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January 2021

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Looking into the Black Box of "Medical Progress": Rising Health Expenditures by Illness Type and Age *

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January 19, 2021

Abstract

There is agreement among health economists that on the whole medical innovation causes health care expenditures (HCE) to rise. This paper analyzes for which diagnoses and in which age groups HCE per patient have grown significantly faster than average HCE. We distinguish decedents (patients in their last four years of life) from survivors and use a unique dataset comprising detailed HCE of all members of a regional health insurance fund in Upper Austria for the period 2005-2018.

Our results indicate that among decedents in particular the expenditures for treatment of neoplasms have exceeded the general trend in HCE. This confirms that medical progress for this group of diseases has been particularly strong over the last 15 years. For survivors, we find a noticeable growth in cases and cost per case for pregnancies and childbirth and also for treatment of mental and behavioral disorders.

The pattern of expenditures over age groups shows that among decedents the younger age groups (below 75) exhibit both the highest HCE per capita and the highest expenditure growth over time. For survivors, we find a steady increase in annual per capita HCE over age in both sexes, but the highest growth rates are observed in the age groups between 20 and 50 years.

Keywords: health care expenditures, medical progress, cost of dying
JEL classification: H51, J11, I19

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The usual disclaimer applies. We gratefully acknowledge financial support from the Austrian Federal Ministry of Science, Research, and Economic Affairs (bmwfw) and the National Foundation of Research, Technology, and Development.

1 Introduction

Health care expenditures (HCE) have been rising considerably faster than GDP in most OECD countries over the past 40-50 years (Chernew and Newhouse (2012), Table 1.2). In particular, in countries with a large share of public expenditures such as the German speaking ones (Austria, Germany and Switzerland), the gap between the average annual growth rate of per-capita HCE and the respective growth rate of GDP was near the top of the OECD countries with values between 1.7 and 2.7 % over the period 1970-2008. Accordingly, the share of HCE in GDP has increased enormously in all these countries and now amounts to between 10.4 and 12.4 %.[1] Extrapolating this trend into the coming decades suggests that health care financing might become a controversial political issue in the near future.

While it is still debated among health economists to what extent population aging contributes to the growth in HCE (for the opposite views, see e.g. Zweifel, Felder, and Meier (1999) and Breyer, Lorenz, and Niebel (2015)), there is much more agreement on the fact that medical innovation is a factor that on the whole causes HCE to rise. However, as Chernew and Newhouse (2012) argue in their comprehensive survey, technology (and thus the rate of innovation as such) is hard to measure, so that there are essentially two approaches to demonstrate the role of medical progress in explaining the rising HCE: In the *residual approach*, calendar time is used as a regressor in the expenditure equation, and the estimated coefficient for the trend variable is interpreted as the contribution of medical progress to the overall increase in HCE. In contrast, papers using the *affirmative approach* look at how the treatment of specific diseases such as heart attacks has evolved over time and how this has affected the costs of treating the respective patients.

Neither of these approaches is fully satisfactory in measuring the contribution of medical progress to the growth in HCE: in the residual approach, time is used merely as a proxy, but this variable will pick up the effects on HCE of all other variables which develop over time and are not explicitly included in the regression. Thus it does not answer the question to what extent medical progress raises expenditures and thus gives no hint at possible interventions which could be suitable to slow down the expenditure trend. On the other hand, when the focus is only on a few specific diseases, it is not clear how the results emanating from this research can be generalized to HCE in total.

The present paper adopts an intermediate approach. We proceed from research by Lorenz, Ihle, and Breyer (2020), who use a panel dataset from a large German sickness fund and find that age-specific HCE have increased particularly strongly in certain age groups, especially the 60 to 80 year olds, when they are in their last $3-4$ years of life. HCE towards the end of life have been a topic of health economic research ever since

[1] OECD Health Statistics: `http://stats.oecd.org/index.aspx?DataSetCode=SHA` (10-10-2017)

Ginzberg's (1980) outcry about the high cost of dying.[2]

In fact, medical expenditures peak in the last years of life: Although in most developed countries, little more than 1 % of the population dies in any given year, this group typically accounts for about 10 % of total HCE in the respective country. If the analysis is extended to all people in their last 4 years of life, the expenditure share increases to about 20 % of the total (see, e.g. the papers in French and Kelly (2016) and French et al. (2017)).

Focusing on the relatively small share of the population (people near their death), which accounts for an over-proportional share of HCE seems to be a promising approach for opening the black box of "medical progress" and attacking the question for what types of patients treatment costs have risen so much that this has contributed appreciably to the overall HCE growth. Moreover and more importantly, for patients who were about to die, it is easier to identify one particular illness with which their HCE can be associated, namely the ICD code specified as either the cause of death or, alternatively, the primary disease treated during their last hospital stay.[3] Thus the research questions to be answered in this paper are:

1. What were the most frequent causes of death and how have HCE for the respective patient groups evolved over time?

2. How has the number of patients who died from any of these diseases evolved over time?

3. In which age groups have per-capita HCE in the last years of life increased particularly strongly?

The similar procedure for patients who survived a given hospital stay for more than 4 years is more difficult because for these patients the error committed by attributing total HCE in the respective year to the (main) illness which was treated during one particular hospital episode is probably larger. However, given that the bulk of HCE is caused by this group of patients, we perform the analysis for this group, too.

