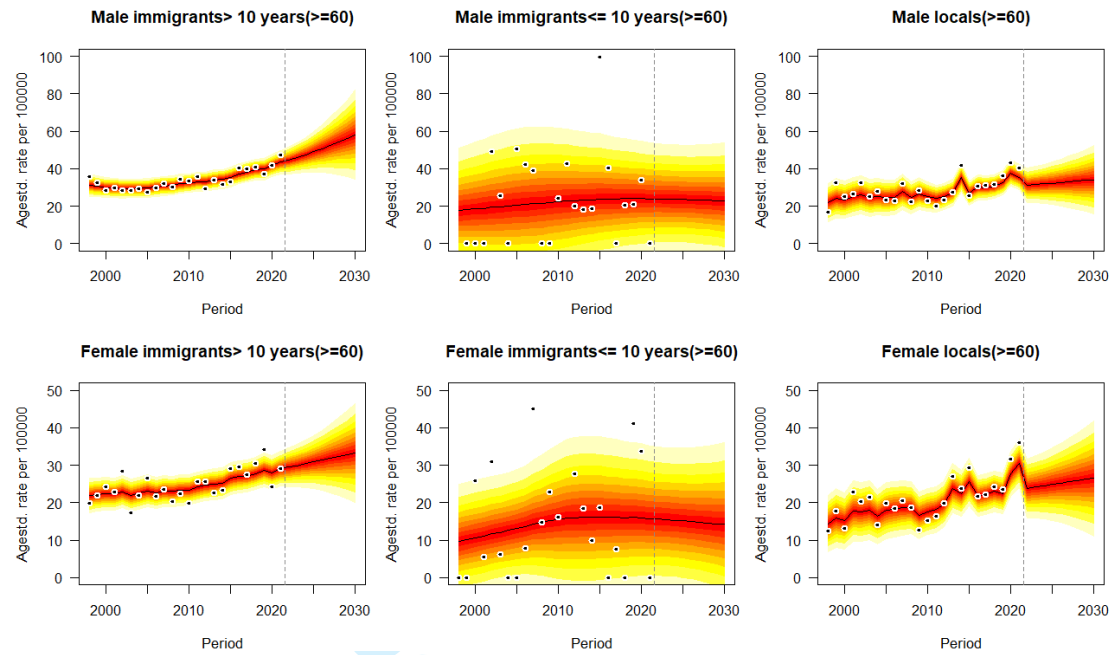
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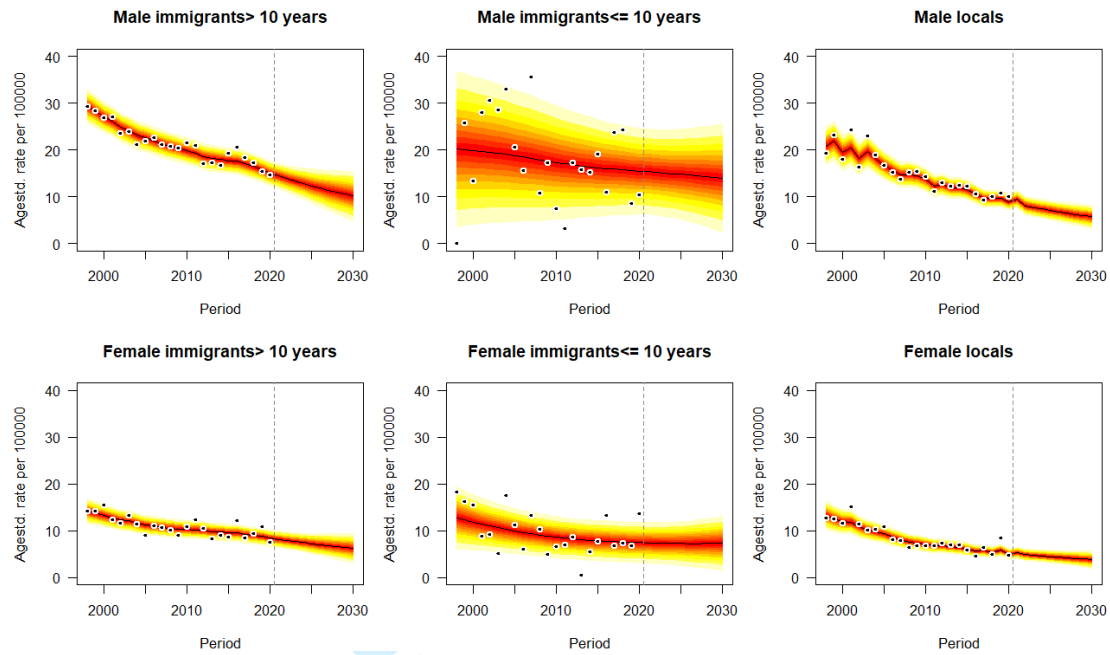
eFigure 4(a). Projections of pancreatic cancer mortality rates by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



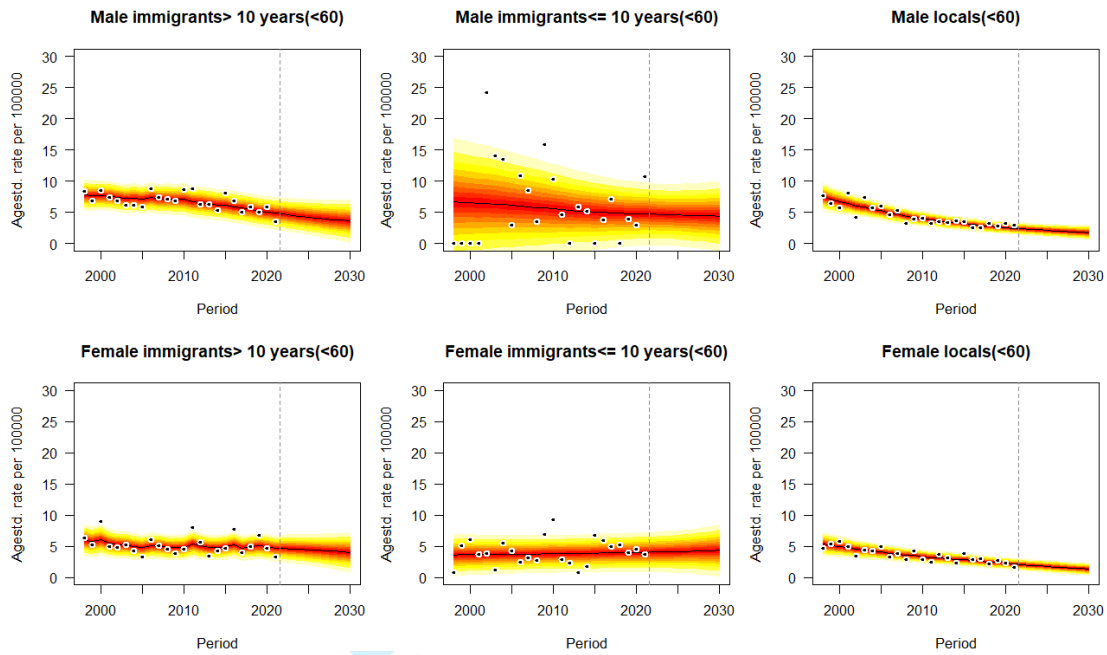
eFigure 4(b). Projections of pancreatic cancer mortality rates for the population younger than 60 by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



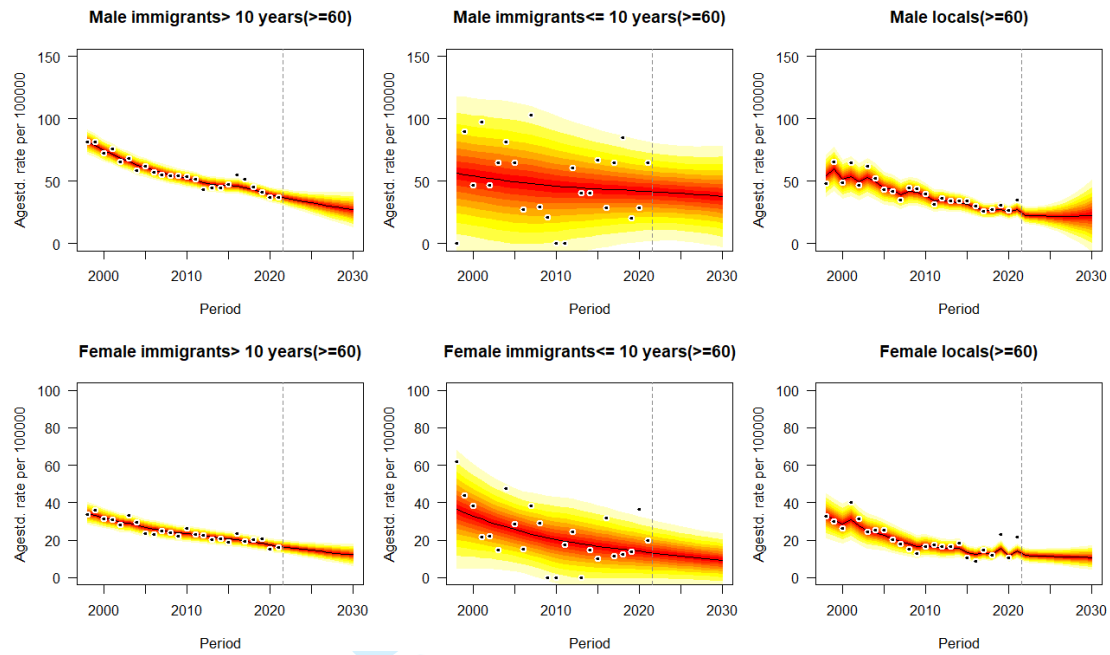
eFigure 4(c). Projections of pancreatic cancer mortality rates for the population older than or equal to 60 by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



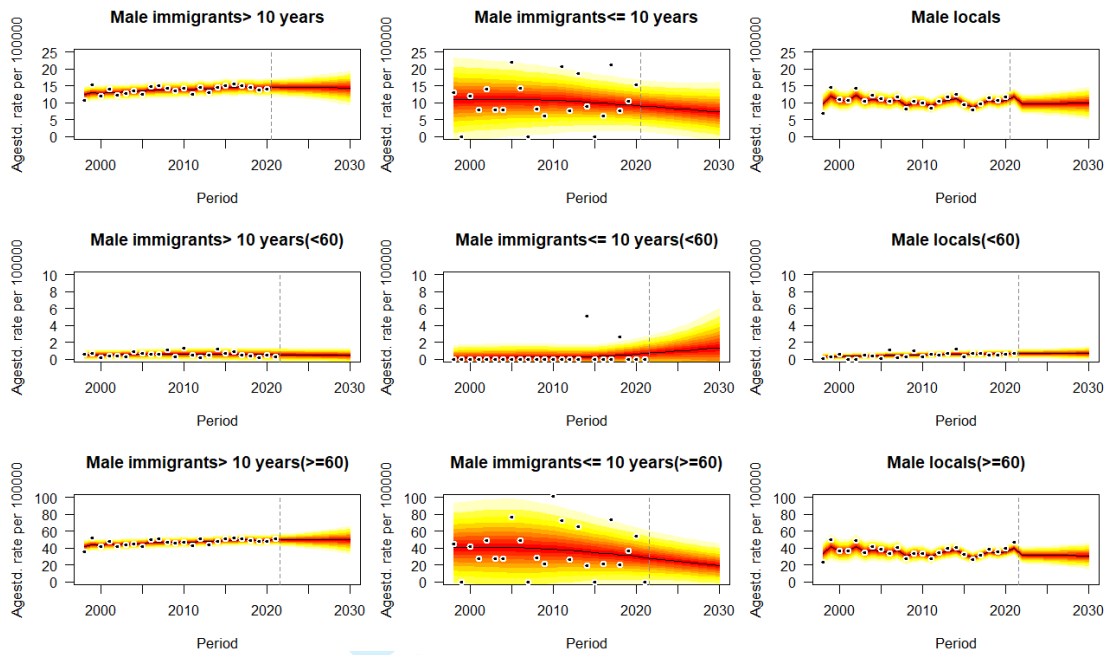
eFigure 5(a). Projections of stomach cancer mortality rates by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



eFigure 5(b). Projections of stomach cancer mortality rates for the population younger than 60 by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



eFigure 5(c). Projections of stomach cancer mortality rates for the population older than or equal to 60 by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



eFigure 6. Projections of prostate cancer mortality rates for males by immigrant status and age groups (less than, greater than or equal to 60 years old) from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.

Predictive mean of age-standardized mortality rates of lung cancer per 100,000 population										
Year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Female immigrants >10	41.80 (1.27)	41.34 (1.86)	40.58 (2.27)	39.87 (2.75)	39.19 (3.28)	38.53 (3.86)	37.89 (4.46)	37.26 (5.09)	36.65 (5.74)	36.04 (6.4)
Female immigrants ≤ 10	23.92 (4.00)	22.22 (4.67)	20.56 (5.38)	19.01 (6.10)	17.57 (6.80)	16.24 (7.45)	15.00 (8.04)	13.85 (8.56)	12.79 (9.01)	11.81 (9.39)
Female locals	34.67 (1.76)	30.22 (3.54)	30.63 (4.77)	31.05 (6.38)	31.48 (8.29)	31.9 (10.47)	32.32 (12.87)	32.73 (15.48)	33.15 (18.31)	33.55 (21.33)
Male immigrants >10	102.90 (2.43)	100.18 (4.18)	97.18 (5.33)	94.34 (6.72)	91.71 (8.24)	89.15 (9.84)	86.66 (11.47)	84.19 (13.11)	81.81 (14.74)	79.55 (16.37)
Male immigrants ≤10	81.26 (9.21)	79.90 (10.41)	79.81 (11.82)	79.72 (13.42)	79.62 (15.19)	79.50 (17.09)	79.32 (19.09)	79.08 (21.18)	78.78 (23.32)	78.41 (25.53)
Male locals	60.96 (2.82)	52.27 (4.86)	50.83 (5.39)	49.56 (6.13)	48.18 (6.97)	46.64 (7.84)	45.13 (8.76)	43.83 (9.76)	42.67 (10.8)	41.43 (11.8)
Female immigrants>10(<60y)	15.51 (1.12)	14.51 (1.50)	13.90 (1.76)	13.29 (2.04)	12.71 (2.33)	12.13 (2.62)	11.57 (2.91)	11.02 (3.18)	10.49 (3.43)	9.98 (3.68)
Female immigrants ≤ 10(<60y)	8.14 (1.91)	7.79 (1.95)	7.18(2.23)	6.62(2.53)	6.10(2.81)	5.63(3.08)	5.19(3.32)	4.79 (3.53)	4.42 (3.72)	4.09 (3.88)
Female locals(<60y)	10.25 (0.77)	9.48 (0.89)	9.17(1.02)	8.87(1.16)	8.57(1.32)	8.27(1.49)	7.97(1.65)	7.68 (1.82)	7.38 (1.98)	7.09 (2.13)
Male immigrants>10(<60y)	27.81 (2.10)	26.36 (3.58)	24.96 (3.94)	23.64 (4.35)	22.38 (4.79)	21.17 (5.23)	20.03 (5.67)	18.96 (6.10)	17.96 (6.51)	17.03 (6.90)
Male immigrants ≤ 10(<60y)	15.01 (2.98)	13.38 (3.71)	12.02 (4.17)	10.79 (4.59)	9.68 (4.95)	8.69 (5.24)	7.79 (5.46)	6.98 (5.61)	6.25 (5.69)	5.59 (5.72)
Male locals(<60y)	15.19 (0.78)	14.45 (1.15)	14.03 (1.29)	13.61 (1.46)	13.14 (1.64)	12.65 (1.82)	12.13 (2.01)	11.55 (2.17)	10.93 (2.31)	10.26 (2.43)
Female immigrants >10(≥ 60y)	108.85 (4.80)	107.21 (5.17)	106.26 (6.24)	105.52 (7.54)	104.94 (9.04)	104.51 (10.72)	104.21 (12.57)	104.07 (14.61)	104.06 (16.78)	104.16 (19.14)
Female immigrants ≤ 10(≥60y)	66.16 (13.25)	63.84 (15.72)	59.88 (17.50)	56.14 (19.31)	52.60 (21.03)	49.27 (22.66)	46.14 (24.16)	43.20 (25.52)	40.44 (26.74)	37.85 (27.81)
Female locals(≥60y)	77.33 (9.40)	76.53 (10.11)	76.22 (10.85)	75.94 (11.79)	75.69 (12.94)	75.49 (14.28)	75.32 (15.80)	75.19 (17.48)	75.10 (19.33)	75.03 (21.32)
Male immigrants>10(≥60y)	293.56 (9.13)	289.8 (11.7)	286.6 (15.19)	284.28 (19.51)	282.78 (24.49)	281.99 (30.07)	281.88 (36.31)	282.31 (43.15)	283.37 (50.66)	285.03 (58.86)
Male immigrants ≤ 10(≥60y)	244.88 (30.29)	247.01 (36.85)	251.24 (42.94)	255.62 (50.06)	260.14 (58.14)	264.82 (67.14)	269.61 (77.01)	274.52 (87.75)	279.55 (99.34)	284.69 (111.81)
Male locals(≥60y)	150.75 (16.22)	146.29 (18.46)	143.54 (20.58)	141.84 (23.97)	140.07 (28.24)	138.14 (33.39)	136.65 (39.82)	136.49 (47.87)	137.24 (57.47)	138.26 (68.52)

eTable 1. Predictive means and standard deviations (in brackets) of age-standardized mortality rates of lung cancer per 100,000 population for each gender, age group (less than, greater or equal to 60 years old) and immigrant status from 2022 to 2030. Reported means and standard deviations (in brackets) of age-standardized mortality rates in 2021 are also listed.

Predictive mean of age-standardized mortality rates of colon cancer per 100,000 population										
Year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Female immigrants >10	20.03 (0.95)	18.95 (1.13)	18.77 (1.37)	18.59 (1.66)	18.42 (1.98)	18.27 (2.33)	18.12 (2.71)	17.98 (3.11)	17.85 (3.53)	17.73 (3.96)
Female immigrants ≤ 10	8.11 (2.19)	7.70 (2.51)	7.25 (2.81)	6.82 (3.11)	6.42 (3.37)	6.03 (3.61)	5.67 (3.83)	5.33 (4.01)	5.01 (4.17)	4.71 (4.31)
Female locals	13.77 (1.30)	13.47 (1.61)	13.24 (1.72)	13.01 (1.87)	12.77 (2.04)	12.53 (2.24)	12.29 (2.46)	12.06 (2.68)	11.82 (2.92)	11.59 (3.16)
Male immigrants >10	31.22 (1.28)	29.82 (1.46)	29.66 (1.79)	29.52 (2.19)	29.41 (2.63)	29.30 (3.11)	29.21 (3.64)	29.14 (4.19)	29.06 (4.78)	28.98 (5.39)
Male immigrants ≤ 10	15.47 (2.14)	16.77 (3.77)	17.02 (4.18)	17.23 (4.64)	17.45 (5.14)	17.67 (5.69)	17.88 (6.27)	18.09 (6.91)	18.31 (7.56)	18.50 (8.26)
Male locals	21.28 (1.38)	19.81 (2.07)	19.39 (2.22)	18.97 (2.42)	18.57 (2.61)	18.18 (2.85)	17.81 (3.12)	17.43 (3.40)	17.06 (3.71)	16.71 (4.03)
Female immigrants >10(<60y)	7.09 (0.99)	7.36 (1.12)	7.46 (1.28)	7.56 (1.46)	7.65 (1.68)	7.74 (1.92)	7.83 (2.19)	7.92 (2.48)	8.01 (2.79)	8.09 (3.13)
Female immigrants ≤ 10(<60y)	3.11 (0.67)	2.82 (0.86)	2.65 (0.91)	2.51 (0.97)	2.36 (1.02)	2.22 (1.07)	2.08 (1.11)	1.95 (1.14)	1.83 (1.18)	1.72 (1.22)
Female locals(<60y)	4.10 (0.41)	3.87 (0.50)	3.73 (0.54)	3.61 (0.59)	3.47 (0.65)	3.34 (0.70)	3.22 (0.76)	3.11 (0.82)	2.99 (0.88)	2.88 (0.94)
Male immigrants >10(<60y)	8.29 (0.91)	7.98 (1.17)	7.85 (1.38)	7.71 (1.60)	7.54 (1.83)	7.36 (2.08)	7.17(2.32)	6.97(2.57)	6.76(2.81)	6.55(3.05)
Male immigrants ≤ 10(<60y)	5.03 (1.44)	5.18 (1.58)	5.22 (1.75)	5.26 (1.93)	5.30 (2.14)	5.34 (2.36)	5.38(2.59)	5.43(2.84)	5.47(3.11)	5.51(3.38)
Male locals(<60y)	5.14 (0.43)	4.88 (0.63)	4.66 (0.79)	4.46 (0.96)	4.26 (1.13)	4.08 (1.31)	3.91(1.48)	3.73(1.65)	3.57(1.82)	3.42(1.97)
Female immigrants >10(≥60y)	52.16 (2.59)	49.21 (2.99)	48.70 (3.56)	48.26 (4.26)	47.87 (5.05)	47.54 (5.94)	47.26 (6.90)	47.05 (7.94)	46.91 (9.06)	46.81 (10.26)
Female immigrants ≤ 10(≥60y)	24.01 (5.83)	22.44 (6.56)	21.69 (6.96)	20.95 (7.38)	20.23 (7.80)	19.52 (8.23)	18.84 (8.66)	18.17 (9.08)	17.51 (9.49)	16.86 (9.90)
Female locals(≥60y)	37.42 (5.31)	36.69 (5.74)	36.29 (6.06)	35.87 (6.46)	35.46 (6.95)	35.04 (7.5)	34.61 (8.12)	34.19 (8.79)	33.77 (9.51)	33.34 (10.27)
Male immigrants >10(≥60y)	84.17 (3.55)	82.72 (4.09)	82.16 (4.95)	81.64 (5.97)	81.19 (7.12)	80.81 (8.39)	80.47 (9.77)	80.15 (11.24)	79.85 (12.81)	79.56 (14.45)
Male immigrants ≤ 10(≥60y)	43.25 (11.07)	44.93 (13.09)	45.62 (14.52)	46.30 (16.09)	46.96 (17.80)	47.61 (19.64)	48.25 (21.62)	48.88 (23.73)	49.51 (25.97)	50.13 (28.34)
Male locals(≥60y)	55.79 (6.86)	54.89 (7.65)	53.75 (8.03)	52.63 (8.52)	51.54 (9.12)	50.47 (9.8)	49.43 (10.55)	48.42 (11.37)	47.42 (12.25)	46.44 (13.16)

eTable 2. Predictive means and standard deviations (in brackets) of age-standardized mortality rates of colon cancer per 100,000 population for each gender, age group (less than, greater or equal to 60 years old) and immigrant status from 2022 to 2030. Reported means and standard deviations (in brackets) of age-standardized mortality rates in 2021 are also listed.