Our analysis is inherently descriptive. We do not attempt to explain either individual or societal HCE, an endeavor which would require searching for "causal" factors such as income, education, social class or even the determinants of illness. Instead, the purpose of this study is to break down the trend in total HCE over time to the development in different age groups and patients suffering from different, but widespread diseases.

We draw on a unique data set from a large regional health insurance fund in Austria, more precisely the province ("Bundesland") of Upper Austria. The Upper Austrian Re-

[2]17 years earlier, Harmer (1963) wrote a book entitled "The High Cost of Dying", but this had nothing to do with health care. Instead the author complained about the costs of funerals.

[3]The cause of death specified on the death certificate is often not reliable, in particular if persons die outside a hospital. In Section A.1, we compare the frequencies of end-of-life diagnoses in health registers with the official death register's causes of death for decedents who we observe in both datasets.

gional Health Insurance Fund (OOEGKK), which covers about 75 % of the regional population (roughly 1 million insureds in any given year), provides detailed data on individual health care utilization in the inpatient and outpatient sector for the years 2005-2018.

The remainder of this paper is organized as follows. In Section 2, we give a short survey of the existing literature on the relationship between medical progress and HCE. In Section 3, we describe the data and explain the empirical strategy of estimating the determinants of HCE. The regression results are presented in Section 4, and in Section 5, we discuss the results and conclude.

2 Literature

As mentioned above, Chernew and Newhouse (2012) distinguished between the residual approach and the affirmative approach to estimate the effect of medical progress on the overall increase in HCE. The former approach goes back to the seminal paper by Newhouse (1992), who tried to explain the 780 % growth of per-capita HCE in the U.S. over the period 1940-1990 and found that only about one-quarter could be traced back to an increase in income and even including other determinants such as population aging and the spread of health insurance could explain less than half of the expenditure growth. Newhouse further noted that "trying to attribute a residual to a specific factor is an inherently frustrating exercise", but nevertheless conjectured that "the bulk of the residual increase was attributable to technological change" (p.11).

Following this approach and applying it to the time period $1960 - 2007$, Smith, Newhouse, and Freeland (2009) attributed $27-48$ % of HCE growth in the U.S. to spending on new technologies. Similarly, Di Matteo (2005) used regional panel data for the U.S. and Canada for $1975-2000$ and regressed real per-capita HCE on income, age structure of the population and year fixed effects and found that more than 60 % of the growth in HCE could be accounted for by the latter variables. For Germany, Breyer and Ulrich (2000) regressed total per-capita HCE of German sickness funds over the period $1970 - 1995$ on GDP, share of population over 65 and time and found that the latter variable accounted for a 1 percent annual growth rate in HCE, holding everything else constant. Similarly, Breyer et al. (2015) regressed real per-capita HCE by age group in Germany over a 12-year period on age, the mortality rate, the (predicted) 5-year survival rate and year and found that year fixed effects could be translated into a 2 % annual growth rate of HCE, even holding the other included variables constant. However, since GDP was not in the equation, the mentioned effect also picked up the impact of GDP growth.

The most frequently cited paper in the literature using the *affirmative approach*, the discussion paper by Cutler and McClellan (1996), started from the observation that average Medicare reimbursement per heart attack patient in the U.S. rose in real terms by 4 % annually between 1984 and 1991 and was thus in line with total per-capita HCE growth in that country, which stood at 4.7 %. The authors then showed that the "expansion of intensive cardiac surgeries accounted for essentially all of the growth in treatment costs. In contrast, the real price of heart attack treatments has been nearly constant." (p.29). The study most similar to ours is Thorpe and Howard (2006). The authors examined Medicare expenditures over the period 1987 − 2002 and first observed that two-thirds of the total change in Medicare spending was accounted for by the treatment of 10 common conditions. For each of these conditions they broke up the total change in expenditures to a change in prevalence and a change in the cost by case.[4] Interestingly, for some conditions such as cancer, hyperlipidemia and cerebrovascular disease, almost all the expenditure growth could be attributed to an increase in prevalence, whereas for others (most notably heart disease, trauma and hypertension), the by far predominant factor was a change in cost per case, which reflects technological progress.

3 Research Design

The Austrian Bismarck-type health care system guarantees universal access to services for the whole population. With very few exceptions[5], the mandatory health insurance covers all expenses for medical care in the outpatient sector, inpatient hospital treatment, and medical drugs. Nine provincial health insurance funds ("Gebietskrankenkassen") cover insurance for all private-sector employees, retirees, unemployed individuals and their co-insured dependents. Affiliation with the insurance institution is determined by place of occupation (residence) and therefore cannot be freely chosen.

3.1 Data

For our quantitative analysis, we use administrative register data provided by the *Upper Austrian Regional Health Insurance Fund.*[6] The data include detailed individual inpatient sector information such as the number and length of hospital stays, hospitalization expenditures[7], and the patient's admission diagnosis according to the ICD-10 (International Statistical Classification of Diseases and Related Health Problems) classification system.

[4]They included a third category, change in enrollment, which is not of interest for our study.

[5]Patients pay a small daily allowance in hospital and a prescription charge of 5.85 € (in 2017) per medical drug.

[6]The province of Upper Austria has 1.474 million inhabitants representing 16.7 % of the Austrian population. Per capita health care expenditures in 2017 (4,012 €) were 6.5 % below the Austrian average of 4,291 € (Hofmarcher & Singhuber, 2019). Life expectancy in good and excellent health for women (men) was six months higher (lower) than the country mean of 66.7 (65.9) years (Hofmarcher & Molnárová, 2017).

[7]Hospital expenditures are derived from the Austrian diagnosis-related group (DRG) system. For a few smaller hospitals, we cannot directly observe individual inpatient expenditures. In these (rare) cases, we impute the expenditure information by multiplying a daily allowance fee set by the government to compensate hospitals outside the DRG system with the number of days a patient spent in hospital.

The data also include individual expenses for medical attendance and medication in the outpatient sector.

The empirical analysis covers the time period from 2005 to 2018. Further, we distinguish survivors from decedents. For survivors, who have at least four more years to live, we aggregate the health care expenditures for each calendar year. For decedents, we analyze the last four years of life. The final year of life comprises the quarter of death and the three preceding quarters, the second year before death comprises the quarters 4 to 7 before death, and so on. We observe information on the state of insurance for the first day of each quarter, and include only observations where the individual is insured in all four quarters, i.e., we exclude individuals with long insurance gaps.

3.2 Empirical strategy

As was mentioned above, we conduct our analysis separately for decedents and survivors. There is no consensus in the literature as to how many years before death the end of life begins. Several authors (e.g, Stearns and Norton (2004)) count the last two years towards this period of life, others (Zweifel, Felder, & Werblow, 2004) use 3.5 years. In order to be as general as possible, we alternatively look at HCE in the last 12 months and in the last 48 months of life when we analyze decedents. Our survivor category consists of individuals who we know have lived at least 4 more years after the particular expenditures incurred. Given that our expenditure data span the years $2005 - 2018$ and the mortality data reach until December 31, 2019, we analyze the following subsamples:

- *Decedents (last year)*: This group includes 116,112 individuals who we observe in the last 12 months of their lives and who died in the period 2005 (last quarter) - 2018.
- *Decedents (last 4 years)*: This group includes 86,870 individuals who we observe during the last 48 months of their lives and who died in the period 2008 (last quarter) - 2018.
- *Survivors*: This group includes 1.416 million individuals who have lived at least 4 more years. As a consequence, we observe their expenditure data between 2005 and 2015 (10.585 million person-years).

Each decedent is linked with a specific diagnosis if the person was treated in a hospital within the period of observation and the diagnosis was the principal diagnosis of this hospital stay. In case of several hospital episodes, we use the last stay before death.[8] We

[8] Given the relatively short period of data availability and the above-mentioned reliability problems, we do not use the cause of death specified in the Austrian death records. However, for the 28,201 deaths between 2005 and 2010, we can match the end-of-life diagnoses to the official causes of death. As can be seen from Table A.1 in the Appendix, the ICD-10 chapter matches the cause of death category in 14,017 cases (49.7 %).

group the diagnoses by 3-digit ICD-10 codes and use the cutoff criterion for inclusion that the respective ICD code must be relevant for at least 900 cases. This criterion is met by 22 ICD-10 codes comprising in total 42,769 cases or 36.9 % of the total decedent (last year) sample. We also analyze diagnoses grouped into important ICD-10 chapters. Here, we use a cut-off of 6000 cases, which is met by 5 ICD-10 chapters.

For the survivor analysis, 1.755 million person-years (16.6 %) contain a hospital episode and can therefore be linked to an ICD-10 chapter. Of these we include only ICD-10 chapters with more than 50,000 cases each (which corresponds to about 0.5 % of all person-years). Altogether these 12 ICD-10 chapters are relevant for 1.56 million cases or 88.8 % of all person-years with a hospital stay.

A disease contributes more than proportionally to per capita HCE whenever

1. its prevalence increases, and

2. its cost per case increases faster than overall HCE.