Predictive mean of age-standardized mortality rates of liver cancer per 100,000 population										
Year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Female immigrants >10	11.34 (0.66)	10.68 (0.71)	10.09 (0.85)	9.54 (1.01)	9.01 (1.16)	8.50 (1.31)	8.02(1.45)	7.57(1.59)	7.14(1.72)	6.74(1.83)
Female immigrants ≤10	9.15 (1.55)	8.66 (1.82)	8.38 (1.95)	8.11 (2.08)	7.84 (2.22)	7.58 (2.36)	7.32(2.49)	7.07(2.63)	6.82(2.76)	6.58(2.88)
Female locals	6.72 (0.69)	6.36 (0.88)	6.08 (0.90)	5.81 (0.93)	5.53 (0.97)	5.26 (1.01)	5.01(1.06)	4.77(1.11)	4.53(1.15)	4.3(1.21)
Male immigrants >10	52.17 (1.78)	49.22 (2.36)	47.76 (2.93)	46.35 (3.59)	45.01 (4.31)	43.67 (5.05)	42.37 (5.81)	41.1(6.56)	39.89 (7.33)	38.71 (8.08)
Male immigrants ≤10	42.33 (5.87)	39.03 (6.49)	37.39 (7.47)	35.81 (8.51)	34.26 (9.58)	32.76 (10.63)	31.31 (11.65)	29.91 (12.62)	28.56 (13.54)	27.25 (14.40)
Male locals	24.22 (1.77)	22.16 (2.09)	21.02 (2.22)	19.91 (2.39)	18.85 (2.58)	17.83 (2.79)	16.85 (3.03)	15.92 (3.21)	15.03 (3.40)	14.18 (3.59)
Female immigrants >10(<60y)	3.62 (0.45)	3.39 (0.52)	3.29 (0.57)	3.20 (0.63)	3.12 (0.69)	3.04 (0.75)	2.96(0.82)	2.89(0.89)	2.82(0.96)	2.75(1.03)
Female immigrants ≤10(<60y)	4.10 (0.79)	3.81 (0.91)	3.69 (0.96)	3.57 (1.02)	3.46 (1.08)	3.36 (1.15)	3.25(1.22)	3.15(1.29)	3.06(1.36)	2.97(1.43)
Female locals(<60y)	1.50 (0.13)	1.37 (0.2)	1.29 (0.21)	1.22 (0.23)	1.16 (0.24)	1.10 (0.26)	1.04(0.27)	0.99(0.29)	0.94(0.30)	0.89(0.31)
Male immigrants >10(<60y)	26.32 (2.11)	24.04 (2.35)	23.02 (2.63)	22.05 (2.94)	21.13 (3.27)	20.25 (3.61)	19.41 (3.95)	18.62 (4.30)	17.86 (4.64)	17.14 (4.98)
Male immigrants ≤10(<60y)	25.52 (2.99)	22.56 (3.96)	21.71 (4.44)	20.87 (4.94)	20.04 (5.45)	19.22 (5.95)	18.42 (6.45)	17.63 (6.91)	16.86 (7.36)	16.11 (7.78)
Male locals(<60y)	8.25 (0.69)	7.47 (0.74)	6.97 (0.79)	6.52 (0.86)	6.11 (0.93)	5.73 (1.01)	5.38(1.08)	5.04(1.15)	4.73(1.21)	4.44(1.27)
Female immigrants >10(≥60y)	33.67 (1.88)	29.63 (2.01)	27.99 (2.36)	26.42 (2.75)	24.92 (3.14)	23.49 (3.52)	22.13 (3.88)	20.85 (4.23)	19.64 (4.55)	18.50 (4.85)
Female immigrants ≤10(≥60y)	21.72 (5.11)	19.08 (5.81)	18.38 (6.14)	17.71 (6.48)	17.03 (6.83)	16.39 (7.16)	15.76 (7.49)	15.16 (7.80)	14.57 (8.11)	14.01 (8.39)
Female locals(≥60y)	20.63 (3.03)	18.41 (3.23)	17.55 (3.26)	16.72 (3.32)	15.91 (3.40)	15.11 (3.49)	14.34 (3.59)	13.59 (3.69)	12.87 (3.81)	12.17 (3.93)
Male immigrants >10(≥60y)	115.39 (4.54)	113.96 (5.95)	113.43 (7.65)	113.17 (9.70)	113.16 (12.04)	113.37 (14.66)	113.79 (17.56)	114.39 (20.73)	115.19 (24.18)	116.17 (27.91)
Male immigrants ≤10(≥60y)	88.61 (15.58)	85.14 (18.85)	82.59 (20.6)	80.02 (22.44)	77.42 (24.34)	74.83 (26.24)	72.23 (28.12)	69.64 (29.94)	67.07 (31.70)	64.52 (33.38)
Male locals(≥60y)	62.88 (5.97)	58.95 (7.91)	56.51 (8.20)	54.14 (8.61)	51.84 (9.12)	49.61 (9.70)	47.46 (10.33)	45.38 (11.01)	43.38 (11.68)	41.45 (12.36)

eTable 3. Predictive means and standard deviations (in brackets) of age-standardized mortality rates of liver cancer per 100,000 population for each gender, age group (less than, greater or equal to 60 years old) and immigrant status from 2022 to 2030. Reported means and standard deviations (in brackets) of age-standardized mortality rates in 2021 are also listed.

Predictive mean of age-standardized mortality rates of pancreatic cancer per 100,000 population										
Year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Female immigrants >10	10.89 (0.62)	11.11 (0.75)	11.36 (0.91)	11.61 (1.09)	11.87 (1.31)	12.14 (1.56)	12.42 (1.84)	12.71 (2.15)	13.01 (2.48)	13.3(2.85)
Female immigrants ≤ 10	5.51 (1.44)	5.44 (1.56)	5.44 (1.69)	5.43(1.84)	5.42(1.99)	5.41(2.15)	5.39(2.32)	5.36(2.49)	5.34(2.66)	5.31(2.84)
Female locals	8.79 (1.10)	9.01 (1.22)	9.15 (1.34)	9.29(1.48)	9.43(1.64)	9.57(1.83)	9.71(2.05)	9.85(2.28)	9.99(2.54)	10.14 (2.83)
Male immigrants >10	16.30 (0.98)	17.87 (1.19)	18.48 (1.49)	19.11 (1.87)	19.78 (2.32)	20.47 (2.83)	21.18 (3.42)	21.92 (4.07)	22.69 (4.81)	23.49 (5.61)
Male immigrants ≤ 10	8.10 (2.02)	7.87 (2.37)	7.76 (2.53)	7.64(2.70)	7.51(2.87)	7.38(3.05)	7.24(3.23)	7.09(3.41)	6.95(3.58)	6.81(3.75)
Male locals	11.97 (1.26)	12.29 (1.49)	12.49 (1.64)	12.69 (1.83)	12.91 (2.06)	13.11 (2.33)	13.33 (2.63)	13.55 (2.97)	13.78 (3.34)	14.02 (3.74)
Female immigrants >10(<60y)	3.47 (0.33)	3.62 (0.57)	3.74 (0.66)	3.87(0.77)	4.01(0.89)	4.14(1.02)	4.28(1.18)	4.42(1.34)	4.57(1.53)	4.72(1.73)
Female immigrants ≤ 10(<60y)	1.12 (0.33)	1.21 (0.48)	1.22 (0.52)	1.23(0.56)	1.24(0.61)	1.25(0.66)	1.26(0.71)	1.26(0.77)	1.27(0.83)	1.28(0.89)
Female locals(<60y)	2.76 (0.27)	2.88 (0.36)	2.91 (0.41)	2.93(0.48)	2.96(0.55)	2.99(0.63)	3.02(0.71)	3.04(0.81)	3.07(0.90)	3.10(1.01)
Male immigrants >10(<60y)	6.88 (0.98)	7.05 (1.11)	7.24 (1.32)	7.43(1.56)	7.62(1.84)	7.82(2.16)	8.01(2.50)	8.21(2.88)	8.40(3.30)	8.61(3.75)
Male immigrants ≤ 10(<60y)	2.20 (0.71)	2.01 (0.85)	1.95 (0.91)	1.9(0.94)	1.84(0.99)	1.79(1.04)	1.74(1.09)	1.69(1.14)	1.64(1.19)	1.60(1.24)
Male locals(<60y)	4.16 (0.35)	4.33 (0.48)	4.41 (0.57)	4.46(0.68)	4.53(0.81)	4.61(0.94)	4.69(1.09)	4.77(1.26)	4.85(1.44)	4.93(1.63)
Female immigrants >10(≥60y)	28.58 (1.83)	29.45 (2.11)	29.91 (2.54)	30.38 (3.06)	30.85 (3.66)	31.33 (4.33)	31.81 (5.08)	32.29 (5.91)	32.78 (6.79)	33.27 (7.74)
Female immigrants ≤ 10(≥60y)	16.79 (5.29)	15.65 (6.08)	15.49 (6.71)	15.33 (7.36)	15.16 (8.03)	14.97 (8.73)	14.79 (9.43)	14.59 (10.14)	14.39 (10.86)	14.19 (11.58)
Female locals(≥60y)	22.80 (4.23)	23.85 (4.46)	24.21 (4.81)	24.56 (5.23)	24.91 (5.73)	25.25 (6.30)	25.58 (6.95)	25.90 (7.67)	26.22 (8.47)	26.54 (9.34)
Male immigrants >10(≥60y)	42.70 (2.55)	44.36 (3.02)	45.85 (3.76)	47.41 (4.69)	49.04 (5.78)	50.73 (7.05)	52.48 (8.50)	54.28 (10.13)	56.16 (11.95)	58.11 (13.98)
Male immigrants ≤ 10(≥60y)	24.68 (8.21)	23.96 (9.01)	23.87 (9.74)	23.75 (10.52)	23.61 (11.33)	23.45 (12.17)	23.28 (13.04)	23.09 (13.93)	22.89 (14.83)	22.68 (15.75)
Male locals(≥60y)	30.10 (4.68)	31.17 (5.22)	31.55 (5.63)	31.93 (6.14)	32.30 (6.75)	32.66 (7.45)	33.01 (8.23)	33.35 (9.11)	33.69 (10.08)	34.03 (11.12)

eTable 4. Predictive means and standard deviations (in brackets) of age-standardized mortality rates of pancreatic cancer per 100,000 population for each gender, age group (less than, greater or equal to 60 years old) and immigrant status from 2022 to 2030. Reported means and standard deviations (in brackets) of age-standardized mortality rates in 2021 are also listed.

Predictive mean of age-standardized mortality rates of stomach cancer per 100,000 population										
Year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Female immigrants >10	8.20 (0.55)	7.95 (0.62)	7.71 (0.74)	7.47 (0.87)	7.25 (1.01)	7.03 (1.15)	6.83 (1.29)	6.62 (1.43)	6.43 (1.57)	6.24 (1.71)
Female immigrants ≤ 10	7.51 (1.44)	7.36 (1.56)	7.33 (1.69)	7.30 (1.85)	7.28 (2.01)	7.27 (2.20)	7.27 (2.40)	7.28 (2.61)	7.31 (2.84)	7.33 (3.09)
Female locals	5.26 (0.40)	4.91 (0.52)	4.75 (0.57)	4.61 (0.63)	4.47 (0.71)	4.34 (0.77)	4.21 (0.84)	4.08 (0.91)	3.95 (0.99)	3.83 (1.06)
Male immigrants >10	15.22 (0.64)	13.89 (0.97)	13.34(1.21)	12.81 (1.46)	12.31 (1.73)	11.83 (1.99)	11.38 (2.26)	10.95 (2.51)	10.54 (2.76)	10.15 (3.01)
Male immigrants ≤10	15.83 (3.04)	15.21 (3.38)	15.07 (3.67)	14.93 (3.98)	14.79 (4.31)	14.64 (4.65)	14.51 (5.02)	14.35 (5.39)	14.19 (5.78)	14.03 (6.17)
Male locals	8.14 (0.89)	8.07 (0.99)	7.73 (1.03)	7.41(1.07)	7.10 (1.13)	6.81 (1.19)	6.51 (1.26)	6.23 (1.33)	5.97 (1.39)	5.71 (1.46)
Female immigrants >10(<60y)	4.81 (0.56)	4.69 (0.79)	4.62 (0.87)	4.55 (0.96)	4.47 (1.07)	4.39 (1.17)	4.31 (1.29)	4.22 (1.41)	4.13 (1.52)	4.03 (1.64)
Female immigrants ≤ 10(<60y)	3.89 (0.80)	4.08 (0.93)	4.10 (1.03)	4.13 (1.14)	4.17 (1.27)	4.21 (1.41)	4.24 (1.55)	4.28 (1.70)	4.32 (1.87)	4.36 (2.05)
Female locals(<60y)	2.28 (0.21)	2.08 (0.27)	1.98 (0.29)	1.88 (0.32)	1.79 (0.35)	1.71 (0.37)	1.61 (0.41)	1.53 (0.43)	1.44 (0.45)	1.37 (0.47)
Male immigrants >10(<60y)	4.94 (0.57)	4.71 (0.79)	4.55 (0.89)	4.41 (0.99)	4.25 (1.10)	4.12 (1.21)	3.98 (1.32)	3.86 (1.43)	3.74 (1.54)	3.63 (1.65)
Male immigrants ≤ 10(<60y)	4.81 (1.31)	4.70 (1.42)	4.66 (1.55)	4.63 (1.69)	4.59 (1.83)	4.55 (1.99)	4.52 (2.15)	4.48 (2.32)	4.44 (2.50)	4.41 (2.68)
Male locals(<60y)	2.48 (0.21)	2.37 (0.29)	2.28 (0.32)	2.21 (0.35)	2.12 (0.38)	2.04 (0.42)	1.97 (0.45)	1.91 (0.49)	1.83 (0.52)	1.77(0.55)
Female immigrants >10(≥60y)	17.80 (1.04)	16.23 (1.26)	15.65 (1.47)	15.08 (1.70)	14.55 (1.94)	14.03 (2.18)	13.54 (2.43)	13.07 (2.68)	12.62 (2.92)	12.19 (3.16)
Female immigrants ≤ 10(≥60y)	14.72 (4.29)	13.01 (4.83)	12.52 (5.11)	12.03 (5.37)	11.55 (5.63)	11.08 (5.88)	10.63 (6.12)	10.19 (6.35)	9.76(6.56)	9.34 (6.75)
Female locals(≥60y)	12.20 (1.66)	11.86 (1.84)	11.67 (1.98)	11.49 (2.15)	11.33 (2.35)	11.18 (2.58)	11.04 (2.84)	10.91 (3.11)	10.79(3.4)	10.68 (3.71)
Male immigrants >10(≥ 60y)	37.23 (2.29)	36.59 (2.56)	35.17(3.18)	33.82 (3.86)	32.55 (4.57)	31.34 (5.28)	30.19 (6.01)	29.08 (6.70)	28.02 (7.40)	27.01 (8.07)
Male immigrants ≤ 10(≥60y)	42.30 (10.88)	41.43 (11.78)	41.03 (12.71)	40.61 (13.70)	40.17 (14.75)	39.71 (15.85)	39.24 (16.99)	38.75 (18.16)	38.23 (19.35)	37.71 (20.57)
Male locals(≥60y)	23.04 (3.29)	22.69 (3.56)	22.37(4.07)	22.16(4.84)	21.89 (5.86)	21.61 (7.22)	21.52 (9.02)	21.74 (11.29)	22.17 (14.03)	22.73 (17.28)

eTable 5. Predictive means and standard deviations (in brackets) of age-standardized mortality rates of stomach cancer per 100,000 population for each gender, age group (less than, greater or equal to 60 years old) and immigrant status from 2022 to 2030. Reported means and standard deviations (in brackets) of age-standardized mortality rates in 2021 are also listed.

Predictive mean of age-standardized mortality rates of prostate cancer per 100,000 population										
Year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Male immigrants >10	14.81 (0.61)	14.59 (0.79)	14.57 (0.96)	14.56 (1.15)	14.54 (1.37)	14.51 (1.61)	14.48 (1.86)	14.45 (2.13)	14.42 (2.42)	14.38 (2.72)
Male immigrants ≤10	9.03 (2.95)	8.78 (3.11)	8.58 (3.29)	8.39 (3.49)	8.19(3.69)	8.10(3.89)	7.82(4.11)	7.63(4.31)	7.45(4.51)	7.27(4.72)
Male locals	9.54 (1.40)	9.66 (1.57)	9.67 (1.66)	9.69 (1.77)	9.72(1.91)	9.75(2.06)	9.78(2.23)	9.82(2.43)	9.86(2.64)	9.9(2.88)
Male immigrants >10(<60y)	0.57 (0.12)	0.52 (0.17)	0.51 (0.19)	0.50 (0.21)	0.49(0.22)	0.48(0.24)	0.47(0.25)	0.46(0.27)	0.45(0.29)	0.44(0.31)
Male immigrants ≤10(<60y)	0.65 (0.59)	0.73 (0.77)	0.81 (0.93)	0.87 (1.10)	0.94(1.31)	1.01(1.51)	1.09(1.75)	1.16(2.02)	1.24(2.32)	1.33(2.64)
Male locals(<60y)	0.63 (0.12)	0.66 (0.14)	0.66 (0.16)	0.66 (0.19)	0.67(0.21)	0.67(0.24)	0.67(0.27)	0.68(0.31)	0.68(0.33)	0.69(0.37)
Male immigrants >10(≥60y)	49.43 (2.59)	49.61 (2.73)	49.63 (3.29)	49.64 (3.94)	49.64 (4.68)	49.64 (5.51)	49.63 (6.38)	49.62 (7.32)	49.61 (8.32)	49.58(9.37)
Male immigrants ≤10(≥60y)	28.29 (9.15)	27.66 (9.78)	26.53 (10.21)	25.4 (10.63)	24.28 (11.03)	23.16 (11.41)	22.07 (11.76)	21.01 (12.09)	19.96 (12.38)	18.95(12.63)
Male locals(≥60y)	31.57 (5.17)	31.48 (5.49)	31.40 (5.76)	31.32 (6.09)	31.24 (6.48)	31.15 (6.94)	31.06 (7.44)	30.96 (8.01)	30.86 (8.61)	30.74(9.26)

eTable 6. Predictive means and standard deviations (in brackets) of age-standardized mortality rates of prostate cancer per 100,000 population for each age group (less than, greater or equal to 60 years old) and immigrant status from 2022 to 2030. Reported means and standard deviations (in brackets) of age-standardized mortality rates in 2021 are also listed.

Reporting checklist for cohort study.

Based on the STROBE cohort guidelines.

Instructions to authors

Complete this checklist by entering the page numbers from your manuscript where readers will find each of the items listed below.

Your article may not currently address all the items on the checklist. Please modify your text to include the missing information. If you are certain that an item does not apply, please write "n/a" and provide a short explanation.

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In your methods section, say that you used the STROBE cohort reporting guidelines, and cite them as:

von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The Strengthening of Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies.

		Reporting Item	Page Number
Title and abstract			
Title	#1a	Indicate the study's design with a commonly used term in the title or the abstract	1
Abstract	#1b	Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background / rationale	#2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	#3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	#4	Present key elements of study design early in the paper	5
Setting	#5	Describe the setting, locations, and relevant dates, including periods	5

1			of recruitment, exposure, follow-up, and data collection	
2				
3	Eligibility criteria	#6a	Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up.	5
4				
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6	Eligibility criteria	#6b	For matched studies, give matching criteria and number of exposed and unexposed	n/a
7				
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10	Variables	#7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
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15	Data sources /	#8	For each variable of interest give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group. Give information separately for for exposed and unexposed groups if applicable.	5
16	measurement			
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22	Bias	#9	Describe any efforts to address potential sources of bias	5
23				
24	Study size	#10	Explain how the study size was arrived at	5
25				
26				
27	Quantitative	#11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why	5
28	variables			
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31	Statistical	#12a	Describe all statistical methods, including those used to control for confounding	
32	methods			
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34	5			
35				
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37	Statistical	#12b	Describe any methods used to examine subgroups and interactions	5
38	methods			
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41	Statistical	#12c	Explain how missing data were addressed	5
42	methods			
43				
44	Statistical	#12d	If applicable, explain how loss to follow-up was addressed	n/a
45	methods			
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48	Statistical	#12e	Describe any sensitivity analyses	
49	methods			
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52	n/a			
53				
54	Results			
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57	Participants	#13a	Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible,	n/a
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included in the study, completing follow-up, and analysed. Give information separately for for exposed and unexposed groups if applicable.

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5	Participants	#13b	Give reasons for non-participation at each stage 5
6			
7	Participants	#13c	Consider use of a flow diagram
8			
9	n/a		
10			
11			
12	Descriptive data	#14a	Give characteristics of study participants (eg demographic, clinical, 5
13			social) and information on exposures and potential confounders. Give
14			information separately for exposed and unexposed groups if
15			applicable.
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19	Descriptive data	#14b	Indicate number of participants with missing data for each variable of
20			interest
21			
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25	Descriptive data	#14c	Summarise follow-up time (eg, average and total amount)
26			
27	n/a		
28			
29			
30	Outcome data	#15	Report numbers of outcome events or summary measures over time.
31			Give information separately for exposed and unexposed groups if
32			applicable.
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35	n/a		
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37			
38	Main results	#16a	Give unadjusted estimates and, if applicable, confounder-adjusted 6
39			estimates and their precision (eg, 95% confidence interval). Make
40			clear which confounders were adjusted for and why they were
41			included
42			
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44	Main results	#16b	Report category boundaries when continuous variables were n/a
45			categorized
46			
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48	Main results	#16c	If relevant, consider translating estimates of relative risk into absolute
49			risk for a meaningful time period
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51	n/a		
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54	Other analyses	#17	Report other analyses done—eg analyses of subgroups and 7
55			interactions, and sensitivity analyses
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Discussion

1	Key results	#18	Summarise key results with reference to study objectives	8
2				
3	Limitations	#19	Discuss limitations of the study, taking into account sources of	10
4			potential bias or imprecision. Discuss both direction and magnitude of	
5			any potential bias.	
6				
7				
8	Interpretation	#20	Give a cautious overall interpretation considering objectives,	8
9			limitations, multiplicity of analyses, results from similar studies, and	
10			other relevant evidence.	
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13	Generalisability	#21	Discuss the generalisability (external validity) of the study results	9
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16	Other			
17	Information			
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20	Funding	#22	Give the source of funding and the role of the funders for the present	11
21			study and, if applicable, for the original study on which the present	
22			article is based	
23				
24				

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An age-period-cohort analysis and projection of cancer mortality in Hong Kong, 1998–2030

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An age-period-cohort analysis and projection of cancer mortality in Hong Kong, 1998–2030

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23 Abstract

24 **Objectives:** To explore the relationship between immigration groups and cancer mortality, this
25 study aimed to explore age, period, birth cohort effects and effects across genders and
26 immigration groups on mortality rates of lung, pancreatic, colon, liver, prostate and stomach
27 cancers and their projections.