As a prevalence measure, we use the number of cases adjusted by the membership in the health insurance fund. As can be seen from Table 1, membership in the Upper Austrian Health Insurance Fund (OOEGKK) increased from 1.14 million insured persons in 2005 to 1.27 million in 2018, which corresponds to an annual growth rate of 0.77 % per year. We subtract this figure from the growth rate in absolute prevalence to determine the relative growth in prevalence. As a benchmark for an over-proportional growth in costs per case, we use the growth rate of expenditures per capita of the sickness fund between 2005 and 2018. The annual growth rate of total expenditures amounts to 4.6 %, but since membership grew by 0.77 % annually, the per-capita HCE growth rate is 3.83 %.[9]

The development of costs per case for a particular disease is calculated as follows: For decedents, we allocate each person to the quarter of his/her death, and for the so defined group of patients, we determine the average costs in the last 12 (48) months, which we attribute to the respective quarter, which gives

- a time series of length 53 (last quarter of 2005 until last quarter of 2018) for the variable *average HCE in the last year of life*,

- a time series of length 41 (last quarter of 2008 until last quarter of 2018) for the variable *average HCE in the last 4 years of life.*

Per-capita expenditures by disease group: To obtain the growth rates per quarter for total HCE, we estimate the following equation

$$ln(\bar{h}_t) = \alpha + \beta q + \epsilon_t \tag{1}$$

[9]The growth rates are calculated from regressions of the variables in logs on a linear time trend.

with $\bar{h}_t$ representing total HCE expenditures in a certain DRG group for people who died in quarter q. These expenditures refer to either the decedents' last or the last four years. Total HCE include expenditure for inpatient treatment, medical attendance in the outpatient sector, medication, medical aids, and transport services. The right-hand-side variable q represents a linear quarterly trend. The coefficient β in the semi-log specification gives the growth rate in HCE per quarter. The annual growth rate is simply the quarterly growth rate multiplied by 4.

For survivors with a particular disease (defined by the last hospitalization in the respective year), we attribute total annual HCE to this disease and calculate the average over all patients in this disease group for each year. The annual growth rates for each DRG group can then be calculated analogous to equation 1.

Age, HCE , and HCE growth by group of disease: To analyze the age profiles of HCE for survivors and decedents, we apply local regression techniques. In particular, we follow Lorenz et al. (2020) and calculate smoothed values of HCE over the lifecycle using kernel-weighted local linear regressions. The idea is to use a weighted average of observations close to a specific age to derive a non-parametric estimate of the according expenditures. We pool the available annual observations and estimate the weighted regression

$$h_{it} = \beta_0 + \beta_1(a_0 - a_i) + \beta_2 t + \epsilon_{it}, \tag{2}$$

for the expenditures h of individual i at time t separately for the age groups a_0 ranging from 0 to 99, allowing for linear effects of ages in the neighborhood of a_0 $(a_0 - a_i)$ and a time trend t. Consequently, β_0 is a non-parametric estimate of expenditures in age group a_0. We also report β_2/β_0 as an estimate for the age-specific expenditure growth rate per year.[10] Estimations are run for different expenditure components and disease groups separately.

4 Results

Table 2 shows the distribution of total HCE between survivors and decedents over time in the estimation sample. Approximately 80% of the aggregate expenditures can be attributed to survivors whereas 9% are spent for patients in their last year of life. The proportion of total HCE caused by patients in their second, third, and fourth year before death is approximately 4.6%, 3.6%, and 3.2%, respectively. The percentages are stable over time.

[10]For the estimation weights, we follow Lorenz et al. (2020) and use the normal kernel with a constant bandwidth (i.e., the bandwidth is the same for all age classes). Because of the higher number of observations and a lower variance of the dependent variable, a smaller bandwidth can be employed for survivors than for decedents.

4.1 Disease-specific expenditures

Decedents: The main results for the group of decedents are summarized in Tables 3 and 4. For decedents in their last year of life (Table 3, column (5)), treatment per case of cancer was most expensive (36,646 €), followed by treatment of diseases of the digestive (26,412 €) and respiratory system (22,409 €). Expenditure growth was over-proportional for neoplasms, diseases of the respiratory system, injury and poisoning in the sense that treatment of these diseases clearly exceeded the 3.8 % overall expenditure growth per sickness fund member and year (see column (8)). The growth in expenditures for treatment of diseases of the circulatory and digestive system remained significantly behind this overall growth rate.

In 9 of the 22 most frequent 3-digit ICD codes, expenditure growth has been at least 2 percentage points higher than the overall growth in expenditures per sickness fund member. These 9 ICD codes contain 4 referring to malignant neoplasms (bronchus and lung, pancreas, liver and breast) with altogether 6881 patients (or 6 % of all decedents), and in all these cases the "excessive" expenditure growth derives primarily from a more-than average growth of costs per case. However, the number of cases also increased by approximately 2 % or more per year.

The non-cancer ICD codes with an over-proportional expenditure growth were chronic obstructive pulmonary disease, pneumonitis, disorders of the urinary system, and acute renal failure but only in the first of these groups expenditures per case grew slightly faster than overall HCE per sickness fund member, whereas in the other three groups the expenditure growth was exclusively due to an excessive growth of the frequency of cases. We find a substantial expenditure growth for cerebral infarction also (I63). However, the result is accompanied by a strong decline in the number of cases of the neighboring code I64 (stroke, not specified as haemorrhage or infarction) which is not shown in Table 3 due to the lower number of cases (below 900). Taken together, the findings likely reflect a change in coding practices in favor of the more specific I63 at the expense of I64.