29 **Design, setting, and participants:** Death registry data in Hong Kong between 1998 and 2021,
30 which were stratified by age, sex and immigration status. Immigration status was classified into
31 three groups: locals born in Hong Kong, long-stay immigrants and short-stay immigrants.

33 **Methods:** Age-period-cohort analysis was used to examine age, period, and birth cohort effects
34 for genders and immigration groups from 1998 to 2021. Bayesian age-period-cohort models
35 were applied to predict the mortality rates from 2022 to 2030.

37 **Results:** Short-stay immigrants revealed pronounced fluctuations of mortality rates by age and
38 of relative risks by cohort and period effects for six types of cancers than those of long-stay
39 immigrants and locals. Immigrants for each type of cancer and gender will be at a higher
40 mortality risk than locals. After 2021, decreasing trends ($p<0.05$) or plateau ($p>0.05$) of
41 forecasting mortality rates of cancers occur for all immigration groups, except for increasing
42 trends for short-stay male immigrants with colon cancer ($p<0.05$, Avg +0.30 deaths/100,000
43 per annum from 15.47 to 18.50 deaths/100,000) and long-stay male immigrants with pancreatic
44 cancer ($p<0.05$, Avg +0.72 deaths/100,000 per annum from 16.30 to 23.49 deaths/100,000),.

46 **Conclusions:** Findings underscore the effect of gender and immigration status in Hong Kong
47 on mortality risks of cancers that immigrants for each type of cancer and gender will be at a
48 higher mortality risk than locals.

50 **Keywords:** Age-period-cohort analysis, immigration, mortality, lung cancer, pancreatic cancer,
51 colon cancer, liver cancer, prostate cancer, stomach cancer

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52 **Strengths and limitations of this study**

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54 • This study provides new evidence regarding the relationship between immigration status
55 and cancer mortality, given the effects of age, period, birth cohort and their predictions.

56

57 • The non-identifiability problem has not been interpreted in age-period-cohort models.

58

59 • The future perspective of cancer therapies and techniques have not been considered.

For peer review only

61 **Introduction**

62 Several migration waves from mainland China to Hong Kong have occurred over the past
63 century. These migration waves included a large-scale migration inflow from 1945 to 1950 (the
64 Chinese Civil War) and a few small-scale inflows in the 1950s, 1970s, and 1990s [1-3]. In 2016,
65 immigrants from mainland China formed approximately 38% of the population of Hong Kong.
66 These inflows have led to a growing interest in research on the disparity of health conditions
67 between the locals and immigrants.

68
69 Cancer has been one of the most common causes of death, as an estimated 19.3 million new
70 cancer cases and 9.9 million new cancer-associated deaths occurred worldwide in 2020 [4]. In
71 Hong Kong, lung cancer is one of the most common causes of cancer deaths [5, 6]. Previous
72 studies suggested that the primary cause of lung cancer is cigarette smoking [7-11]. Genetic
73 factors, asbestos, radon gas, second-hand smoke, and other forms of air pollution have been
74 proven to influence the risk of lung cancer [12-18]. The overall daily smoking rate in mainland
75 China was approximately 23.2% in 2018 [19], whereas the daily smoking rate in Hong Kong
76 was only 10.2% in 2019 [20]. The leading causes of liver cancer include viral infection,
77 drinking of alcohol and polluted water and food supplies which are also culprits for colon,
78 stomach and pancreatic cancer [21]. Alcohol consumption per capita in Hong Kong has reached
79 2.37 liters in 2021 [22], compared to 7.0 liters of per capita consumption of alcohol in mainland
80 China in 2018 [23]. As approximately 99% of prostate cancer cases occur after age 50, factors
81 of prostate cancer have been regarded as old age, race, family history and the diet of red meat
82 consumption [24]. In addition to these risk factors, studies have suggested that cancer mortality
83 rates vary depending on migrant status [25-28]. According to data from the Census and
84 Statistics Department of Hong Kong, approximately 81% of immigrants in Hong Kong
85 immigrated from mainland China, Macau, and Taiwan. Immigrants from mainland China
86 account for the bulk of this population. Previous studies have shown that child immigrants in
87 Hong Kong tend to suffer from a higher risk of wheezing disorders and cardiovascular diseases,
88 and immigrant women have higher age-specific mortality rates of breast cancer than locally-
89 born women in Hong Kong [29, 30]. However, to date, few studies have investigated the effect
90 of length of stay in Hong Kong and birthplace on the risk of other types of cancer.

91
92 In this study, we compared the mortality rates of lung, pancreatic, colon, liver, prostate and
93 stomach cancers between locally born residents in Hong Kong and immigrants from mainland
94 China. Both populations are widely considered as ethnically homogeneous with similar cultures.
95 Nevertheless, due to different early life experiences, immigrants are exposed to more various
96 social economy and lifestyles than locals. Therefore, it's constructive to ascertain whether
97 immigrants from mainland China have a different mortality pattern of cancers from locals to
98 verify the significance of migration status for this health outcome. As age-period-cohort (APC)

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3 99 analysis plays a vital role in studying time-specific phenomena in epidemiology, in this study,
4 100 to evaluate the effect of immigration on cancer mortality in the past and future, we developed
5 101 APC models specified by sex and migrant status to assess the effects of age, period, birth cohort,
6 102 and of the length of stay in Hong Kong on the mortality risks of cancers. Additionally, we
7 103 explore the projection of mortality rates for the locally born population and immigrants in Hong
8 104 Kong who were younger or older than 60 using a predictive model, taking into account age,
9 105 period, and birth cohort effects as well.
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16 107 **Methods**

17 108 *Data*

18 109 We obtained the death registry data in Hong Kong between 1998 and 2021 from the Census
19 110 and Statistics Department of Hong Kong, as the data in 2022 has not been available up to now.
20 111 The data was extracted from a routine census held by the Hong Kong government as subjective
21 112 errors caused by resampling can be neglected. The population data were stratified by age, sex,
22 113 immigration status, and length of stay in Hong Kong. We retrieved six types of cancer cases
23 114 from the death registry data using ICD codes, such as ICD-9 code 162 and ICD-10 codes
24 115 C34.0–C34.3, C348, and C349 for lung cancer. To assure comparability among
25 116 registries, deaths from the age group of 35–85 years were selected, since cases younger than 35
26 117 and older than 85 were relatively trivial for lack of statistical interpretability [31]. Immigration
27 118 status was classified into three groups: locals born in Hong Kong, immigrants who have lived
28 119 in Hong Kong for >10 years before death defined as long-stay immigrants, and immigrants who
29 120 have lived in Hong Kong for ≤10 years before death defined as short-stay immigrants. Notably,
30 121 much focus was placed on immigrants from mainland China, because approximately 81% of
31 122 immigrants in Hong Kong came from mainland China, Macau, and Taiwan based on the data
32 123 from the Census and Statistics Department of Hong Kong. Moreover, few cases recorded from
33 124 Macau and Taiwan are statistically insignificant in the analysis. Demographics and population
34 125 projections from 2022 to 2030 were retrieved from the Census and Statistics Department of
35 126 Hong Kong and estimated with cubic smoothing spline as the prerequisite of the predictive
36 127 model. Codes for APC and BAPC analysis are available in the GitHub repository
37 128 (<https://github.com/kshz2164313/APC-population-projections-for-immigration-HK>).
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52 131 *Statistical analysis*

53 132 We modeled cancer mortality rates in Hong Kong using APC analysis based on log-linear
54 133 Poisson regression models. The model aimed to disentangle age, period, and cohort effects of
55 134 time-varying phenomena simultaneously [32, 33], given that

$$56 135 \log(E_{ij}) = \alpha_i + \beta_j + \gamma_k + \mu + \log(\theta_{ij}) \quad (1)$$

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3 136 where E_{ij} denotes expected mortality; α_i , β_j , and γ_k denote age, period, and cohort
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5 137 effect, respectively, for $i = 1, \dots, I$, $j = 1, \dots, J$, $k = 1, \dots, K$ with $k = I - i + j$.
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7 138 $\log(\theta_{ij})$ is the offset. We mainly focused on the contributions of sex and immigration status
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9 139 due to the non-identifiability problem that the effects of these three components are collinear
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11 140 with each other (denoted as period – age = cohort) [34]. Birth cohort effect and period effect
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13 141 were assessed with relative risks to evaluate the effect of three components. The median year
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15 142 of birth among cases was regarded as the reference cohort [35,36]. Since death cases aged at
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17 143 35–85 years between 1998 and 2021 were selected, the range of birth cohort from 1913 to
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19 144 1986 covered observations and further projections until 2030. The second and penultimate
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21 145 period effects were constrained to the reference for period. For sex and immigration status,
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23 146 maximum likelihood framework was applied to estimate the relative risks and 95%
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25 147 confidence intervals (CIs) by age groups, calendar period, and birth cohort.
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29 149 Several projection approaches for future cancer mortality have been developed, but a
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31 150 Bayesian age-period-cohort (BAPC) model built upon integrated nested Laplace
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33 151 approximations (INLA) [37] yields relatively higher coverage and better performance for all
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35 152 evaluated parameter combinations [38]. To prevent some sampling problems caused by
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37 153 Markov chain Monte Carlo (MCMC), this MCMC-free BAPC approach was applied to
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39 154 predict future cancer mortality within a fully Bayesian inference setting and provide outputs
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41 155 of interest simply, such as projected age-standardized and age-specific rates. Convergence
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43 156 checks are not necessary for this technique [37]. The projections of age-standardized cancer
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45 157 mortality rates for each sex, age group (younger or older than 60 years) and migrant status,
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47 158 taking into account age, period, and birth cohort effects, were performed based on the weights
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49 159 of population age groups from the WHO World Standard population [39], with 95%
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51 160 prediction intervals. Mann-Kendall trend test was applied to verify the projection trend.
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53 161 Friedman's Two-Way Analysis of Variance was applied to test interactions between gender
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55 162 and immigration groups for each year.
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59 164 All analyses were performed via R version 4.2.1 (R Core Team, R Foundation for Statistical
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61 165 Computing, Vienna, Austria, 2013, <http://www.R-project.org/>). The APC models were
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63 166 established using the Epi package, and the projections based on Bayesian APC models were
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65 167 performed with the BAPC package.
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68 69 Patient and public involvement

70 None.

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73 **Results**

74 Figure 1 & 2 and eFigure 1(a-e) in **Supplementary Material** illustrate the estimates of age
75 (assessed by cancer mortality), cohort and period effects (assessed by relative risk) based on
76 APC models among three migrant groups for men and women with six types of cancers,

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4 177 respectively. All the mortality rates for each gender and immigration status exhibit notable
5 178 increasing trends with age. Age, cohort and period effects of six types of cancer for immigrants
6 179 who stayed in Hong Kong for ≤ 10 years revealed relatively more pronounced fluctuations and
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8 180 deviations from those effects in the other two immigration groups. Significant increasing trends
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10 181 of age effect occurred in all types of cancer, regardless of gender and immigration status. For
11 182 example, while relatively insignificant differences in lung cancer mortality rates by
12 183 immigration status among females have performed, male immigrants who remained in Hong
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14 184 Kong for > 10 years had higher lung cancer mortality rates at ages above 50 years and those
15 185 who arrived ≤ 10 years had lower lung cancer mortality at ages below 62 years compared to
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17 186 local men Figure 1. In addition to compatible dynamics of period effect for locals and long-stay
18 187 immigrants, similar changes of relative risks by birth cohort for locals and long-stay immigrants
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20 188 in lung, colon, liver and stomach cancers occurred before 1945, whereas significant differences
21 189 of relative risks by birth cohort between these two immigration groups occurred after 1960
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23 190 (Figure 1 & eFigure 1(a,b,d)). Locals and long-stay immigrants in pancreatic and prostate
24 191 cancer perform almost similar changes of relative risks by birth cohort effects all the time
25 192 (eFigure 1(c,e)). Short-stay immigrants who have stayed in Hong Kong for ≤ 10 years had more
26 193 fluctuating relative risks affected by period effects before 2020 than those for locals and long-
27 194 stay immigrants. Lack of young cases, especially young short-stay immigrants, of prostate
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29 195 cancer leads to significant deviations and variances in age and cohort effects.
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33 197 Figure 3-5, eFigure 2-6 in **Supplementary Material** illustrate the age-standardized mortality
34 198 rates of six types of cancer from 1998 to 2021 and their projections by sex, immigrant status
35 199 and age groups from 2022 to 2030, taking into account age, period, and birth cohort effects.
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37 200 Means and standard deviations of predictive mortality rates are shown in eTable 1-6 in
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39 201 **Supplementary Material**. For all ages projection (Figure 2 & eFigure 2-6), as approximately
40 202 significant interactions between gender and immigration groups emerge for each type of cancer
41 203 in each year ($p < 0.05$), given the projected trends, immigrants for each gender, especially who
42 204 have stayed in Hong Kong for > 10 years will suffer from higher mortality rates of cancer in
43 205 each year than locals. Monotone decreasing trends or plateau of forecasting occur for both
44 206 genders and all immigration groups in cancers, except for increasing trends for male immigrants
45 207 who have stayed in Hong Kong for ≤ 10 years with colon cancer ($p < 0.05$, Avg +0.30
46 208 deaths/100,000 per annum) from 15.47 deaths/100,000 (95% CI: 11.28, 19.66) in 2021 to 18.50
47 209 deaths/100,000 (95% CI: 2.31, 34.69) in 2030, and male immigrants who have stayed in Hong
48 210 Kong for > 10 years with pancreatic cancer ($p < 0.05$, Avg +0.72 deaths/100,000 per annum)
49 211 from 16.30 deaths/100,000 (95% CI: 14.38, 17.26) in 2021 to 23.49 deaths/100,000 (95% CI:
50 212 12.49, 34.49) in 2030. Most of predictive trends for younger cases (< 60 years) and older cases
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53 213 (≥ 60 years) reach a consensus with those for all ages population, except for two phenomena:
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56 214 1.) mortality rates of lung cancer for men immigrants ≤ 10 that insignificant trend for all ages

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3 215 (p > 0.05) vs. decline for younger cases (p < 0.05) vs. increase for older cases (p < 0.05); 2.)
4 216 mortality rates of liver cancer for men immigrants >10 that decline for all ages (p < 0.05) vs.
5 217 decline for younger cases (p < 0.05) vs. insignificant trend for older cases (p > 0.05). Some
6 218 particular cases occur in the projection of prostate cancer that young long-stay male immigrants
7 219 (0.44 deaths/100,000, 95% CI: 0, 1.05) aged less than 60 will be at lower mortality rate than
8 220 locals (0.69 deaths/100,000, 95% CI: 0, 1.42) in 2030 (eTable 6). Compared with other cancers
9 221 and immigration groups, male immigrants who have stayed in Hong Kong for >10 years with
10 222 lung cancer would perform the most significant decline in predictive mean from 102.90 (95%
11 223 CI: 98.14, 107.66) to 79.55 (95% CI: 47.46, 111.64) deaths per 100,000 population (Avg -2.34
12 224 deaths/100,000 per annum) (eTable 1), while the same immigration group with pancreatic
13 225 cancer would indicate the most significant uptrend in each year of 16.30 (95% CI: 14.38,17.26)
14 226 and 23.49 (95% CI: 12.49, 34.49) deaths per 100,000 population in 2021 and 2030, respectively
15 227 (Avg +0.72 deaths/100,000 per annum) (eTable 4).
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231 Discussion

232 Early detection of cancer is positive and instructive for increasing chances of cure. Nevertheless,
233 the high mortality rate of cancer results from late diagnosis among most patients after
234 progression to more advanced or severe stages. Individuals at high risk of cancer, such as
235 smokers, alcoholics or those who are frequently exposed to susceptible circumstances, should
236 be screened for early detections to increase opportunities for cure [40]. Therefore, the
237 differences in mortality rates among immigration groups are synonymous with detection means,
238 therapies, and social history in disparate periods and areas.
239

240 While the changes in mortality rates by age for long-stay immigrants reached approximate
241 harmony with those for locals, the changes in mortality rates by age for short-stay immigrants
242 revealed clear differences with those for the other two populations. The group of long-stay
243 immigrants had a higher risk of death from lung, colon and liver cancers than the other two
244 immigration groups after the age of 60 years. Short-stay male immigrants were less likely to
245 die from lung cancer before the age of 65 years. The contrast in age effects among the
246 immigration groups was partially consistent with studies [25, 41] that highlighted the age
247 effects for locals and immigrants on breast cancer mortality in Hong Kong and lung cancer
248 incidence in Sweden, as they both showed similar trends and magnitudes between locals and
249 immigrants before the age of 60 years. They are also compatible with the results in [42] that
250 diagnosis of liver cancer is the most frequent among populations at 55 to 65 years old.

251 According to these trends, young individuals, especially new young immigrant men, who
252 have benefited from all-rounded development in mainland China and Hong Kong, are more

253 likely to seek early detection and be treated for cancers using more advanced treatments [43].
254 Differences in birth cohort effects among immigrant groups partially comply with the
255 interpretation above.

256
257 We observed significant trends of cohort effects among locals and immigrants. These findings
258 are partially consistent but subtly different from previous findings, regarding the effect of
259 immigration status on cancers. Zhao et al. [25] described multiple peaks of cohort effects on
260 breast cancer mortality between locals and immigrants in Hong Kong, as well as a significant
261 decline in cohort effects after 1950. In contrast, Sung et al. [44] investigated the difference in
262 breast cancer incidence between Chinese Americans and non-Hispanic whites in the U.S. and
263 emphasized that Chinese Americans were at lower risk of breast cancer than non-Hispanic
264 whites born in the same year. Here, we interpret the cohort-driven trends resulting from the
265 intricacy of social history and lifestyle. Compared to a relatively stable social development in
266 Hong Kong, representing downward trends of relative risks for locals, wars and social
267 instability in mainland China resulted in several immigration waves from mainland China to
268 Hong Kong before 1950. Additionally, remarkable increasing trends were recorded for new
269 immigrants after 1950, which corresponded to the economic downturn after wars and famine
270 between 1959 and 1961 during their youth [45]. The increasing trends for new immigrants
271 and similar trends for locals and long-stay immigrants were consistent with the finding that
272 nutrient deficiency contributes to a higher risk of severe mortality rates of cancers [46].
273 Furthermore, we speculate that these trends, especially those for locals and long-stay
274 immigrants, are most likely attributed to social development and personal behaviors, such as
275 daily habits, occupational history, different diagnoses and treatments, and domestic
276 environmental exposures. Notably, short-stay immigrants suffered from a lower risk of death
277 from colon cancer for all ages (eFigure 1a in **Supplementary Material**). As locals and
278 immigrants in Hong Kong transitioned to more westernized lifestyles, higher consumption of
279 meat was associated with a higher risk of these types of cancer, whereas consumption of
280 vegetables had a strong protective effect against pancreatic cancer, and moderate
281 consumption of coffee appeared to be beneficial against lung cancer [47,48]. Further studies
282 on potential risk factors are required.

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284 Short-stay immigrants had more fluctuating and non-stationary but inconspicuous relative
285 risks by period effects before 2021 than locals and long-stay immigrants. Cumulatively, an
286 arch pattern and fluctuating curve depicting period effects externally resulted in an arch
287 pattern of age-standardized mortality rates for short-stay immigrant women and irregular rates
288 for short-stay immigrant men before 2021. The external performance of different period
289 effects on mortality rates could be most likely attributed to the higher effect of different
290 lifestyles and social development on new immigrants than on long-stay immigrants and locals
291 in Hong Kong. For the age-standardized mortality rates and projections, consistent with

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4 292 previous findings [49,50], we predict that the mortality rates of cancer in Hong Kong after
5 293 2021 will continue to decline or remain relatively stable, consistent with the trends before
6 294 2020, except for male immigrants who have stayed in Hong Kong for ≤ 10 years with colon
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8 295 cancer and male immigrants who have stayed in Hong Kong for >10 years with pancreatic
9 296 cancer. Men will be at higher risk of mortality rates of cancer than women, regardless of
10 297 immigration status. They are also compatible with the results in [4] that men suffer from a
11 298 higher risk of these types of cancer than women, excluding prostate cancer. Furthermore, new
12 299 immigrant women will be at lower risk than local women, even though long-stay immigrants
13 300 will suffer from higher mortality rates than locals in the future. Potential interpretations could
14 301 be consistent with those for birth cohort effects, as age and period effects are considered as
15 302 confounders of cohort effect.
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21 304 In the past few decades, spurred by an increasing burden of high incidence and mortality rates
22 305 of cancer, several studies focused on the inherent identification dilemma of three effects in the
23 306 APC model. Further, complicated population distribution and immigration status in Hong
24 307 Kong, one of the areas with the highest population density and migration frequency in the
25 308 world, have intricate causes and inherent dynamics of cancer and other diseases. To our
26 309 knowledge, few studies have assessed the relationship between immigration status and cancer
27 310 mortality. Therefore, this study is original to examine the effect of the length of stay in Hong
28 311 Kong and origins of previous residence on cancer deaths, which is instructive for further
29 312 immigration policy-making and targeted strategies of disease detection and intervention.
30 313 However, this study had several limitations. Given the non-identifiability problem in age-
31 314 period-cohort models, we could only depict trends and variations among different
32 315 immigration and sex groups, as illustrated in figures, and insufficiently perform the estimates
33 316 of the contributions of three effects or subgroups to mortality rates. Furthermore, we adopted
34 317 a cubic smoothing spline to estimate populations of immigrants and locals due to the large
35 318 proportion of unspecified immigration status from official demographic projections. A few
36 319 acceptable cases resulted in a limited type of cancer so that some common cancers, such as
37 320 the ovary and cervix, were discarded. Since the issue of quantification, the future perspective
38 321 of cancer therapies and techniques have not been considered in the model of projection.
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52 324 **Conclusion**

53 325 We conclude that immigrants, especially short-stay immigrants, had more pronounced
54 326 fluctuations of mortality rates by age and of relative risks by cohort and period effects for six
55 327 types of cancers than those of long-stay immigrants and locals. Male immigrants who have
56 328 stayed in Hong Kong for ≤ 10 years with colon cancer and male immigrants who have stayed
57 329 in Hong Kong for >10 years with pancreatic cancer would perform significant uptrend in the

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4 330 future, while other immigration groups for each type of cancer would continue to decline or
5 331 remain relatively stable. Immigrants for each gender in Hong Kong would suffer from higher
6 332 mortality risks of cancers than locals in the future.
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333 **Declaration**

334 **Ethical approval and consent to participate**

335 Ethical approval and consent to participate are not applicable. This study does not directly
336 involve human participants. Data was obtained from the Census and Statistics Department of
337 Hong Kong.