The pattern of growth rates in cases and expenditures per case for decedents in their last four years of life is very similar, as can be seen in Table 4. Remarkable is, however, that the expenditure growth rate for pneumonitis runs up to almost 9 %. This figure is mainly driven by a more than 8 % annual growth in the number of cases.

Survivors: Turning to the group of survivors, the results in Table 5 reveal that two ICD chapters stand out: conditions related to pregnancy, childbirth and the puerperium (chapter 15) and treatment of mental and behavioral disorders (chapter 5) showed strong increases in both the number of cases and expenditures per case. The latter result is particularly striking, given that these patients belong to the most expensive ones with average annual expenditures of 12,872 €. Finally, neoplasms (chapter 2) show above-average growth of expenditures per patient, which confirms the result for decedents that medical progress for this group of diseases has been particularly strong over the last 10 years.

4.2 Does expected success play a role?

Apparently, expenditure growth for decedents was particularly concentrated at some types of cancer including lung, pancreas, breast, and liver cancer. One possible explanation for the fact that these types of cancer have attracted an increasing share of total resources may be that in these diseases therapeutic success has improved more than in other diseases, in particular other types of cancer. For cancer types, it is easier to answer this question than for other diseases because therapeutic success is usually measured using 5-year survival rates (5YSR), and these rates are regularly collected for the world as a whole and even for individual countries.

CONCORD Working Group and others (2018) present data on survival rates for 17 different types of cancer in three time periods (2000-04, 2005-09 and 2010-14) for Austria (and many other countries).[11] Together with the provided information on the number of patients diagnosed with any of the neoplasm categories in 2000-2014, we are able to compare the 5-year survival rates (5YSRs) of cancer types with above-average expenditure growth with other frequent cancer types with at least 10,000 patients in this period (see Table 6).

The upper panel of the table depicts that in the group of neoplasms with strong expenditure growth, 5YSRs have all increased about the same, namely between 3.1 and 4.3 percentage points in the 10-year period considered, with a patient-weighted average of 3.6 percentage points. In contrast, the group with less rapid expenditure growth contains cancer types with a strong increase in the 5YSR (such as leukaemia and stomach cancer) and also those without any noticeable increase in the 5YSR (ovaries and prostate cancer). On average, the 2.7 percentage point increase of the patient-weighted 5YSR in the latter group of cancers is a quarter lower than that of the former group (3.6 percentage points). We interpret this difference at least as weak evidence that the expected success may have been one of the factors explaining the rapid expenditure growth in some diseases.

4.3 Age profiles and age-specific expenditure growth

In this subsection, we will present age profiles of HCE and their growth over time for survivors and decedents (β_0 and β_2/β_0 in equation 2). As a starting point, the number of cumulative deaths over sex and age are depicted for all deaths (Figure 1) and for the selected ICD chapters (Figure 2). Figure 1 demonstrates that cumulative deaths are higher for males over all age groups until the age of 92 years. Moreover, the increase in figures at younger ages is greater for males than for females.

[11] Of the cancer types included in our Tables 3 and 4, only ICD code C78 (secondary malignant neoplasms of respiratory and digestive organs) is not listed.

The pattern of higher cumulative deaths for males up to an age of 85 years can be observed for all ICD-10 chapters (Figure 2). Neoplasm is the most frequent cause of death for younger age groups in both sexes reaching approximately 2,000 cumulative deaths at the age of 60. This figure is surpassed only by the number of cumulative deaths for 60 year old males without a previous hospital visit, which runs up to approximately 3,000 cases, mainly driven by accidents.

Decedents: Age profiles for total HCE of decedents and their growth rates are depicted in Figure 3. We restrict the graphical analysis to decedents aged 45 and above, because deaths among younger people are very rare and therefore not representative and economically less interesting. The graphs illustrate pronounced differences over the age groups in per capita HCE among persons who have 1-4 more years to live (left upper and lower panel). Until the age of 75, people who die within a period of one year have approximately twice as high expenditures than those of the same age who are in their second last life year. The differences in HCE per capita between those who have 2-4 more years to live are much lower. The age profiles for women and men look similar, however, the expenditure levels for the age groups 45-70 are higher for females than for males. Expenditures for men increase until the age of 55, remain constant until age 70, and decrease thereafter. For women, per capita expenditures are constant until age 65 and decrease continuously thereafter.

Growth rates estimates of total HCE per capita (right upper and lower panel in Figure 3) reveal high increases in expenditures per year in the younger age groups in their last year of life with a drop in relative trends for older groups. This means that the age groups with the highest total HCE per capita also exhibit the highest expenditure growth over time.

The analyses for individual ICD-10 chapters reveal the highest per capita expenditures for treatment of cancer and diseases of the respiratory system in both sexes (see Figure 4). For both disease categories, costs are highest for the relatively young age group 50-60 whereas the costs for diseases of the circulatory and digestive system and for treatment of injury and poisoning peak at ages between 60-70 years.