338 **Consent for publication**

339 Not applicable.

340 **Data availability statement**

341 Data are available upon reasonable request.

342 **Contributors**

343 Yanji Zhao: Methodology, Formal analysis, Data Curation, Writing - Original Draft,
344 Visualization. Zian Zhuang: Methodology, Formal analysis, Data Curation, Writing - Review
345 & Editing. Lin Yang: Validation, Writing - Review & Editing. Daihai He: Conceptualization,
346 Writing - Review & Editing, Supervision

347
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351 **Competing interests**

352 None declared.

References

1. Fan S-C. The population projection of Hong Kong. *Southeast Asian Journal of Social Science*. 1974;2(1/2):105-17.
2. Department CaS. Hong Kong Statistics 1947-1967 (Report). https://www.statistics.gov.hk/pub/hist/1961_1970/B10100031967AN67E0100.pdf Accessed 4th May 2019.
3. Department CaS. Demographic Trends in Hong Kong 1981-2011 (Report). <http://www.statistics.gov.hk/pub/B1120017032012XXXXB0100.pdf>, Accessed 4th May 2019.
4. Sung H, Ferlay J, Siegel RL, Laversanne M, Soerjomataram I, Jemal A, et al. Global Cancer Statistics 2020: GLOBOCAN Estimates of Incidence and Mortality Worldwide for 36 Cancers in 185 Countries. *CA: A Cancer Journal for Clinicians*. 2021 2021/05/01;71(3):209-49. doi: <https://doi.org/10.3322/caac.21660>.
5. Wang XR, Chiu YL, Qiu H, Au JSK, Yu ITS. The roles of smoking and cooking emissions in lung cancer risk among Chinese women in Hong Kong. *Annals of Oncology*. 2009 2009/04/01;20(4):746-51. doi: <https://doi.org/10.1093/annonc/mdn699>.
6. Chiu Y-L, Wang X-R, Qiu H, Yu IT-S. Risk factors for lung cancer: a case-control study in Hong Kong women. *Cancer Causes & Control*. 2010 2010/05/01;21(5):777-85. doi: 10.1007/s10552-010-9506-9.
7. Office on S, Health. Publications and Reports of the Surgeon General. Women and Smoking: A Report of the Surgeon General. Atlanta (GA): Centers for Disease Control and Prevention (US); 2001.
8. Escobedo LG, Peddicord JP. Smoking prevalence in US birth cohorts: the influence of gender and education. *American Journal of Public Health*. 1996 1996/02/01;86(2):231-6. doi: 10.2105/AJPH.86.2.231.
9. Husten CG, Shelton DM, Chrismon JH, Lin YC, Mowery P, Powell FA. Cigarette smoking and smoking cessation among older adults: United States, 1965-94. *Tobacco Control*. 1997;6(3):175. doi: 10.1136/tc.6.3.175.
10. Bolego C, Poli A, Paoletti R. Smoking and gender. *Cardiovascular Research*. 2002;53(3):568-76. doi: 10.1016/S0008-6363(01)00520-X.
11. Doll R, Hill AB. The mortality of doctors in relation to their smoking habits; a preliminary report. *Br Med J*. 1954;1(4877):1451-5. PMID: 13160495. doi: 10.1136/bmj.1.4877.1451.
12. Ramada Rodilla JM, Calvo Cerrada B, Serra Pujadas C, Delclos GL, Benavides FG. Fiber burden and asbestos-related diseases: an umbrella review. *Gaceta Sanitaria*. 2021 2021/06/11/. doi: <https://doi.org/10.1016/j.gaceta.2021.04.001>.
13. Collishaw NE, Kirkbride J, Wigle DT. Tobacco smoke in the workplace: an occupational health hazard. *Can Med Assoc J*. 1984;131(10):1199-204. PMID: 6498670.
14. Dresler CM, Fratelli C, Babb J, Everley L, Evans AA, Clapper ML. Gender differences in genetic susceptibility for lung cancer. *Lung Cancer*. 2000 2000/12/01;30(3):153-60. doi: [https://doi.org/10.1016/S0169-5002\(00\)00163-X](https://doi.org/10.1016/S0169-5002(00)00163-X).
15. Alexandrov K, Cascorbi I, Rojas M, Bouvier G, Kriek E, Bartsch H. CYP1A1 and GSTM1 genotypes affect benzo[a]pyrene DNA adducts in smokers' lung: comparison with aromatic/hydrophobic adduct formation. *Carcinogenesis*. 2002;23(12):1969-77. doi:

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3 397 10.1093/carcin/23.12.1969.
- 4 398 16. Samet JM. Radon and Lung Cancer. JNCI: Journal of the National Cancer Institute.
5 399 1989;81(10):745-58. doi: 10.1093/jnci/81.10.745.
- 6 400 17. Darby S, Hill D, Auvinen A, Barros-Dios JM, Baysson H, Bochicchio F, et al. Radon in
7 401 homes and risk of lung cancer: collaborative analysis of individual data from 13 European case-
8 402 control studies. BMJ. 2005;330(7485):223. doi: 10.1136/bmj.38308.477650.63.
- 9 403 18. Raaschou-Nielsen O, Andersen ZJ, Beelen R, Samoli E, Stafoggia M, Weinmayr G, et al.
10 404 Air pollution and lung cancer incidence in 17 European cohorts: prospective analyses from the
11 405 European Study of Cohorts for Air Pollution Effects (ESCAPE). The Lancet Oncology. 2013
12 406 2013/08/01/;14(9):813-22. doi: [https://doi.org/10.1016/S1470-2045\(13\)70279-1](https://doi.org/10.1016/S1470-2045(13)70279-1).
- 13 407 19. 2018 Summary-20190719. Retrieved August 26, 2022, from
14 408 [https://www.who.int/docs/default-source/wpro---documents/countries/china/2018-gats-china-](https://www.who.int/docs/default-source/wpro---documents/countries/china/2018-gats-china-factsheet-cn-en.pdf?sfvrsn=3f4e2da9_2)
15 409 [factsheet-cn-en.pdf?sfvrsn=3f4e2da9_2](https://www.who.int/docs/default-source/wpro---documents/countries/china/2018-gats-china-factsheet-cn-en.pdf?sfvrsn=3f4e2da9_2)
- 16 410 20. *Thematic household survey*. Retrieved August 26, 2022, from
17 411 https://www.censtatd.gov.hk/en/data/stat_report/product/B1130201/att/B11302702020XXXX
18 412 [B0100.pdf](https://www.censtatd.gov.hk/en/data/stat_report/product/B1130201/att/B11302702020XXXX)
- 19 413 21. Abubakar II, Tillmann T, Banerjee A. Global, regional, and national age-sex specific all-
20 414 cause and cause-specific mortality for 240 causes of death, 1990-2013: a systematic analysis
21 415 for the Global Burden of Disease Study 2013. Lancet. 2015 Jan 10;385(9963):117-71.
- 22 416 22. Estimated alcohol consumption per capita in Hong Kong. Change4Health. (n.d.).
23 417 Retrieved December 1, 2022, from
24 418 https://www.change4health.gov.hk/en/alcohol_aware/figures/alcohol_consumption/index.htm
25 419 1
- 26 420 23. World Health Organization. Global status report on alcohol and health 2018. World
27 421 Health Organization; 2019 Feb 14.
- 28 422 24. Wild C. World cancer report 2014. Wild CP, Stewart BW, editors. Geneva, Switzerland:
29 423 World Health Organization; 2014.
- 30 424 25. Zhao S, Dong H, Qin J, Liu H, Li Y, Chen Y, et al. Breast cancer mortality in Chinese
31 425 women: does migrant status play a role? Annals of Epidemiology. 2019 2019/12/01/;40:28-
32 426 34.e2. doi: <https://doi.org/10.1016/j.annepidem.2019.10.006>.
- 33 427 26. Gomez SL, Yang J, Lin S-W, McCusker M, Sandler A, Cheng I, et al. Incidence trends of
34 428 lung cancer by immigration status among Chinese Americans. Cancer Epidemiol Biomarkers
35 429 Prev. 2015;24(8):1157-64. PMID: 25990553. doi: 10.1158/1055-9965.EPI-15-0123.
- 36 430 27. Hemminki K, Li X, Czene K. Cancer risks in first-generation immigrants to Sweden.
37 431 International Journal of Cancer. 2002 2002/05/10;99(2):218-28. doi:
38 432 <https://doi.org/10.1002/ijc.10322>.
- 39 433 28. Vanthomme K, Roskamp M, De Schutter H, Vandenheede H. Lung cancer incidence
40 434 differences in migrant men in Belgium, 2004–2013: histology-specific analyses. BMC Cancer.
41 435 2021 2021/03/30;21(1):328. doi: 10.1186/s12885-021-08038-6.
- 42 436 29. Schooling M, Leung GM, Janus ED, Ho SY, Hedley AJ, Lam TH. Childhood migration
43 437 and cardiovascular risk. International Journal of Epidemiology. 2004;33(6):1219-26. doi:
44 438 10.1093/ije/dyh221.
- 45 439 30. Leung JYY, Li AM, Leung GM, Schooling CM. Mode of delivery and childhood
46 440 hospitalizations for asthma and other wheezing disorders. Clinical & Experimental Allergy.

- 1
2
3 441 2015 2015/06/01;45(6):1109-17. doi: <https://doi.org/10.1111/cea.12548>.
- 4 442 31. Baker A, Bray I. Bayesian projections: what are the effects of excluding data from younger
5 443 age groups?. *American Journal of Epidemiology*. 2005 Oct 15;162(8):798-805.
- 6 444 32. Rosenberg PS, Anderson WF. Age-Period-Cohort Models in Cancer Surveillance Research:
7 445 Ready for Prime Time? APC Models. *Cancer Epidemiology, Biomarkers & Prevention*. 2011
8 446 Jul 1;20(7):1263-8.
- 9 447 33. Holford T. Analyzing the effects of age, period and cohort on incidence and mortality rates.
10 448 *Stat Meth Med Res*. 1992;1:317-37.
- 11 449 34. Brookmeyer R, Stroup DF, editors. *Monitoring the health of populations: statistical*
12 450 *principles and methods for public health surveillance*. Oxford University Press; 2004.
- 13 451 35. Yang Y, Land KC. *Age-period-cohort analysis: New models, methods, and empirical*
14 452 *applications*. Taylor & Francis; 2013.
- 15 453 36. Robertson C, Gandini S, Boyle P. Age-period-cohort models: a comparative study of
16 454 available methodologies. *Journal of clinical epidemiology*. 1999 Jun 1;52(6):569-83.
- 17 455 37. Riebler A, Held L. Projecting the future burden of cancer: Bayesian age-period-cohort
18 456 analysis with integrated nested Laplace approximations. *Biometrical Journal*. 2017
19 457 May;59(3):531-49.
- 20 458 38. Knoll M, Furkel J, Debus J, Abdollahi A, Karch A, Stock C. An R package for an integrated
21 459 evaluation of statistical approaches to cancer incidence projection. *BMC medical research*
22 460 *methodology*. 2020 Dec;20(1):1-1.
- 23 461 39. Ahmad OB, Boschi-Pinto C, Lopez AD, Murray CJ, Lozano R, Inoue M. *Age*
24 462 *standardization of rates: a new WHO standard*. Geneva: World Health Organization. 2001
25 463 Jan;9(10):1-4.
- 26 464 40. Sung H, Ferlay J, Siegel RL, Laversanne M, Soerjomataram I, Jemal A, Bray F. *Global*
27 465 *cancer statistics 2020: GLOBOCAN estimates of incidence and mortality worldwide for 36*
28 466 *cancers in 185 countries*. CA: a cancer journal for clinicians. 2021 May;71(3):209-49.
- 29 467 41. Mousavi SM, Fallah M, Sundquist K, Hemminki K. Age-and time-dependent changes in
30 468 cancer incidence among immigrants to Sweden: colorectal, lung, breast and prostate cancers.
31 469 *International journal of cancer*. 2012 Jul 15;131(2):E122-8.
- 32 470 42. National Cancer Institute. *SEER stat fact sheets: liver and intrahepatic bile duct cancer*.
- 33 471 43. Wu X, Chung VC, Hui EP, Ziea ET, Ng BF, Ho RS, Tsoi KK, Wong S, Wu JC.
34 472 *Effectiveness of acupuncture and related therapies for palliative care of cancer: overview of*
35 473 *systematic reviews*. *Scientific reports*. 2015 Nov 26;5(1):1-5.
- 36 474 44. Sung H, Rosenberg PS, Chen WQ, Hartman M, Lim WY, Chia KS, Wai-Kong Mang O,
37 475 Tse L, Anderson WF, Yang XR. The impact of breast cancer-specific birth cohort effects among
38 476 younger and older Chinese populations. *International journal of cancer*. 2016 Aug
39 477 1;139(3):527-34.
- 40 478 45. *The world economy volume 1: a millennial perspective, 2, Historical statistics*: Academic
41 479 *Foundation, Gurgaon, India (2007)*
- 42 480 46. Elias SG, Peeters PH, Grobbee DE, van Noord PA. The 1944-1945 Dutch famine and
43 481 subsequent overall cancer incidence. *Cancer Epidemiology Biomarkers & Prevention*. 2005
44 482 Aug;14(8):1981-5.
- 45 483 47. Chiu YL, Wang XR, Qiu H, Yu IT. Risk factors for lung cancer: a case-control study in
46 484 Hong Kong women. *Cancer Causes & Control*. 2010 May;21(5):777-85.

- 1
2
3 485 48. Li J, Lam AS, Yau ST, Yiu KK, Tsoi KK. Antihypertensive treatments and risks of lung
4 486 Cancer: A large population-based cohort study in Hong Kong. *BMC cancer*. 2021 Dec;21(1):1-
5 487 9.
6
7 488 49. Du J, Sun H, Sun Y, Du J, Cao W, Sun S. Assessment of age, period, and cohort effects of
8 489 lung cancer incidence in Hong Kong and projection up to 2030 based on changing
9 490 demographics. *American Journal of Cancer Research*. 2021;11(12):5902.
10
11 491 50. *Centre for Health Protection, Department of Health - Lung Cancer*. Centre for Health
12 492 Protection. Retrieved August 10, 2022, from
13 493 <https://www.chp.gov.hk/en/healthtopics/content/25/49.html>

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FIGURE LEGENDS

Figure 1. Parameter estimates of age (a), cohort (b) and period (c) effects based on an age-period-cohort model of male lung cancer mortality rates by immigrant groups: locals, immigrants stay in Hong Kong for more than 10 years and immigrants stay in Hong Kong for less than or equal to 10 years. Age effect was assessed by mortality (left axis). Cohort and period effects were assessed by relative risk (right axis), 95% confidence intervals are shown as shaded bands.

Figure 2. Parameter estimates of age (a), cohort (b) and period (c) effects based on an age-period-cohort model of female lung cancer mortality rates by immigrant groups: locals, immigrants stay in Hong Kong for more than 10 years and immigrants stay in Hong Kong for less than or equal to 10 years. Age effect was assessed by mortality (left axis). Cohort and period effects were assessed by relative risk (right axis), 95% confidence intervals are shown as shaded bands.

Figure 3. Projections of lung cancer mortality rates by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.

Figure 4. Projections of lung cancer mortality rates for the population younger than 60 by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.

Figure 5. Projections of lung cancer mortality rates for the population older than or equal to 60 by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.

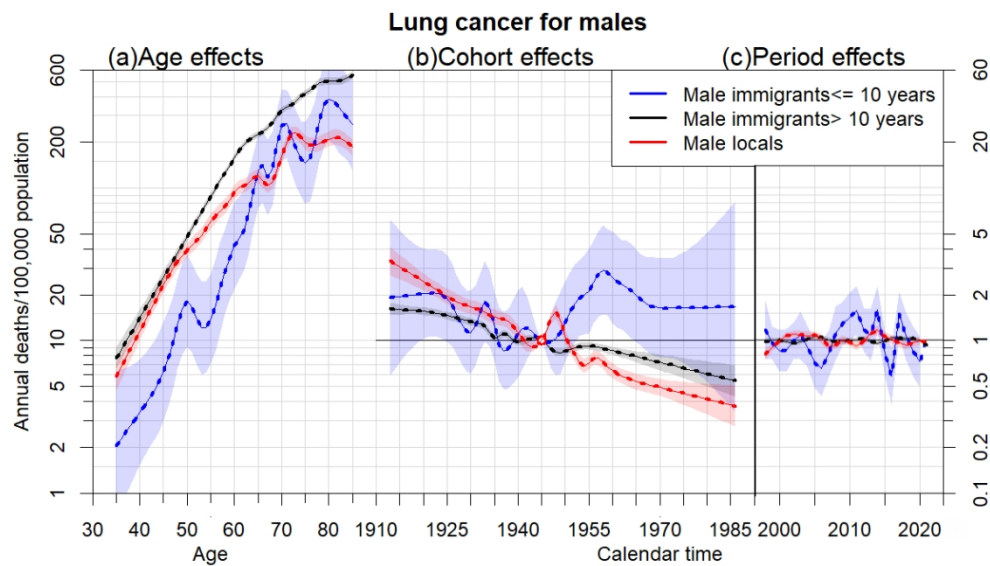


Figure 1. Parameter estimates of age (a), cohort (b) and period (c) effects based on an age-period-cohort model of male lung cancer mortality rates by immigrant groups: locals, immigrants stay in Hong Kong for more than 10 years and immigrants stay in Hong Kong for less than or equal to 10 years. Age effect was assessed by mortality (left axis). Cohort and period effects were assessed by relative risk (right axis), 95% confidence intervals are shown as shaded bands.

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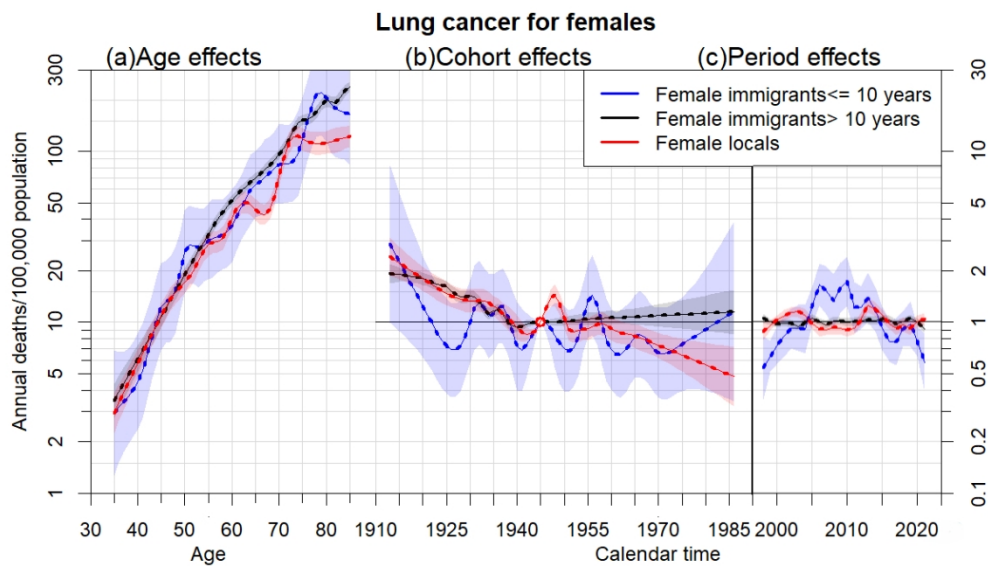


Figure 2. Parameter estimates of age (a), cohort (b) and period (c) effects based on an age-period-cohort model of female lung cancer mortality rates by immigrant groups: locals, immigrants stay in Hong Kong for more than 10 years and immigrants stay in Hong Kong for less than or equal to 10 years. Age effect was assessed by mortality (left axis). Cohort and period effects were assessed by relative risk (right axis), 95% confidence intervals are shown as shaded bands.

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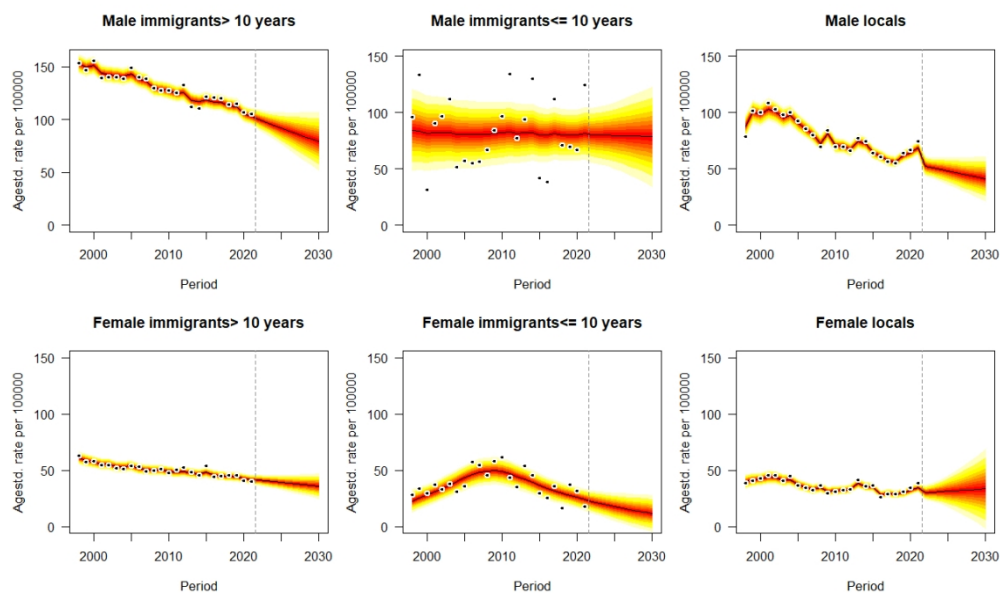


Figure 3. Projections of lung cancer mortality rates by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.

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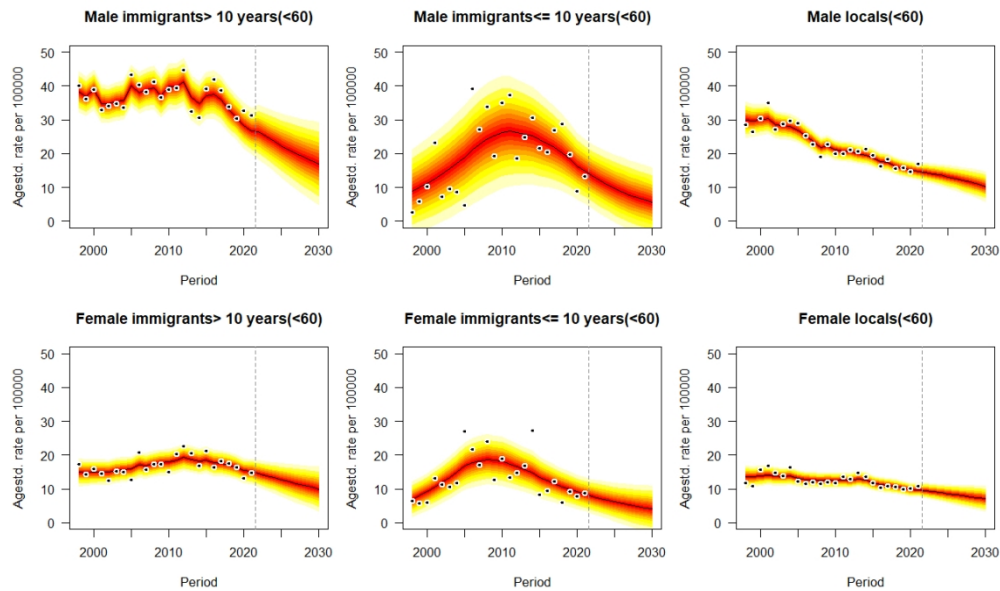


Figure 4. Projections of lung cancer mortality rates for the population younger than 60 by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.

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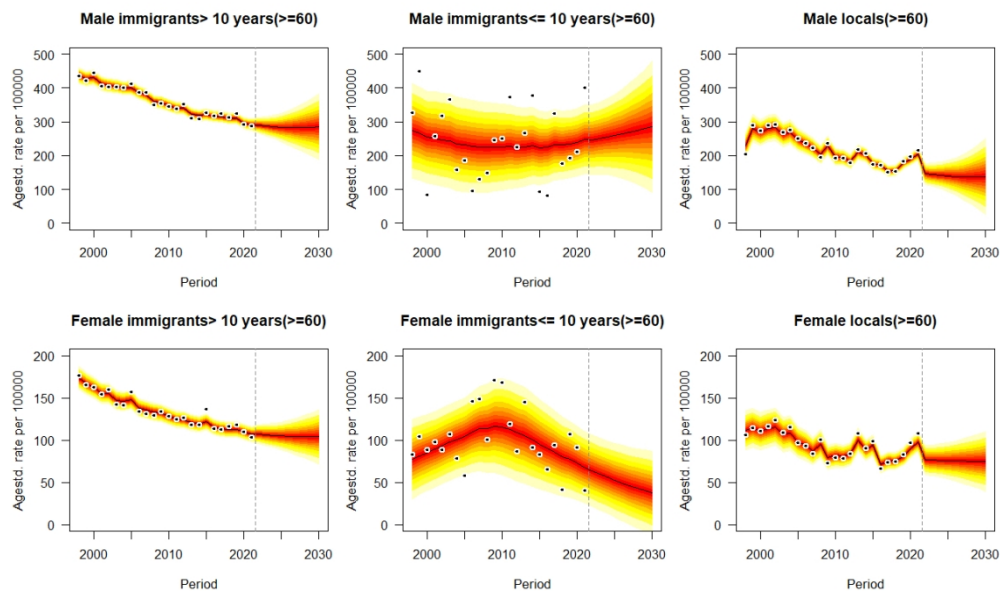


Figure 5. Projections of lung cancer mortality rates for the population older than or equal to 60 by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.

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4 **Supplementary Material for**
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8 **“An age-period-cohort analysis and projection of cancer mortality in**
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10 **Hong Kong, 1998–2030”**
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20 **APC Figures**

21
22 eFigure 1(a) Colon cancer3
23 eFigure 1(b) Liver cancer4
24 eFigure 1(c) Pancreatic cancer5
25 eFigure 1(d) Stomach cancer6
26 eFigure 1(e) Prostate cancer7
27
28
29
30
31

32 **Projection Figures**

33 Colon cancer
34
35 eFigure 2(a)Projection (all ages)8
36 eFigure 2(b)Projection (<60 years)9
37 eFigure 2(c)Projection (≥ 60 years) 10
38
39
40 Liver cancer
41
42 eFigure 3(a)Projection (all ages) 11
43 eFigure 3(b)Projection (<60 years) 12
44 eFigure 3(c)Projection (≥ 60 years) 13
45
46
47 Pancreatic cancer
48
49 eFigure 4(a)Projection (all ages) 14
50 eFigure 4(b)Projection (<60 years) 15
51 eFigure 4(c)Projection (≥ 60 years) 16
52
53
54 Stomach cancer
55
56 eFigure 5(a)Projection (all ages) 17
57 eFigure 5(b)Projection (<60 years) 18
58
59
60

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eFigure 5(c)Projection (≥ 60 years)..... 19

Prostate cancer

eFigure 6 Projection (all ages, < 60 years and ≥ 60 years)..... 20

Tables

eTable 1 Lung cancer..... 21

eTable 2 Colon cancer..... 22

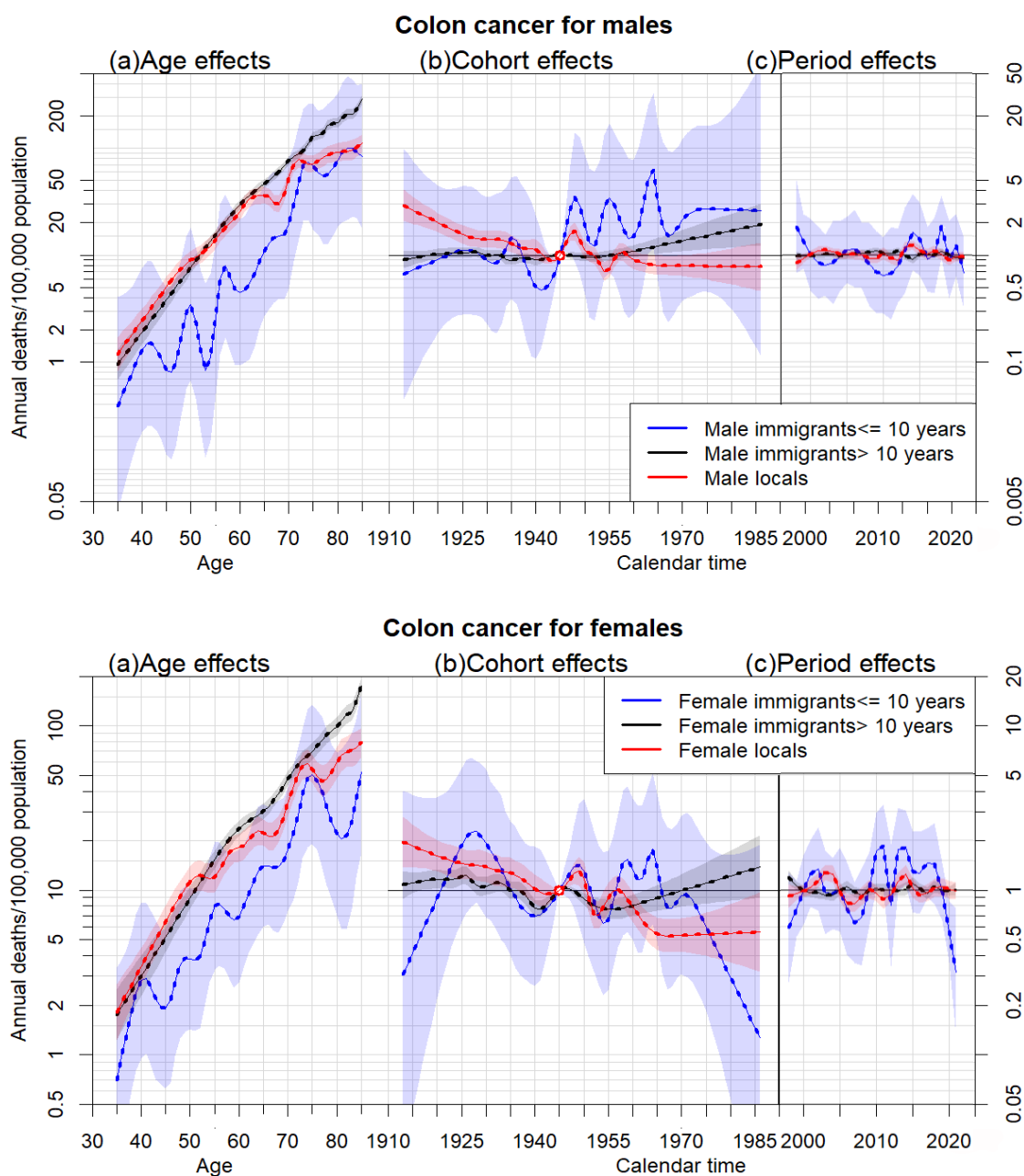
eTable 3 Liver cancer 23

eTable 4 Pancreatic cancer 24

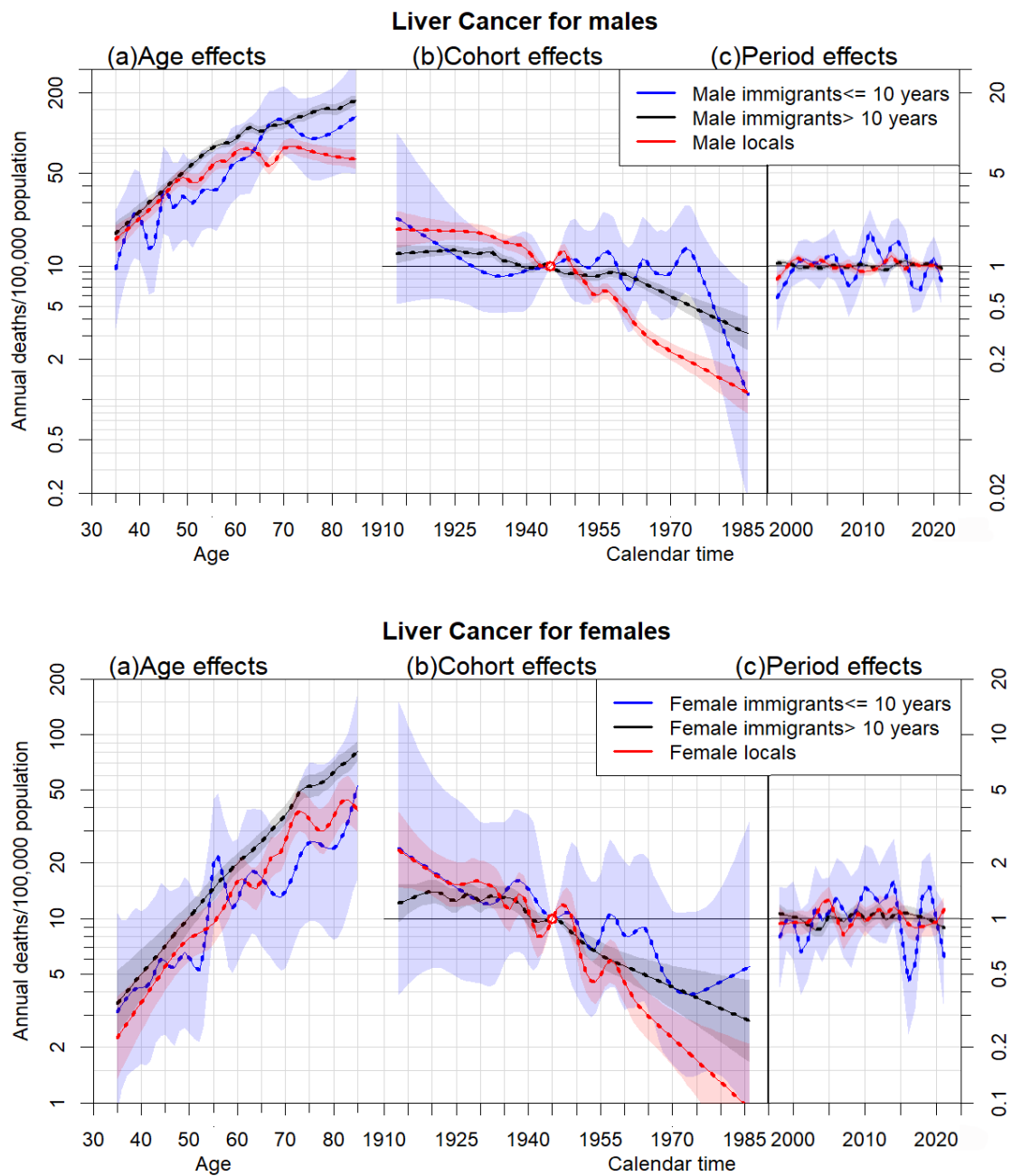
eTable 5 Stomach cancer 25

eTable 6 Prostate cancer 26

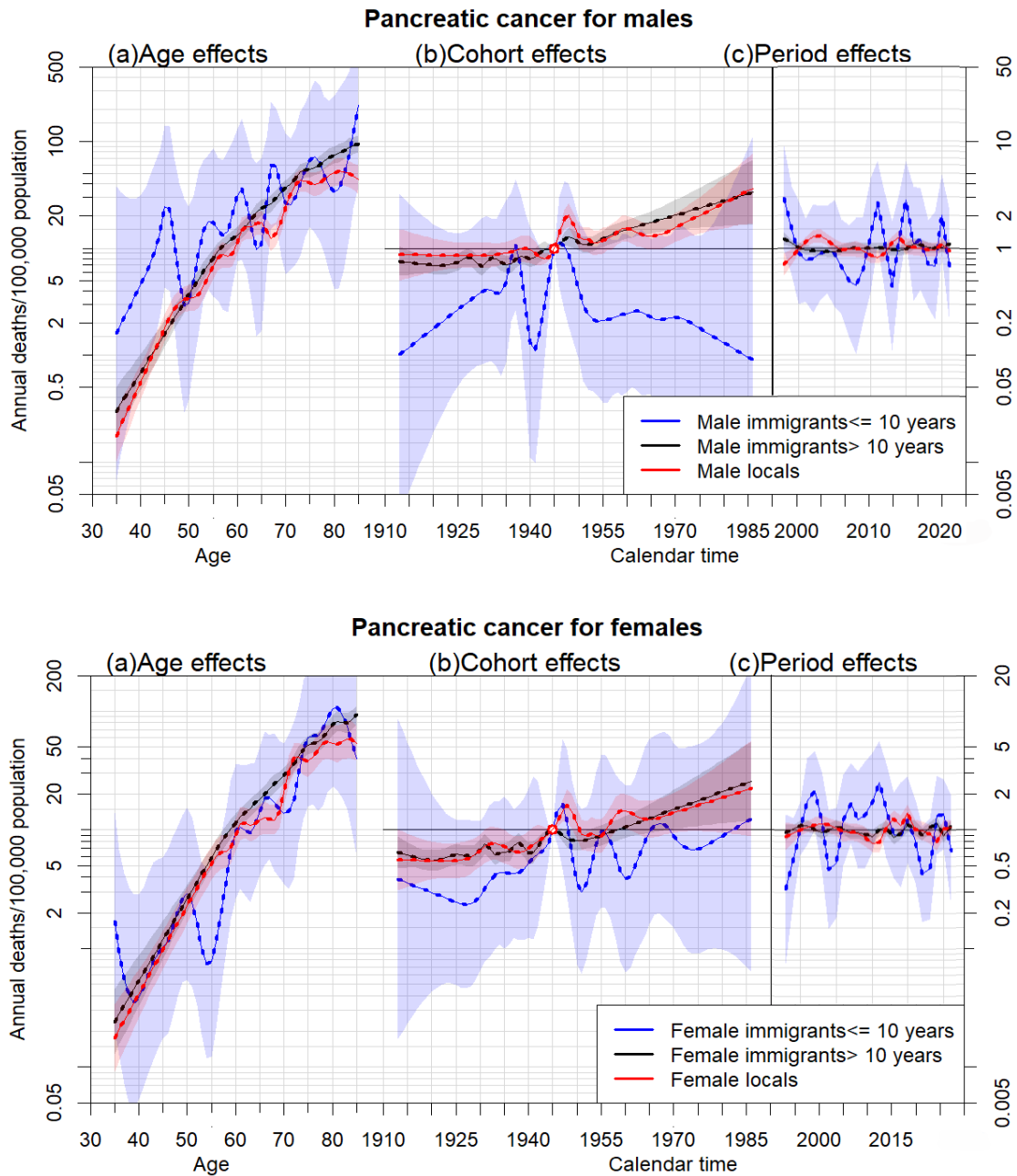
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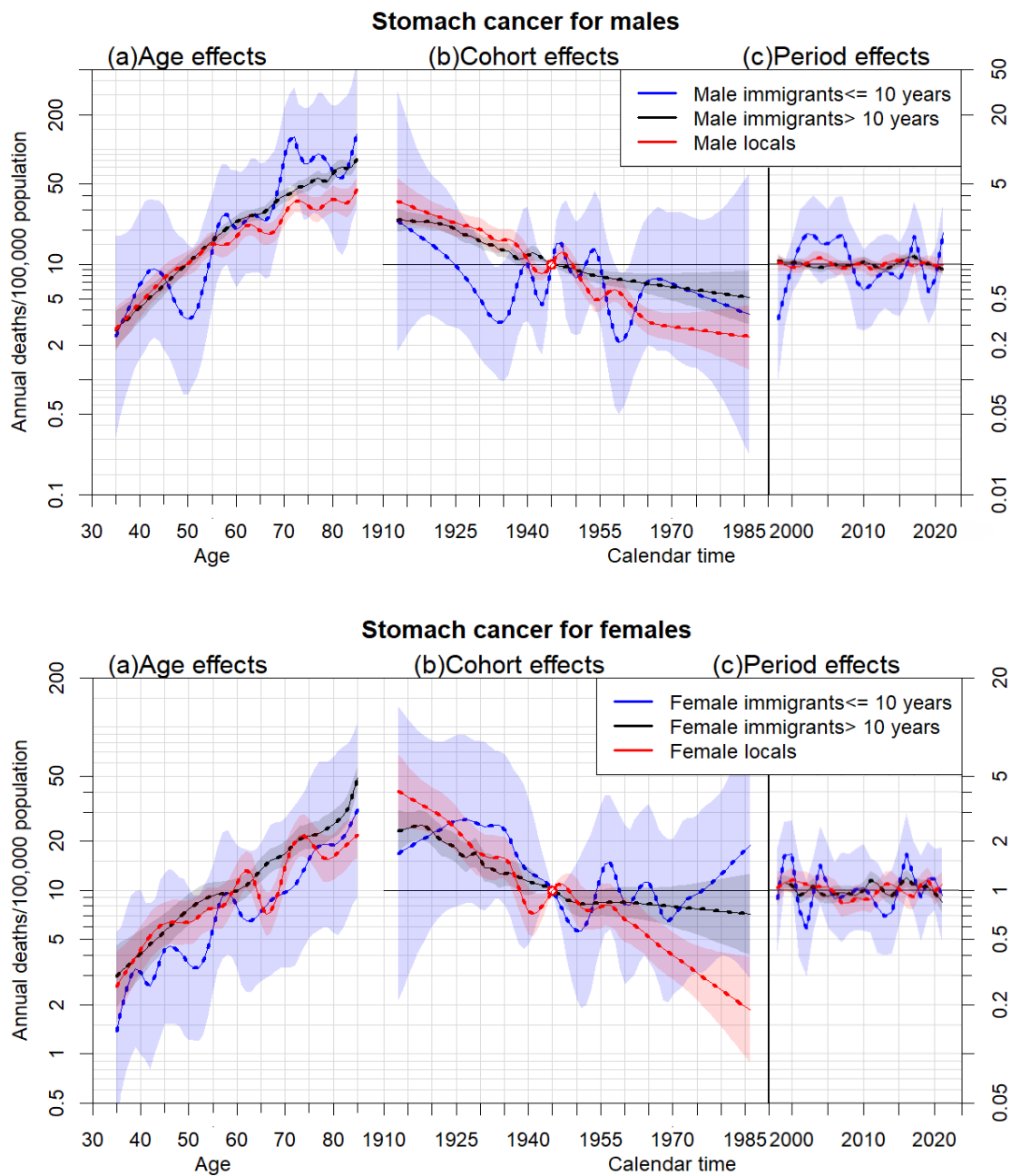
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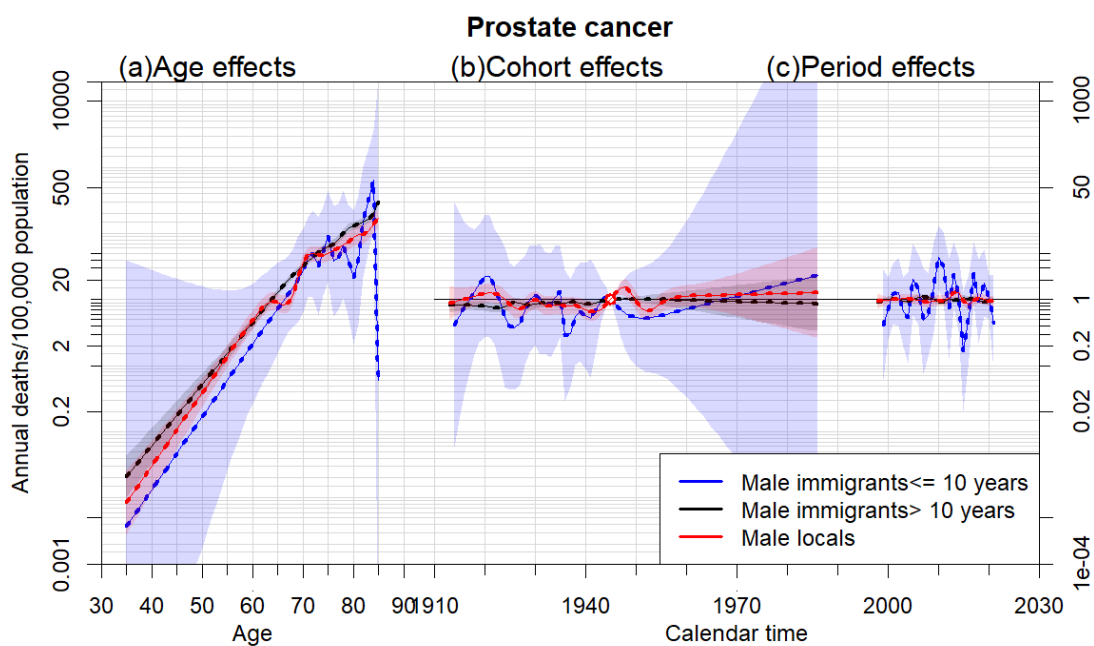
eFigure 1(b). Parameter estimates of age (a), cohort (b) and period (c) effects based on an age-period-cohort model of male and female liver cancer mortality rates by immigrant groups: locals, immigrants stay in Hong Kong for more than 10 years and immigrants stay in Hong Kong for less than or equal to 10 years. Age effect was assessed by mortality (left axis). Cohort and period effects were assessed by relative risk (right axis), 95% confidence intervals are shown as shaded bands.