The results in the previous section revealed a strong increase in expenditures for cancer treatment over the last years. This increase is not due to a particular age group. Rather, the expenditure growth rates are constant over age, which means that the comparatively higher expenditures in the younger age cohorts also develop dynamically over time. This pattern is even more pronounced for treatment of diseases of the respiratory system, in particular for men. The youngest age groups exhibit both the highest per capita figures and the highest growth rates over time.

Expenditures for the treatment of injury, poisoning and other external causes also reveal stronger growth rates for decedents below 65 years than for older decedents. For diseases of the circulatory system and the digestive system, the increase in expenditures

is similar for all age groups.
Survivors: The age profiles of HCE for survivors differ from those of decedents. As can be seen from Figure 5, we observe a steady increase in annual per capita HCE over age in both sexes from 1,000 € at age 40 up to 4,000 € at age 80-85 with a sharp drop thereafter. With more than 4.5 % per year, the highest growth rates in expenditures are in the age groups between 20 and 60. It must be noted, though, that the expenditure levels are approximately 10 times lower than those of decedents in their last year of life.

The steady increase in per capita expenditures with the age of survivors can be observed for a series of quantitatively important diseases such as diseases of the musculoskeletal, digestive, genitourinary, respiratory, circulatory, and nervous systems, injury and diseases of the eye (see Figure 6). Expenditures of men for treatment of diseases of the circulatory system increase faster in younger ages as compared to those of women. Men reach their peak at the age of 55, with levels remaining constantly high until age 80.

Another important expenditure category of survivors is the one for treatment of mental and behavioral disorders. They start increasing in very early ages and remain constantly high with levels of more than 10,000 € for all age groups beyond 20. Moreover, this ICD-10 group reveals the highest expenditure growth over time, consistent with the results in the previous section on average HCE. While expenditures increase for all age groups, growth is particularly large for people below 60 with figures of 6 to 7 per cent per year. Expenditures for treatment of cancer start to increase at the age 30 for women and 40 for men. The maximum arises in age groups 60-75 indicating that the peaks for survivors occur in older ages than for decedents from cancer. Here, the expenditure growth is particularly pronounced for women below 20 years and for men between 30 and 45 years of age, where they amount to 10 per cent per year and more.

5 Discussion and conclusions

The present study has analyzed a unique set of high-quality individual data on health care utilization, diagnoses and time of death on a large number of members of a large regional sickness fund in Austria. The main target was to find out in what disease groups the prevalence of cases and expenditures per case increased in an above-average speed in the time period 2005-2018, and we distinguished between decedents (in their last 4 years of life) and survivors.

The following are the most important findings:

- Among decedents, we observe a disproportionate expenditure growth, which is predominantly driven by a strong increase in costs per case, in four types of malignant neoplasms (lung, pancreas, breast, and liver cancer), and there is some evidence that this development is at least partly associated with a somewhat stronger increase of

5-year survival rates in these cancer types than in others.

- Other diseases with above-average expenditure growth for decedents were COPD, acute renal failure, pneumonitis, and other disorders of the urinary system.
- Among survivors, pregnancies and mental and behavioral disorders showed the most rapid expenditure increase, which stems from a growth in the number of cases and expenditures per case.
- When distinguishing by age group, we find that among decedents, the costs for the treatment of cancer and diseases of the respiratory system peak in a relatively young age group (50-60 years), whereas expenditures for diseases of the circulatory and digestive system peak at later ages (60-70 years).
- Among survivors, expenditures for the treatment of cardiovascular diseases in younger ages increase faster for men than for women. Furthermore, expenditures for mental and behavioral disorders increase most strongly in the age groups below 60.
- When comparing age-specific expenditures for cancer patients, it is noticeable that expenditures for survivors peak at older ages (usually 60-75 years) than for decedents, which suggests that cancers tend to be more aggressive and more often lethal when they occur at younger ages. Moreover, expenditure growth was particularly strong in young age groups, even for survivors.

Policy Implications: A further question relates to possible policy reactions to the observed and analyzed expenditure trends. On the one hand, HCE growth that exceeds GDP growth may lead to problems of financing these expenditures from taxes and social insurance contributions. On the other hand, as Hall and Jones (2007) have argued convincingly, higher public expenditures for the treatment of specific diseases may be exactly what citizens want, in particular if these diseases have very special properties (e.g. can occur early in life and cause peculiar anxieties) or have seen spectacular advances in treatment strategies and success in recent times. In the latter case the appropriate policy reaction could be to accommodate the observed development by speeding up the process of approval of new procedures.

As long as the origin of a disease is predominantly lifestyle-driven, however, the growth of the associated expenditures can be slowed down only in the long run by targeted prevention programs. The same applies to mental and behavioral disorders, which were also found to have caused significant growth in HCE. Still other groups of diseases such as diseases of eye and adnexa, of the musculoskeletal and of the genitourinary system might be unavoidable concomitants of ageing societies, and the most adequate policy would consist in preparing the public for the necessary increase in tax revenues in the decades to come.

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6 Tables and figures

Table 1: Upper Austrian Sickness Fund: Members and total HCE

year	(1) HCE in mio. €	(2) members	(3) HCE/member
2005	1,608	1,137,003	1,414
2006	1,716	1,151,143	1,490
2007	1,881	1,163,921	1,616
2008	2,003	1,174,997	1,705
2009	2,068	1,174,869	1,760
2010	2,148	1,180,826	1,819
2011	2,185	1,187,822	1,840
2012	2,288	1,196,435	1,913
2013	2,383	1,208,174	1,972
2014	2,530	1,217,010	2,079
2015	2,633	1,227,854	2,144
2016	2,867	1,245,869	2,301
2017	2,939	1,255,261	2,342
2018	2,959	1,265,631	2,338
growth rate	0.0460	0.0077	0.0383

Notes: This table shows members and expenditures in the Upper Austrian Sickness Fund per year. The bottom line displays the corresponding average annual growth rate.

Table 2: Distribution of total HCE per year between decedents and survivors

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Decedents (in %)										
Last year of life	9.13	8.92	9.04	9.41	9.47	9.46	9.22	8.66	8.34	8.55
Second year before death	4.68	4.59	4.48	4.71	4.88	4.92	4.70	4.22	4.54	4.36
Thrid year before death	3.76	3.57	3.74	3.74	3.83	3.94	3.43	3.58	3.32	3.44
Fourth year before death	3.21	3.20	3.12	3.35	3.46	3.11	3.21	2.99	3.05	2.94
Survivors (in %)	79.22	79.72	79.63	78.80	78.36	78.56	79.43	80.56	80.75	80.72

Notes: This table shows the distribution of total HCE between survivors and decedents (in percent).

Table 3: Decedents: Average HCE growth rates – last year of life

(1) ICD code	(2) Disease group	(3) Cases	(4) GR cases	(5) Expend. per case	(6) GR cases adjusted	(7) GR expend. per case	(8) GR combined
9	Diseases of the circulatory system	23,762	-1.25	20,667	-2.02	3.55	1.54
2	Neoplasms	20,309	1.38	36,646	0.61	5.44	6.05
10	Diseases of the respiratory system	13,314	2.09	22,409	1.32	3.57	4.89
19	Injury, poisoning and other external causes	6,462	2.84	20,295	2.07	3.51	5.59
11	Diseases of the digestive system	6,240	-0.41	26,412	-1.18	3.20	2.02
I50	Heart failure	6,198	-1.26	19,711	-2.03	2.79	0.76
J18	Pneumonia, organism unspecified	6,002	0.51	20,451	-0.26	3.53	3.27
C34	Malignant neoplasm of bronchus and lung	3,435	1.98	34,825	1.21	6.13	7.35
I63	Cerebral infarction	2,833	2.93	19,616	2.16	4.16	6.32
I21	Acute myocardial infarction	2,410	-6.49	17,066	-7.26	2.57	-4.69
A41	Other sepsis	2,114	-0.67	34,199	-1.44	2.93	1.49
S72	Fracture of femur	1,831	2.88	20,615	2.11	2.52	4.63
C25	Malignant neoplasm of pancreas	1,467	2.47	34,668	1.70	5.46	7.16
J69	Pneumonitis due to solids and liquids	1,458	7.07	22,274	6.30	1.56	7.87
I61	Intracerebral haemorrhage	1,420	0.20	21,714	-0.57	3.16	2.59
J15	Bacterial pneumonia, not elsewhere classified	1,380	-3.35	22,418	-4.12	4.16	0.04
J44	Other chronic obstructive pulmonary disease	1,327	1.44	25,421	0.67	5.38	6.05
N39	Other disorders of urinary system	1,277	5.45	15,489	4.68	1.42	6.09
C78	Secondary malignant neoplasm of respiratory and digestive organs	1,243	-1.78	32,934	-2.55	4.56	2.01
S06	Intracranial injury	1,149	2.24	21,257	1.47	3.80	5.28
N17	Acute renal failure	1,146	6.04	23,645	5.27	2.74	8.02
C79	Secondary malignant neoplasm of other and unspecified sites	1,037	-2.26	38,407	-3.03	4.49	1.46
I26	Pulmonary embolism	1,057	-7.05	18,390	-7.82	2.24	-5.58
C50	Malignant neoplasm of breast	1,034	2.60	36,066	1.83	5.70	7.53
I25	Chronic ischaemic heart disease	1,060	-1.89	24,632	-2.66	3.86	1.20
C18	Malignant neoplasm of colon	973	-0.02	37,739	-0.79	5.78	5.00
C22	Malignant neoplasm of liver and intrahepatic bile ducts	945	2.75	28,040	1.98	5.45	7.44

Notes: This table summarizes the development of cases and expenditures for disease groups in the last year of life. Column 1 shows the ICD-10 chapter or 3-digit code, column 2 the name of the disease group, column 3 the absolute number of cases, column 4 the annual growth rate of cases, column 5 the average HCE in the last year of life, column 6 the adjusted growth rate of cases calculated as column 4 minus 0.77, column 7 the growth rate of expenditures per case (β in equation 1 multiplied by 4), and column 8 the combined growth rate calculated as the sum of columns 6 and 7.