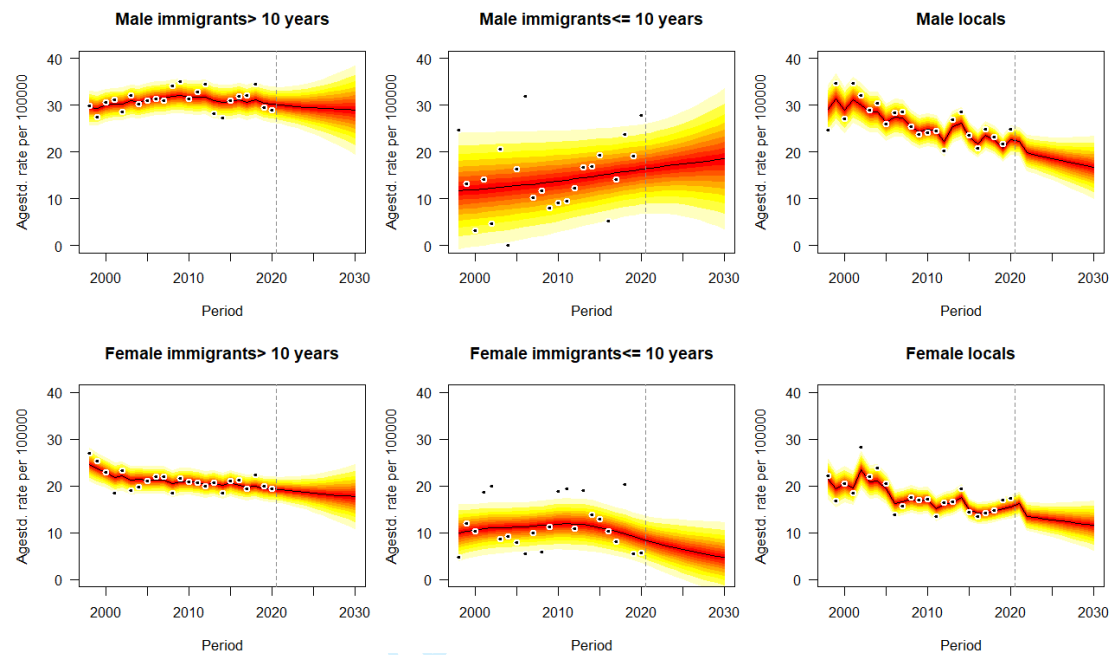
eFigure 1(c). Parameter estimates of age (a), cohort (b) and period (c) effects based on an age-period-cohort model of male and female pancreatic cancer mortality rates by immigrant groups: locals, immigrants stay in Hong Kong for more than 10 years and immigrants stay in Hong Kong for less than or equal to 10 years. Age effect was assessed by mortality (left axis). Cohort and period effects were assessed by relative risk (right axis), 95% confidence intervals are shown as shaded bands.



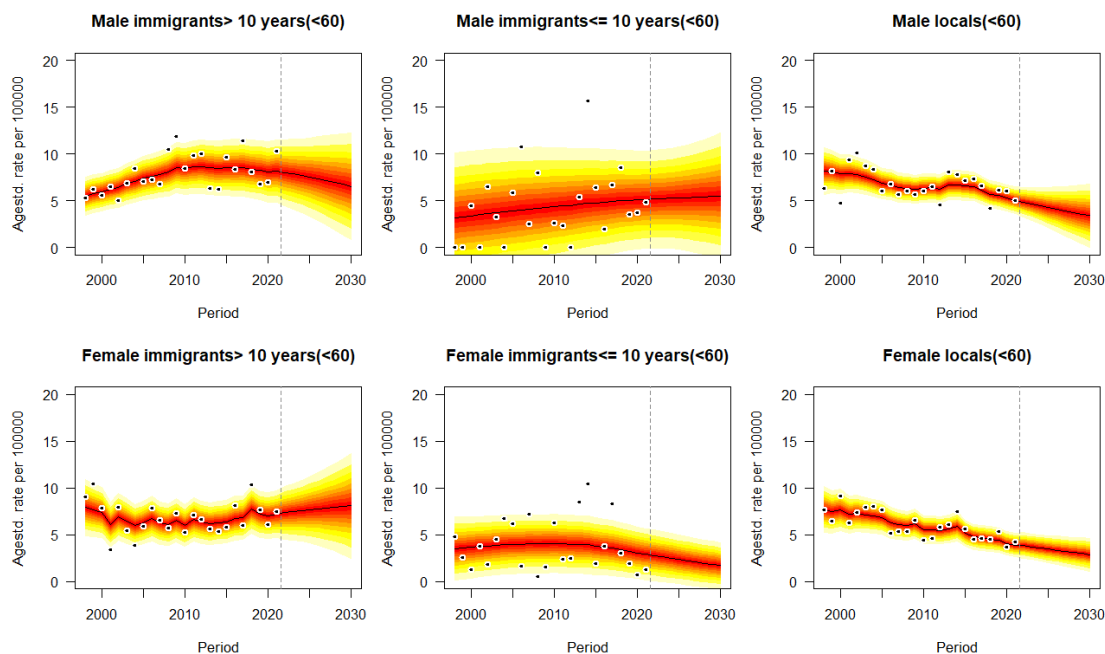
eFigure 1(d). Parameter estimates of age (a), cohort (b) and period (c) effects based on an age-period-cohort model of male and female stomach cancer mortality rates by immigrant groups: locals, immigrants stay in Hong Kong for more than 10 years and immigrants stay in Hong Kong for less than or equal to 10 years. Age effect was assessed by mortality (left axis). Cohort and period effects were assessed by relative risk (right axis), 95% confidence intervals are shown as shaded bands.



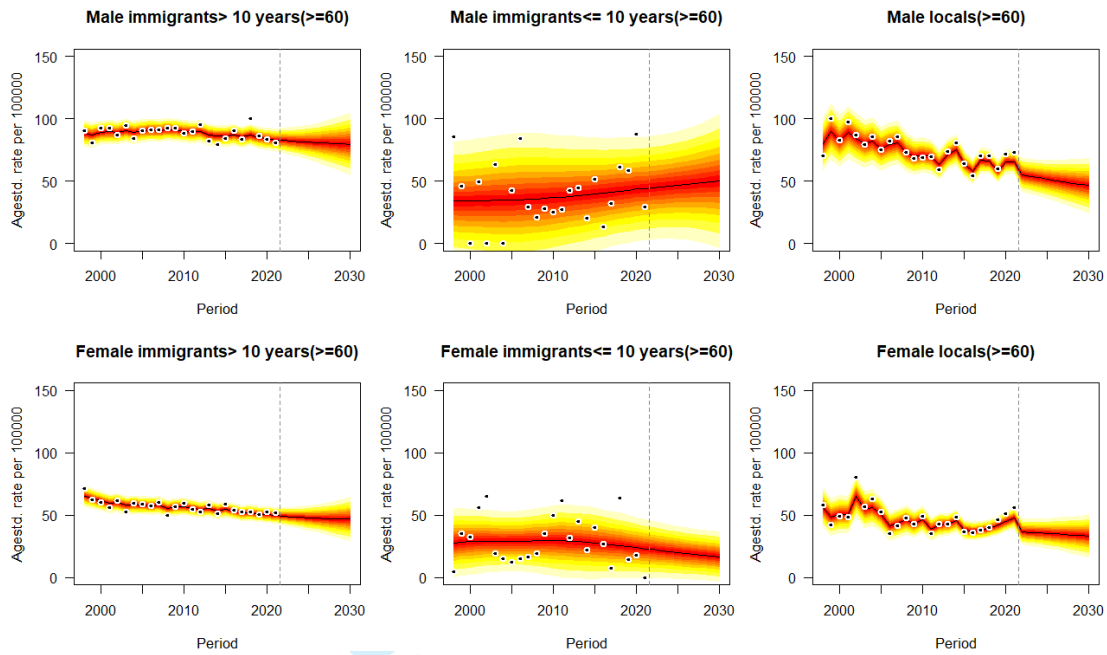
eFigure 1(e). Parameter estimates of age (a), cohort (b) and period (c) effects based on an age-period-cohort model of male prostate cancer mortality rates by immigrant groups: locals, immigrants stay in Hong Kong for more than 10 years and immigrants stay in Hong Kong for less than or equal to 10 years. Age effect was assessed by mortality (left axis). Cohort and period effects were assessed by relative risk (right axis), 95% confidence intervals are shown as shaded bands.



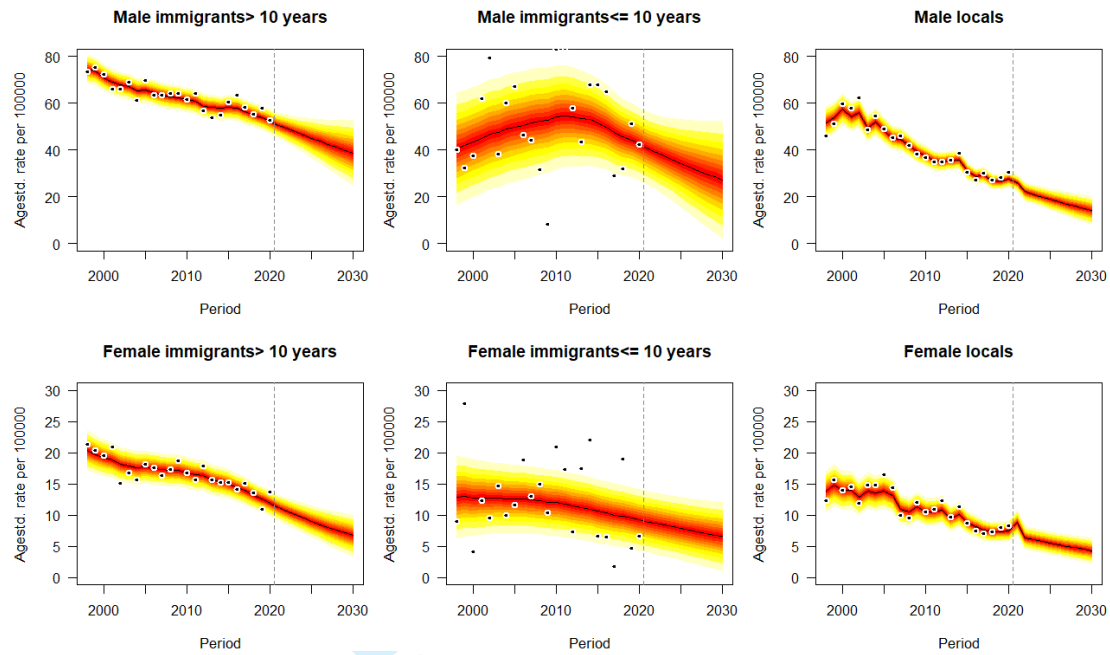
eFigure 2(a). Projections of colon cancer mortality rates by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



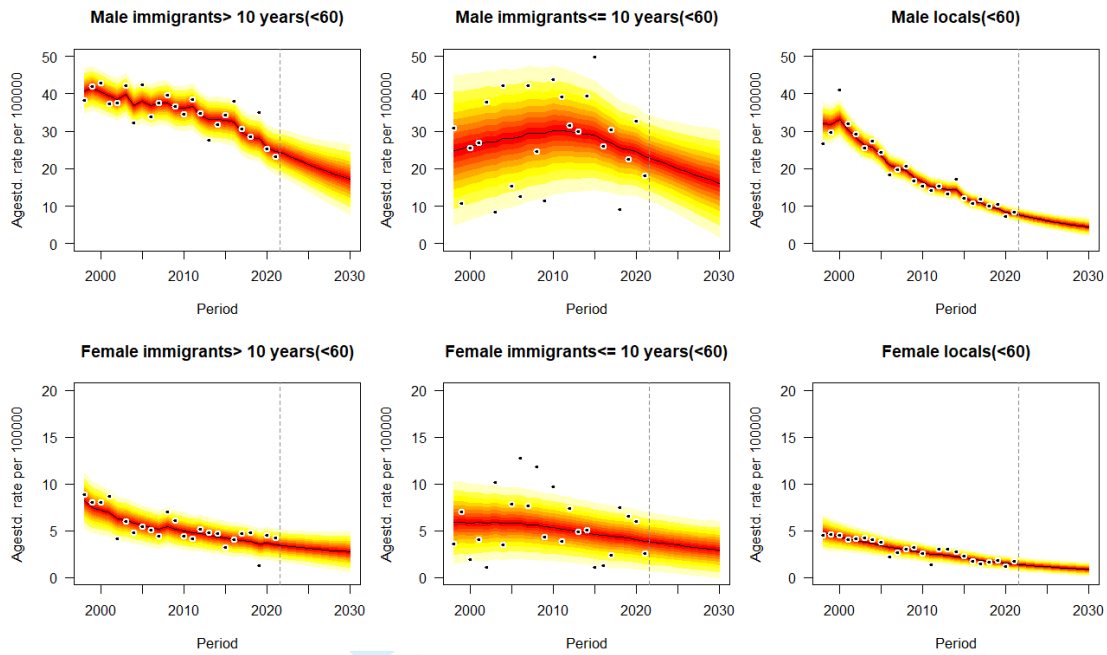
eFigure 2(b). Projections of colon cancer mortality rates for the population younger than 60 by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



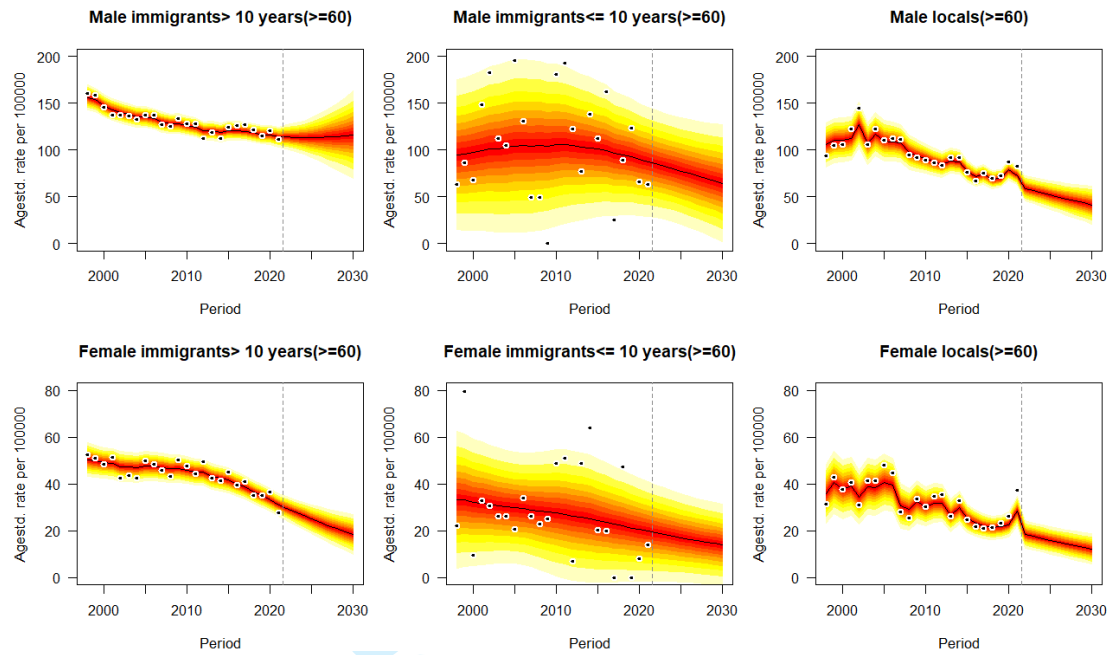
eFigure 2(c). Projections of colon cancer mortality rates for the population older than or equal to 60 by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



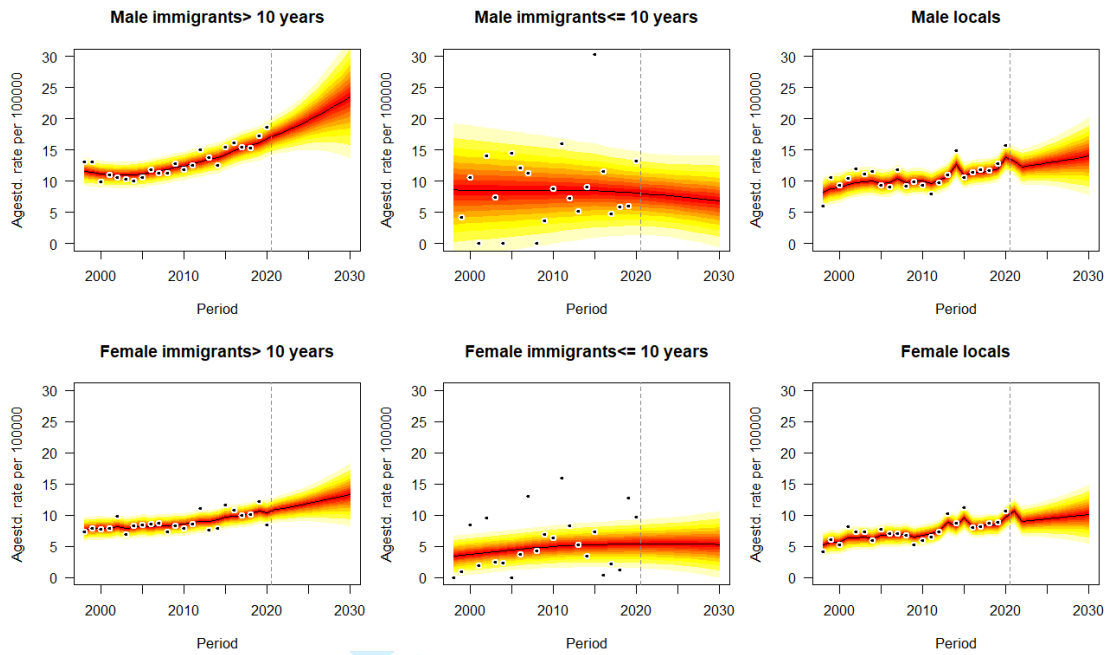
eFigure 3(a). Projections of liver cancer mortality rates by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



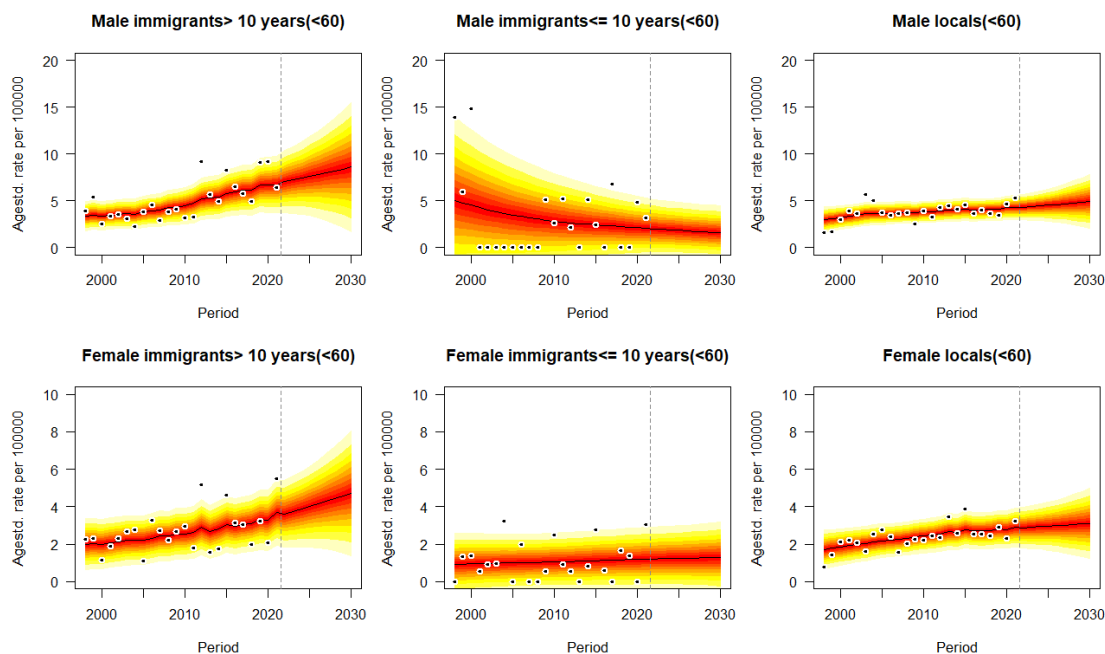
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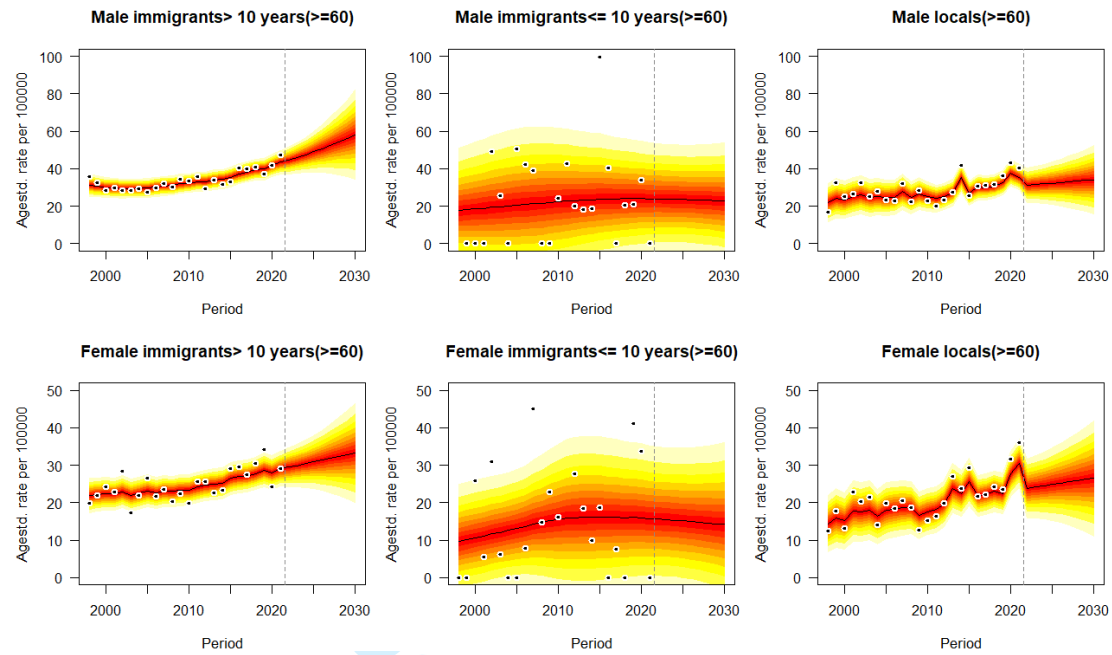
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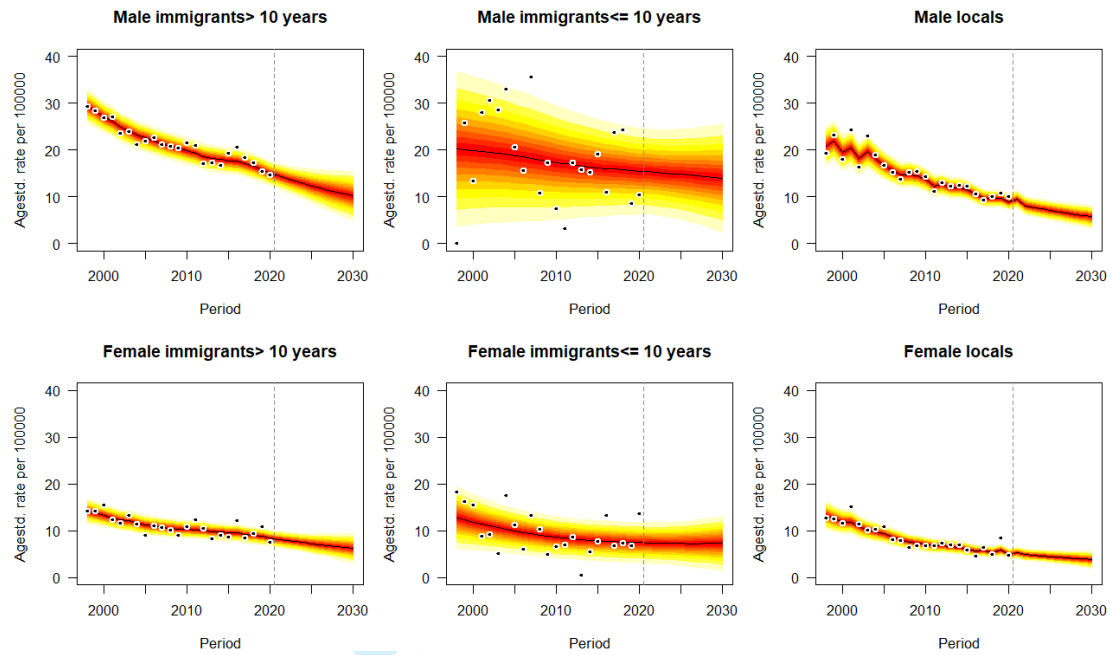
eFigure 4(a). Projections of pancreatic cancer mortality rates by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



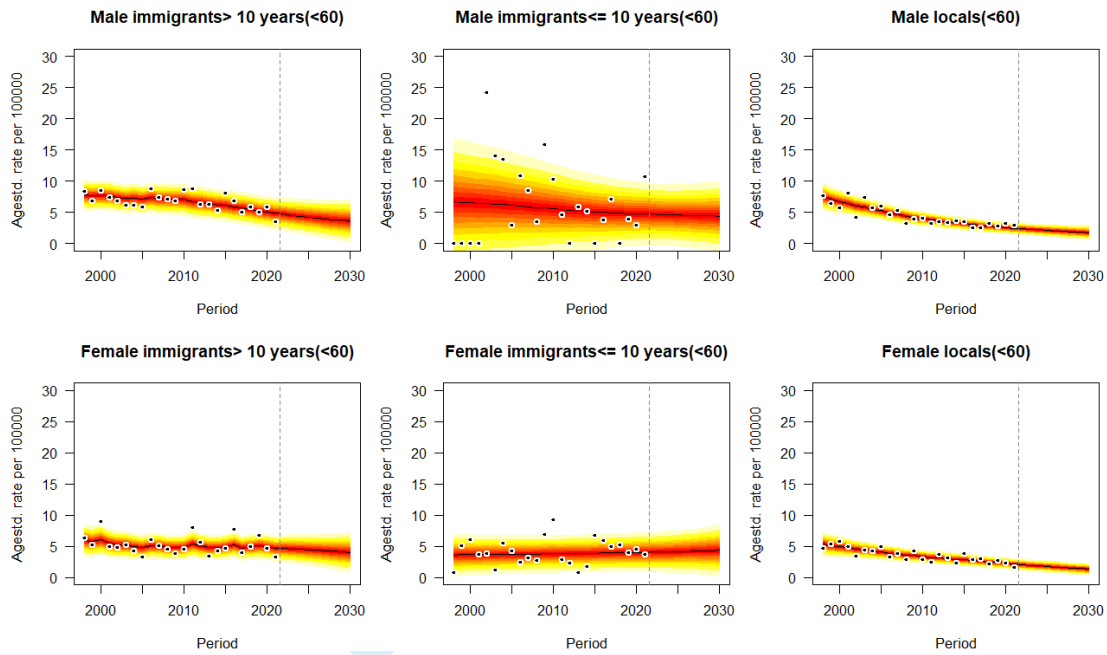
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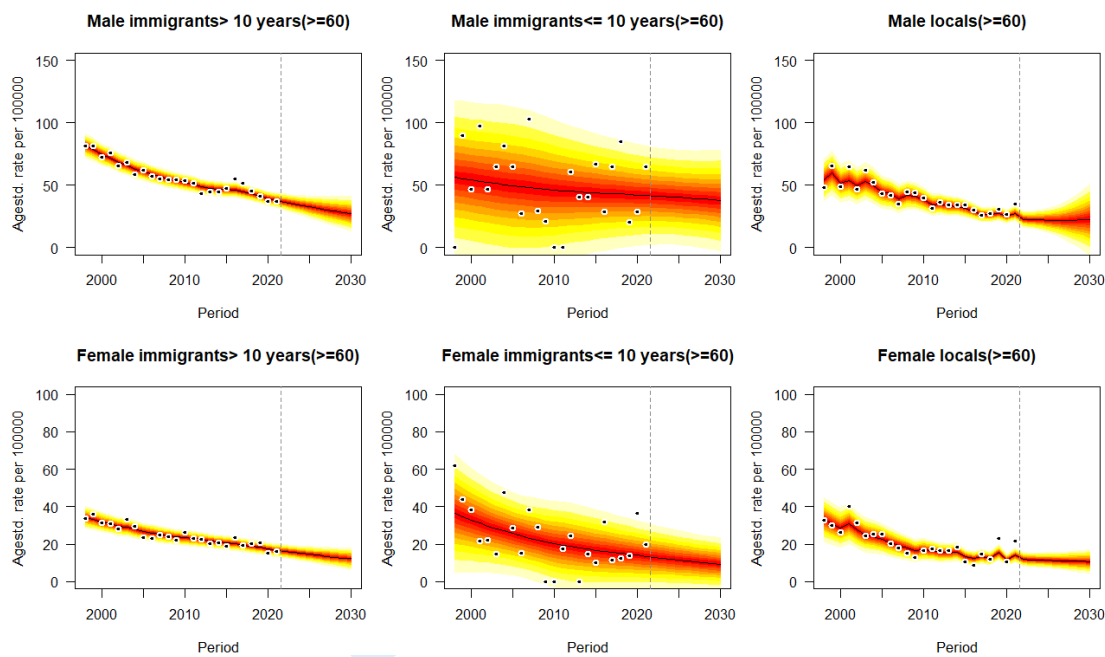
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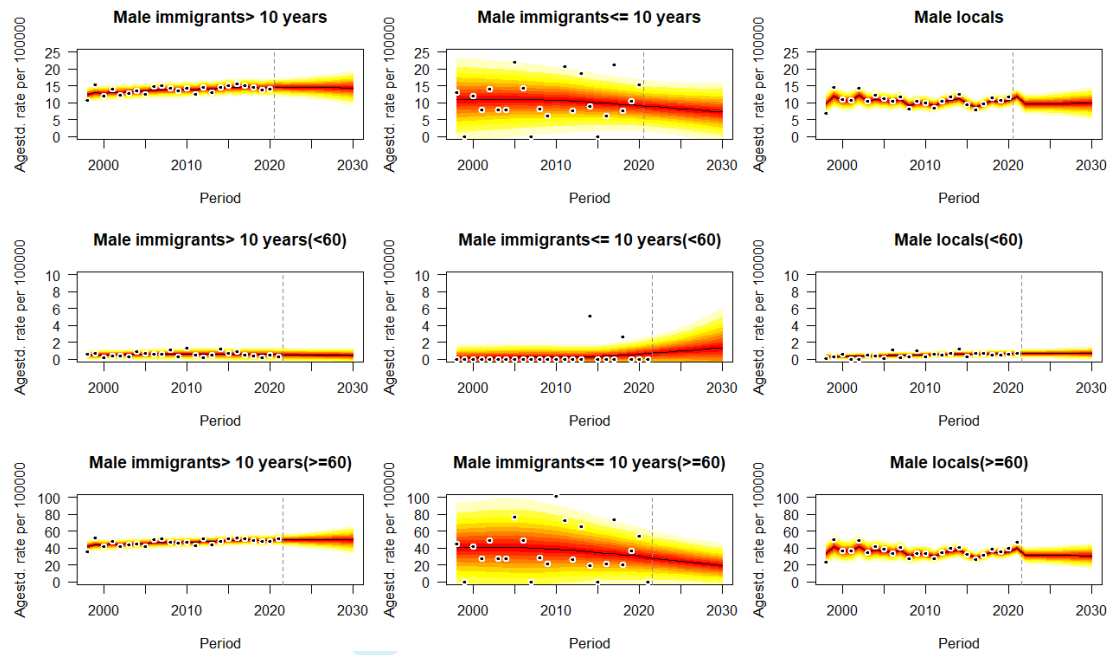
eFigure 5(a). Projections of stomach cancer mortality rates by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



eFigure 5(b). Projections of stomach cancer mortality rates for the population younger than 60 by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



eFigure 5(c). Projections of stomach cancer mortality rates for the population older than or equal to 60 by gender and immigrant status from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.



eFigure 6. Projections of prostate cancer mortality rates for males by immigrant status and age groups (less than, greater than or equal to 60 years old) from 2022 to 2030. Observations are shown as dots with the predictive distribution between the 5% and 95% quantile, whereby each lighter shade of red represents an additional 10% predictive CI. The predictive mean is shown as black solid line and the vertical dashed line indicates where prediction started.

Predictive mean of age-standardized mortality rates of lung cancer per 100,000 population										
Year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Female immigrants >10	41.80 (1.27)	41.34 (1.86)	40.58 (2.27)	39.87 (2.75)	39.19 (3.28)	38.53 (3.86)	37.89 (4.46)	37.26 (5.09)	36.65 (5.74)	36.04 (6.4)
Female immigrants ≤ 10	23.92 (4.00)	22.22 (4.67)	20.56 (5.38)	19.01 (6.10)	17.57 (6.80)	16.24 (7.45)	15.00 (8.04)	13.85 (8.56)	12.79 (9.01)	11.81 (9.39)
Female locals	34.67 (1.76)	30.22 (3.54)	30.63 (4.77)	31.05 (6.38)	31.48 (8.29)	31.9 (10.47)	32.32 (12.87)	32.73 (15.48)	33.15 (18.31)	33.55 (21.33)
Male immigrants >10	102.90 (2.43)	100.18 (4.18)	97.18 (5.33)	94.34 (6.72)	91.71 (8.24)	89.15 (9.84)	86.66 (11.47)	84.19 (13.11)	81.81 (14.74)	79.55 (16.37)
Male immigrants ≤10	81.26 (9.21)	79.90 (10.41)	79.81 (11.82)	79.72 (13.42)	79.62 (15.19)	79.50 (17.09)	79.32 (19.09)	79.08 (21.18)	78.78 (23.32)	78.41 (25.53)
Male locals	60.96 (2.82)	52.27 (4.86)	50.83 (5.39)	49.56 (6.13)	48.18 (6.97)	46.64 (7.84)	45.13 (8.76)	43.83 (9.76)	42.67 (10.8)	41.43 (11.8)
Female immigrants >10(<60y)	15.51 (1.12)	14.51 (1.50)	13.90 (1.76)	13.29 (2.04)	12.71 (2.33)	12.13 (2.62)	11.57 (2.91)	11.02 (3.18)	10.49 (3.43)	9.98 (3.68)
Female immigrants ≤ 10(<60y)	8.14 (1.91)	7.79 (1.95)	7.18(2.23)	6.62(2.53)	6.10(2.81)	5.63(3.08)	5.19(3.32)	4.79 (3.53)	4.42 (3.72)	4.09 (3.88)
Female locals(<60y)	10.25 (0.77)	9.48 (0.89)	9.17(1.02)	8.87(1.16)	8.57(1.32)	8.27(1.49)	7.97(1.65)	7.68 (1.82)	7.38 (1.98)	7.09 (2.13)
Male immigrants >10(<60y)	27.81 (2.10)	26.36 (3.58)	24.96 (3.94)	23.64 (4.35)	22.38 (4.79)	21.17 (5.23)	20.03 (5.67)	18.96 (6.10)	17.96 (6.51)	17.03 (6.90)
Male immigrants ≤ 10(<60y)	15.01 (2.98)	13.38 (3.71)	12.02 (4.17)	10.79 (4.59)	9.68 (4.95)	8.69 (5.24)	7.79 (5.46)	6.98 (5.61)	6.25 (5.69)	5.59 (5.72)
Male locals(<60y)	15.19 (0.78)	14.45 (1.15)	14.03 (1.29)	13.61 (1.46)	13.14 (1.64)	12.65 (1.82)	12.13 (2.01)	11.55 (2.17)	10.93 (2.31)	10.26 (2.43)
Female immigrants >10(≥ 60y)	108.85 (4.80)	107.21 (5.17)	106.26 (6.24)	105.52 (7.54)	104.94 (9.04)	104.51 (10.72)	104.21 (12.57)	104.07 (14.61)	104.06 (16.78)	104.16 (19.14)
Female immigrants ≤ 10(≥60y)	66.16 (13.25)	63.84 (15.72)	59.88 (17.50)	56.14 (19.31)	52.60 (21.03)	49.27 (22.66)	46.14 (24.16)	43.20 (25.52)	40.44 (26.74)	37.85 (27.81)
Female locals(≥60y)	77.33 (9.40)	76.53 (10.11)	76.22 (10.85)	75.94 (11.79)	75.69 (12.94)	75.49 (14.28)	75.32 (15.80)	75.19 (17.48)	75.10 (19.33)	75.03 (21.32)
Male immigrants >10(≥60y)	293.56 (9.13)	289.8 (11.7)	286.6 (15.19)	284.28 (19.51)	282.78 (24.49)	281.99 (30.07)	281.88 (36.31)	282.31 (43.15)	283.37 (50.66)	285.03 (58.86)
Male immigrants ≤ 10(≥60y)	244.88 (30.29)	247.01 (36.85)	251.24 (42.94)	255.62 (50.06)	260.14 (58.14)	264.82 (67.14)	269.61 (77.01)	274.52 (87.75)	279.55 (99.34)	284.69 (111.81)
Male locals(≥60y)	150.75 (16.22)	146.29 (18.46)	143.54 (20.58)	141.84 (23.97)	140.07 (28.24)	138.14 (33.39)	136.65 (39.82)	136.49 (47.87)	137.24 (57.47)	138.26 (68.52)

eTable 1. Predictive means and standard deviations (in brackets) of age-standardized mortality rates of lung cancer per 100,000 population for each gender, age group (less than, greater or equal to 60 years old) and immigrant status from 2022 to 2030. Reported means and standard deviations (in brackets) of age-standardized mortality rates in 2021 are also listed.

Predictive mean of age-standardized mortality rates of colon cancer per 100,000 population										
Year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Female immigrants >10	20.03 (0.95)	18.95 (1.13)	18.77 (1.37)	18.59 (1.66)	18.42 (1.98)	18.27 (2.33)	18.12 (2.71)	17.98 (3.11)	17.85 (3.53)	17.73 (3.96)
Female immigrants ≤ 10	8.11 (2.19)	7.70 (2.51)	7.25 (2.81)	6.82 (3.11)	6.42 (3.37)	6.03 (3.61)	5.67 (3.83)	5.33 (4.01)	5.01 (4.17)	4.71 (4.31)
Female locals	13.77 (1.30)	13.47 (1.61)	13.24 (1.72)	13.01 (1.87)	12.77 (2.04)	12.53 (2.24)	12.29 (2.46)	12.06 (2.68)	11.82 (2.92)	11.59 (3.16)
Male immigrants >10	31.22 (1.28)	29.82 (1.46)	29.66 (1.79)	29.52 (2.19)	29.41 (2.63)	29.30 (3.11)	29.21 (3.64)	29.14 (4.19)	29.06 (4.78)	28.98 (5.39)
Male immigrants ≤10	15.47 (2.14)	16.77 (3.77)	17.02 (4.18)	17.23 (4.64)	17.45 (5.14)	17.67 (5.69)	17.88 (6.27)	18.09 (6.91)	18.31 (7.56)	18.50 (8.26)
Male locals	21.28 (1.38)	19.81 (2.07)	19.39 (2.22)	18.97 (2.42)	18.57 (2.61)	18.18 (2.85)	17.81 (3.12)	17.43 (3.40)	17.06 (3.71)	16.71 (4.03)
Female immigrants >10(<60y)	7.09 (0.99)	7.36 (1.12)	7.46 (1.28)	7.56 (1.46)	7.65 (1.68)	7.74 (1.92)	7.83 (2.19)	7.92 (2.48)	8.01 (2.79)	8.09 (3.13)
Female immigrants ≤ 10(<60y)	3.11 (0.67)	2.82 (0.86)	2.65 (0.91)	2.51 (0.97)	2.36 (1.02)	2.22 (1.07)	2.08 (1.11)	1.95 (1.14)	1.83 (1.18)	1.72 (1.22)
Female locals(<60y)	4.10 (0.41)	3.87 (0.50)	3.73 (0.54)	3.61 (0.59)	3.47 (0.65)	3.34 (0.70)	3.22 (0.76)	3.11 (0.82)	2.99 (0.88)	2.88 (0.94)
Male immigrants >10(<60y)	8.29 (0.91)	7.98 (1.17)	7.85 (1.38)	7.71 (1.60)	7.54 (1.83)	7.36 (2.08)	7.17(2.32)	6.97(2.57)	6.76(2.81)	6.55(3.05)
Male immigrants ≤ 10(<60y)	5.03 (1.44)	5.18 (1.58)	5.22 (1.75)	5.26 (1.93)	5.30 (2.14)	5.34 (2.36)	5.38(2.59)	5.43(2.84)	5.47(3.11)	5.51(3.38)
Male locals(<60y)	5.14 (0.43)	4.88 (0.63)	4.66 (0.79)	4.46 (0.96)	4.26 (1.13)	4.08 (1.31)	3.91(1.48)	3.73(1.65)	3.57(1.82)	3.42(1.97)
Female immigrants >10(≥60y)	52.16 (2.59)	49.21 (2.99)	48.70 (3.56)	48.26 (4.26)	47.87 (5.05)	47.54 (5.94)	47.26 (6.90)	47.05 (7.94)	46.91 (9.06)	46.81 (10.26)
Female immigrants ≤ 10(≥60y)	24.01 (5.83)	22.44 (6.56)	21.69 (6.96)	20.95 (7.38)	20.23 (7.80)	19.52 (8.23)	18.84 (8.66)	18.17 (9.08)	17.51 (9.49)	16.86 (9.90)
Female locals(≥60y)	37.42 (5.31)	36.69 (5.74)	36.29 (6.06)	35.87 (6.46)	35.46 (6.95)	35.04 (7.5)	34.61 (8.12)	34.19 (8.79)	33.77 (9.51)	33.34 (10.27)
Male immigrants >10(≥60y)	84.17 (3.55)	82.72 (4.09)	82.16 (4.95)	81.64 (5.97)	81.19 (7.12)	80.81 (8.39)	80.47 (9.77)	80.15 (11.24)	79.85 (12.81)	79.56 (14.45)
Male immigrants ≤ 10(≥60y)	43.25 (11.07)	44.93 (13.09)	45.62 (14.52)	46.30 (16.09)	46.96 (17.80)	47.61 (19.64)	48.25 (21.62)	48.88 (23.73)	49.51 (25.97)	50.13 (28.34)
Male locals(≥60y)	55.79 (6.86)	54.89 (7.65)	53.75 (8.03)	52.63 (8.52)	51.54 (9.12)	50.47 (9.8)	49.43 (10.55)	48.42 (11.37)	47.42 (12.25)	46.44 (13.16)

eTable 2. Predictive means and standard deviations (in brackets) of age-standardized mortality rates of colon cancer per 100,000 population for each gender, age group (less than, greater or equal to 60 years old) and immigrant status from 2022 to 2030. Reported means and standard deviations (in brackets) of age-standardized mortality rates in 2021 are also listed.

Predictive mean of age-standardized mortality rates of liver cancer per 100,000 population										
Year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Female immigrants >10	11.34 (0.66)	10.68 (0.71)	10.09 (0.85)	9.54 (1.01)	9.01 (1.16)	8.50 (1.31)	8.02(1.45)	7.57(1.59)	7.14(1.72)	6.74(1.83)
Female immigrants ≤10	9.15 (1.55)	8.66 (1.82)	8.38 (1.95)	8.11 (2.08)	7.84 (2.22)	7.58 (2.36)	7.32(2.49)	7.07(2.63)	6.82(2.76)	6.58(2.88)
Female locals	6.72 (0.69)	6.36 (0.88)	6.08 (0.90)	5.81 (0.93)	5.53 (0.97)	5.26 (1.01)	5.01(1.06)	4.77(1.11)	4.53(1.15)	4.3(1.21)
Male immigrants >10	52.17 (1.78)	49.22 (2.36)	47.76 (2.93)	46.35 (3.59)	45.01 (4.31)	43.67 (5.05)	42.37 (5.81)	41.1(6.56)	39.89 (7.33)	38.71 (8.08)
Male immigrants ≤10	42.33 (5.87)	39.03 (6.49)	37.39 (7.47)	35.81 (8.51)	34.26 (9.58)	32.76 (10.63)	31.31 (11.65)	29.91 (12.62)	28.56 (13.54)	27.25 (14.40)
Male locals	24.22 (1.77)	22.16 (2.09)	21.02 (2.22)	19.91 (2.39)	18.85 (2.58)	17.83 (2.79)	16.85 (3.03)	15.92 (3.21)	15.03 (3.40)	14.18 (3.59)
Female immigrants >10(<60y)	3.62 (0.45)	3.39 (0.52)	3.29 (0.57)	3.20 (0.63)	3.12 (0.69)	3.04 (0.75)	2.96(0.82)	2.89(0.89)	2.82(0.96)	2.75(1.03)
Female immigrants ≤10(<60y)	4.10 (0.79)	3.81 (0.91)	3.69 (0.96)	3.57 (1.02)	3.46 (1.08)	3.36 (1.15)	3.25(1.22)	3.15(1.29)	3.06(1.36)	2.97(1.43)
Female locals(<60y)	1.50 (0.13)	1.37 (0.2)	1.29 (0.21)	1.22 (0.23)	1.16 (0.24)	1.10 (0.26)	1.04(0.27)	0.99(0.29)	0.94(0.30)	0.89(0.31)
Male immigrants >10(<60y)	26.32 (2.11)	24.04 (2.35)	23.02 (2.63)	22.05 (2.94)	21.13 (3.27)	20.25 (3.61)	19.41 (3.95)	18.62 (4.30)	17.86 (4.64)	17.14 (4.98)
Male immigrants ≤10(<60y)	25.52 (2.99)	22.56 (3.96)	21.71 (4.44)	20.87 (4.94)	20.04 (5.45)	19.22 (5.95)	18.42 (6.45)	17.63 (6.91)	16.86 (7.36)	16.11 (7.78)
Male locals(<60y)	8.25 (0.69)	7.47 (0.74)	6.97 (0.79)	6.52 (0.86)	6.11 (0.93)	5.73 (1.01)	5.38(1.08)	5.04(1.15)	4.73(1.21)	4.44(1.27)
Female immigrants >10(≥60y)	33.67 (1.88)	29.63 (2.01)	27.99 (2.36)	26.42 (2.75)	24.92 (3.14)	23.49 (3.52)	22.13 (3.88)	20.85 (4.23)	19.64 (4.55)	18.50 (4.85)
Female immigrants ≤10(≥60y)	21.72 (5.11)	19.08 (5.81)	18.38 (6.14)	17.71 (6.48)	17.03 (6.83)	16.39 (7.16)	15.76 (7.49)	15.16 (7.80)	14.57 (8.11)	14.01 (8.39)
Female locals(≥60y)	20.63 (3.03)	18.41 (3.23)	17.55 (3.26)	16.72 (3.32)	15.91 (3.40)	15.11 (3.49)	14.34 (3.59)	13.59 (3.69)	12.87 (3.81)	12.17 (3.93)
Male immigrants >10(≥60y)	115.39 (4.54)	113.96 (5.95)	113.43 (7.65)	113.17 (9.70)	113.16 (12.04)	113.37 (14.66)	113.79 (17.56)	114.39 (20.73)	115.19 (24.18)	116.17 (27.91)
Male immigrants ≤10(≥60y)	88.61 (15.58)	85.14 (18.85)	82.59 (20.6)	80.02 (22.44)	77.42 (24.34)	74.83 (26.24)	72.23 (28.12)	69.64 (29.94)	67.07 (31.70)	64.52 (33.38)
Male locals(≥60y)	62.88 (5.97)	58.95 (7.91)	56.51 (8.20)	54.14 (8.61)	51.84 (9.12)	49.61 (9.70)	47.46 (10.33)	45.38 (11.01)	43.38 (11.68)	41.45 (12.36)

eTable 3. Predictive means and standard deviations (in brackets) of age-standardized mortality rates of liver cancer per 100,000 population for each gender, age group (less than, greater or equal to 60 years old) and immigrant status from 2022 to 2030. Reported means and standard deviations (in brackets) of age-standardized mortality rates in 2021 are also listed.

Predictive mean of age-standardized mortality rates of pancreatic cancer per 100,000 population										
Year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Female immigrants >10	10.89 (0.62)	11.11 (0.75)	11.36 (0.91)	11.61 (1.09)	11.87 (1.31)	12.14 (1.56)	12.42 (1.84)	12.71 (2.15)	13.01 (2.48)	13.3(2.85)
Female immigrants ≤ 10	5.51 (1.44)	5.44 (1.56)	5.44 (1.69)	5.43(1.84)	5.42(1.99)	5.41(2.15)	5.39(2.32)	5.36(2.49)	5.34(2.66)	5.31(2.84)
Female locals	8.79 (1.10)	9.01 (1.22)	9.15 (1.34)	9.29(1.48)	9.43(1.64)	9.57(1.83)	9.71(2.05)	9.85(2.28)	9.99(2.54)	10.14 (2.83)
Male immigrants >10	16.30 (0.98)	17.87 (1.19)	18.48 (1.49)	19.11 (1.87)	19.78 (2.32)	20.47 (2.83)	21.18 (3.42)	21.92 (4.07)	22.69 (4.81)	23.49 (5.61)
Male immigrants ≤ 10	8.10 (2.02)	7.87 (2.37)	7.76 (2.53)	7.64(2.70)	7.51(2.87)	7.38(3.05)	7.24(3.23)	7.09(3.41)	6.95(3.58)	6.81(3.75)
Male locals	11.97 (1.26)	12.29 (1.49)	12.49 (1.64)	12.69 (1.83)	12.91 (2.06)	13.11 (2.33)	13.33 (2.63)	13.55 (2.97)	13.78 (3.34)	14.02 (3.74)
Female immigrants >10(<60y)	3.47 (0.33)	3.62 (0.57)	3.74 (0.66)	3.87(0.77)	4.01(0.89)	4.14(1.02)	4.28(1.18)	4.42(1.34)	4.57(1.53)	4.72(1.73)
Female immigrants ≤ 10(<60y)	1.12 (0.33)	1.21 (0.48)	1.22 (0.52)	1.23(0.56)	1.24(0.61)	1.25(0.66)	1.26(0.71)	1.26(0.77)	1.27(0.83)	1.28(0.89)
Female locals(<60y)	2.76 (0.27)	2.88 (0.36)	2.91 (0.41)	2.93(0.48)	2.96(0.55)	2.99(0.63)	3.02(0.71)	3.04(0.81)	3.07(0.90)	3.10(1.01)
Male immigrants >10(<60y)	6.88 (0.98)	7.05 (1.11)	7.24 (1.32)	7.43(1.56)	7.62(1.84)	7.82(2.16)	8.01(2.50)	8.21(2.88)	8.40(3.30)	8.61(3.75)
Male immigrants ≤ 10(<60y)	2.20 (0.71)	2.01 (0.85)	1.95 (0.91)	1.9(0.94)	1.84(0.99)	1.79(1.04)	1.74(1.09)	1.69(1.14)	1.64(1.19)	1.60(1.24)
Male locals(<60y)	4.16 (0.35)	4.33 (0.48)	4.41 (0.57)	4.46(0.68)	4.53(0.81)	4.61(0.94)	4.69(1.09)	4.77(1.26)	4.85(1.44)	4.93(1.63)
Female immigrants >10(≥60y)	28.58 (1.83)	29.45 (2.11)	29.91 (2.54)	30.38 (3.06)	30.85 (3.66)	31.33 (4.33)	31.81 (5.08)	32.29 (5.91)	32.78 (6.79)	33.27 (7.74)
Female immigrants ≤ 10(≥60y)	16.79 (5.29)	15.65 (6.08)	15.49 (6.71)	15.33 (7.36)	15.16 (8.03)	14.97 (8.73)	14.79 (9.43)	14.59 (10.14)	14.39 (10.86)	14.19 (11.58)
Female locals(≥60y)	22.80 (4.23)	23.85 (4.46)	24.21 (4.81)	24.56 (5.23)	24.91 (5.73)	25.25 (6.30)	25.58 (6.95)	25.90 (7.67)	26.22 (8.47)	26.54 (9.34)
Male immigrants >10(≥60y)	42.70 (2.55)	44.36 (3.02)	45.85 (3.76)	47.41 (4.69)	49.04 (5.78)	50.73 (7.05)	52.48 (8.50)	54.28 (10.13)	56.16 (11.95)	58.11 (13.98)
Male immigrants ≤ 10(≥60y)	24.68 (8.21)	23.96 (9.01)	23.87 (9.74)	23.75 (10.52)	23.61 (11.33)	23.45 (12.17)	23.28 (13.04)	23.09 (13.93)	22.89 (14.83)	22.68 (15.75)
Male locals(≥60y)	30.10 (4.68)	31.17 (5.22)	31.55 (5.63)	31.93 (6.14)	32.30 (6.75)	32.66 (7.45)	33.01 (8.23)	33.35 (9.11)	33.69 (10.08)	34.03 (11.12)

eTable 4. Predictive means and standard deviations (in brackets) of age-standardized mortality rates of pancreatic cancer per 100,000 population for each gender, age group (less than, greater or equal to 60 years old) and immigrant status from 2022 to 2030. Reported means and standard deviations (in brackets) of age-standardized mortality rates in 2021 are also listed.

Predictive mean of age-standardized mortality rates of stomach cancer per 100,000 population										
Year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Female immigrants >10	8.20 (0.55)	7.95 (0.62)	7.71 (0.74)	7.47 (0.87)	7.25 (1.01)	7.03 (1.15)	6.83 (1.29)	6.62 (1.43)	6.43 (1.57)	6.24 (1.71)
Female immigrants ≤ 10	7.51 (1.44)	7.36 (1.56)	7.33 (1.69)	7.30 (1.85)	7.28 (2.01)	7.27 (2.20)	7.27 (2.40)	7.28 (2.61)	7.31 (2.84)	7.33 (3.09)
Female locals	5.26 (0.40)	4.91 (0.52)	4.75 (0.57)	4.61 (0.63)	4.47 (0.71)	4.34 (0.77)	4.21 (0.84)	4.08 (0.91)	3.95 (0.99)	3.83 (1.06)
Male immigrants >10	15.22 (0.64)	13.89 (0.97)	13.34(1.21)	12.81 (1.46)	12.31 (1.73)	11.83 (1.99)	11.38 (2.26)	10.95 (2.51)	10.54 (2.76)	10.15 (3.01)
Male immigrants ≤10	15.83 (3.04)	15.21 (3.38)	15.07 (3.67)	14.93 (3.98)	14.79 (4.31)	14.64 (4.65)	14.51 (5.02)	14.35 (5.39)	14.19 (5.78)	14.03 (6.17)
Male locals	8.14 (0.89)	8.07 (0.99)	7.73 (1.03)	7.41(1.07)	7.10 (1.13)	6.81 (1.19)	6.51 (1.26)	6.23 (1.33)	5.97 (1.39)	5.71 (1.46)
Female immigrants >10(<60y)	4.81 (0.56)	4.69 (0.79)	4.62 (0.87)	4.55 (0.96)	4.47 (1.07)	4.39 (1.17)	4.31 (1.29)	4.22 (1.41)	4.13 (1.52)	4.03 (1.64)
Female immigrants ≤ 10(<60y)	3.89 (0.80)	4.08 (0.93)	4.10 (1.03)	4.13 (1.14)	4.17 (1.27)	4.21 (1.41)	4.24 (1.55)	4.28 (1.70)	4.32 (1.87)	4.36 (2.05)
Female locals(<60y)	2.28 (0.21)	2.08 (0.27)	1.98 (0.29)	1.88 (0.32)	1.79 (0.35)	1.71 (0.37)	1.61 (0.41)	1.53 (0.43)	1.44 (0.45)	1.37 (0.47)
Male immigrants >10(<60y)	4.94 (0.57)	4.71 (0.79)	4.55 (0.89)	4.41 (0.99)	4.25 (1.10)	4.12 (1.21)	3.98 (1.32)	3.86 (1.43)	3.74 (1.54)	3.63 (1.65)
Male immigrants ≤ 10(<60y)	4.81 (1.31)	4.70 (1.42)	4.66 (1.55)	4.63 (1.69)	4.59 (1.83)	4.55 (1.99)	4.52 (2.15)	4.48 (2.32)	4.44 (2.50)	4.41 (2.68)
Male locals(<60y)	2.48 (0.21)	2.37 (0.29)	2.28 (0.32)	2.21 (0.35)	2.12 (0.38)	2.04 (0.42)	1.97 (0.45)	1.91 (0.49)	1.83 (0.52)	1.77(0.55)
Female immigrants >10(≥60y)	17.80 (1.04)	16.23 (1.26)	15.65 (1.47)	15.08 (1.70)	14.55 (1.94)	14.03 (2.18)	13.54 (2.43)	13.07 (2.68)	12.62 (2.92)	12.19 (3.16)
Female immigrants ≤ 10(≥60y)	14.72 (4.29)	13.01 (4.83)	12.52 (5.11)	12.03 (5.37)	11.55 (5.63)	11.08 (5.88)	10.63 (6.12)	10.19 (6.35)	9.76(6.56)	9.34 (6.75)
Female locals(≥60y)	12.20 (1.66)	11.86 (1.84)	11.67 (1.98)	11.49 (2.15)	11.33 (2.35)	11.18 (2.58)	11.04 (2.84)	10.91 (3.11)	10.79(3.4)	10.68 (3.71)
Male immigrants >10(≥ 60y)	37.23 (2.29)	36.59 (2.56)	35.17(3.18)	33.82 (3.86)	32.55 (4.57)	31.34 (5.28)	30.19 (6.01)	29.08 (6.70)	28.02 (7.40)	27.01 (8.07)
Male immigrants ≤ 10(≥60y)	42.30 (10.88)	41.43 (11.78)	41.03 (12.71)	40.61 (13.70)	40.17 (14.75)	39.71 (15.85)	39.24 (16.99)	38.75 (18.16)	38.23 (19.35)	37.71 (20.57)
Male locals(≥60y)	23.04 (3.29)	22.69 (3.56)	22.37(4.07)	22.16(4.84)	21.89 (5.86)	21.61 (7.22)	21.52 (9.02)	21.74 (11.29)	22.17 (14.03)	22.73 (17.28)

eTable 5. Predictive means and standard deviations (in brackets) of age-standardized mortality rates of stomach cancer per 100,000 population for each gender, age group (less than, greater or equal to 60 years old) and immigrant status from 2022 to 2030. Reported means and standard deviations (in brackets) of age-standardized mortality rates in 2021 are also listed.

Predictive mean of age-standardized mortality rates of prostate cancer per 100,000 population										
Year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Male immigrants >10	14.81 (0.61)	14.59 (0.79)	14.57 (0.96)	14.56 (1.15)	14.54 (1.37)	14.51 (1.61)	14.48 (1.86)	14.45 (2.13)	14.42 (2.42)	14.38 (2.72)
Male immigrants ≤10	9.03 (2.95)	8.78 (3.11)	8.58 (3.29)	8.39 (3.49)	8.19(3.69)	8.10(3.89)	7.82(4.11)	7.63(4.31)	7.45(4.51)	7.27(4.72)
Male locals	9.54 (1.40)	9.66 (1.57)	9.67 (1.66)	9.69 (1.77)	9.72(1.91)	9.75(2.06)	9.78(2.23)	9.82(2.43)	9.86(2.64)	9.9(2.88)
Male immigrants >10(<60y)	0.57 (0.12)	0.52 (0.17)	0.51 (0.19)	0.50 (0.21)	0.49(0.22)	0.48(0.24)	0.47(0.25)	0.46(0.27)	0.45(0.29)	0.44(0.31)
Male immigrants ≤10(<60y)	0.65 (0.59)	0.73 (0.77)	0.81 (0.93)	0.87 (1.10)	0.94(1.31)	1.01(1.51)	1.09(1.75)	1.16(2.02)	1.24(2.32)	1.33(2.64)
Male locals(<60y)	0.63 (0.12)	0.66 (0.14)	0.66 (0.16)	0.66 (0.19)	0.67(0.21)	0.67(0.24)	0.67(0.27)	0.68(0.31)	0.68(0.33)	0.69(0.37)
Male immigrants >10(≥60y)	49.43 (2.59)	49.61 (2.73)	49.63 (3.29)	49.64 (3.94)	49.64 (4.68)	49.64 (5.51)	49.63 (6.38)	49.62 (7.32)	49.61 (8.32)	49.58(9.37)
Male immigrants ≤10(≥60y)	28.29 (9.15)	27.66 (9.78)	26.53 (10.21)	25.4 (10.63)	24.28 (11.03)	23.16 (11.41)	22.07 (11.76)	21.01 (12.09)	19.96 (12.38)	18.95(12.63)
Male locals(≥60y)	31.57 (5.17)	31.48 (5.49)	31.40 (5.76)	31.32 (6.09)	31.24 (6.48)	31.15 (6.94)	31.06 (7.44)	30.96 (8.01)	30.86 (8.61)	30.74(9.26)

eTable 6. Predictive means and standard deviations (in brackets) of age-standardized mortality rates of prostate cancer per 100,000 population for each age group (less than, greater or equal to 60 years old) and immigrant status from 2022 to 2030. Reported means and standard deviations (in brackets) of age-standardized mortality rates in 2021 are also listed.

Reporting checklist for cohort study.

Based on the STROBE cohort guidelines.

Instructions to authors

Complete this checklist by entering the page numbers from your manuscript where readers will find each of the items listed below.

Your article may not currently address all the items on the checklist. Please modify your text to include the missing information. If you are certain that an item does not apply, please write "n/a" and provide a short explanation.

Upload your completed checklist as an extra file when you submit to a journal.

In your methods section, say that you used the STROBE cohort reporting guidelines, and cite them as:

von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The Strengthening of Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies.

		Reporting Item	Page Number
Title and abstract			
Title	#1a	Indicate the study's design with a commonly used term in the title or the abstract	1
Abstract	#1b	Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background / rationale	#2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	#3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	#4	Present key elements of study design early in the paper	5
Setting	#5	Describe the setting, locations, and relevant dates, including periods	5

1			of recruitment, exposure, follow-up, and data collection	
2	Eligibility criteria	#6a	Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up.	5
3				
4				
5				
6	Eligibility criteria	#6b	For matched studies, give matching criteria and number of exposed and unexposed	n/a
7				
8				
9				
10	Variables	#7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
11				
12				
13				
14				
15	Data sources /	#8	For each variable of interest give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group. Give information separately for for exposed and unexposed groups if applicable.	5
16	measurement			
17				
18				
19				
20				
21				
22	Bias	#9	Describe any efforts to address potential sources of bias	5
23				
24	Study size	#10	Explain how the study size was arrived at	5
25				
26				
27	Quantitative	#11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why	5
28	variables			
29				
30				
31	Statistical	#12a	Describe all statistical methods, including those used to control for confounding	
32	methods			
33				
34	5			
35				
36				
37	Statistical	#12b	Describe any methods used to examine subgroups and interactions	5
38	methods			
39				
40				
41	Statistical	#12c	Explain how missing data were addressed	5
42	methods			
43				
44	Statistical	#12d	If applicable, explain how loss to follow-up was addressed	n/a
45	methods			
46				
47				
48	Statistical	#12e	Describe any sensitivity analyses	
49	methods			
50				
51				
52	n/a			
53				
54	Results			
55				
56				
57	Participants	#13a	Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible,	n/a
58				
59				
60				

included in the study, completing follow-up, and analysed. Give information separately for for exposed and unexposed groups if applicable.

1			
2			
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5			
6	Participants	#13b	Give reasons for non-participation at each stage 5
7			
8	Participants	#13c	Consider use of a flow diagram
9			
10	n/a		
11			
12	Descriptive data	#14a	Give characteristics of study participants (eg demographic, clinical, 5
13			social) and information on exposures and potential confounders. Give
14			information separately for exposed and unexposed groups if
15			applicable.
16			
17			
18			
19	Descriptive data	#14b	Indicate number of participants with missing data for each variable of
20			interest
21			
22			
23	n/a		
24			
25	Descriptive data	#14c	Summarise follow-up time (eg, average and total amount)
26			
27	n/a		
28			
29			
30	Outcome data	#15	Report numbers of outcome events or summary measures over time.
31			Give information separately for exposed and unexposed groups if
32			applicable.
33			
34			
35	n/a		
36			
37			
38	Main results	#16a	Give unadjusted estimates and, if applicable, confounder-adjusted 6
39			estimates and their precision (eg, 95% confidence interval). Make
40			clear which confounders were adjusted for and why they were
41			included
42			
43			
44	Main results	#16b	Report category boundaries when continuous variables were n/a
45			categorized
46			
47			
48	Main results	#16c	If relevant, consider translating estimates of relative risk into absolute
49			risk for a meaningful time period
50			
51			
52	n/a		
53			
54	Other analyses	#17	Report other analyses done—eg analyses of subgroups and 7
55			interactions, and sensitivity analyses
56			
57			

Discussion

1	Key results	#18	Summarise key results with reference to study objectives	8
2				
3	Limitations	#19	Discuss limitations of the study, taking into account sources of	10
4			potential bias or imprecision. Discuss both direction and magnitude of	
5			any potential bias.	
6				
7				
8	Interpretation	#20	Give a cautious overall interpretation considering objectives,	8
9			limitations, multiplicity of analyses, results from similar studies, and	
10			other relevant evidence.	
11				
12				
13	Generalisability	#21	Discuss the generalisability (external validity) of the study results	9
14				
15				
16	Other			
17	Information			
18				
19				
20	Funding	#22	Give the source of funding and the role of the funders for the present	11
21			study and, if applicable, for the original study on which the present	
22			article is based	
23				
24				

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