Table 4: Decedents: Average HCE growth rates – last four years of life

(1) ICD code	(2) Disease group	(3) Cases	(4) GR cases	(5) Expend. per case	(6) GR cases adjusted	(7) GR expend. per case	(8) GR combined
9	Diseases of the circulatory system	17,543	-1.29	45,774	-2.06	3.11	1.05
2	Neoplasms	15,165	1.12	74,572	0.35	5.24	5.59
10	Diseases of the respiratory system	10,298	2.31	52,237	1.54	2.85	4.40
19	Injury, poisoning and other external causes	4,952	3.30	43,253	2.53	2.04	4.57
11	Diseases of the digestive system	4,516	0.31	53,617	-0.46	2.96	2.49
I50	Heart failure	4,604	-1.53	47,728	-2.30	2.74	0.43
J18	Pneumonia, organism unspecified	4,535	1.34	48,904	0.57	2.57	3.14
C34	Malignant neoplasm of bronchus and lung	2,579	1.52	65,770	0.75	5.24	5.99
I63	Cerebral infarction	2,292	0.81	39,766	0.04	3.81	3.86
I21	Acute myocardial infarction	1,593	-5.90	39,715	-6.67	2.15	-4.52
A41	Other sepsis	1,523	0.01	68,011	-0.76	2.73	1.97
S72	Fracture of femur	1,435	3.45	41,943	2.68	0.90	3.59
C25	Malignant neoplasm of pancreas	1,137	2.14	63,185	1.37	6.55	7.92
J69	Pneumonitis due to solids and liquids	1,198	8.33	50,160	7.56	1.39	8.95
I61	Intracerebral haemorrhage	1,057	1.19	42,427	0.42	2.68	3.10
J15	Bacterial pneumonia, not elsewhere classified	1,027	-9.28	51,093	-10.05	4.04	-6.01
J44	Other chronic obstructive pulmonary disease	1,026	-0.88	65,523	-1.65	4.15	2.50
N39	Other disorders of urinary system	1,051	5.48	41,683	4.71	1.56	6.27
C78	Secondary malignant neoplasm of respiratory and digestive organs	927	-5.63	73,883	-6.40	4.88	-1.51
S06	Intracranial injury	846	3.55	43,161	2.78	3.05	5.84
N17	Acute renal failure	934	6.80	51,262	6.03	3.60	9.63
C79	Secondary malignant neoplasm of other and unspecified sites	740	-4.28	79,985	-5.05	4.92	-0.13
I26	Pulmonary embolism	684	-6.87	38,890	-7.64	2.14	-5.51
C50	Malignant neoplasm of breast	751	4.41	87,066	3.64	5.52	9.16
I25	Chronic ischaemic heart disease	761	0.03	52,519	-0.74	2.59	1.85
C18	Malignant neoplasm of colon	709	0.15	81,033	-0.62	6.29	5.67
C22	Malignant neoplasm of liver and intrahepatic bile ducts	724	4.33	58,170	3.56	5.29	8.84

Notes: This table summarizes the development of cases and expenditures for disease groups in the last four years of life. Column 1 shows the ICD-10 chapter or 3-digit code, column 2 the name of the disease group, column 3 the absolute number of cases, column 4 the annual growth rate of cases, column 5 the average HCE in the last four years of life, column 6 the adjusted growth rate of cases calculated as column 4 minus 0.77, column 7 the growth rate of expenditures per case (β in equation 1 multiplied by 4), and column 8 the combined growth rate calculated as the sum of columns 6 and 7.

Table 5: Survivors: Average HCE growth rates

(1) ICD code	(2) Disease group	(3) Cases	(4) GR cases	(5) Expend. per case	(6) GR cases adjusted	(7) GR expend. per case	(8) GR combined
13	Diseases of the musculoskeletal system and connective tissue	221,915	2.02	7,450	1.25	4.84	6.09
19	Injury, poisoning and certain other consequences of external causes	209,079	0.31	6,206	-0.46	5.23	4.77
11	Diseases of the digestive system	178,120	0.04	5,333	-0.73	3.93	3.20
9	Diseases of the circulatory system	173,701	0.52	9,558	-0.25	4.08	3.83
14	Diseases of the genitourinary system	124,960	0.08	5,036	-0.69	3.71	3.02
7	Diseases of the eye and adnexa	106,376	3.26	4,797	2.49	3.06	5.55
10	Diseases of the respiratory system	104,208	-0.71	4,909	-1.48	5.47	3.99
18	Symptoms, signs and abnormal clinical and laboratory findings	95,585	1.45	4,367	0.68	5.12	5.80
2	Neoplasms	92,982	2.37	10,193	1.60	5.75	7.36
15	Pregnancy, childbirth and the puerperium	86,457	5.92	4,266	5.15	4.49	9.64
6	Diseases of the nervous system	83,807	2.05	6,987	1.28	3.97	5.24
5	Mental and behavioural disorders	80,803	4.43	12,872	3.66	5.67	9.33

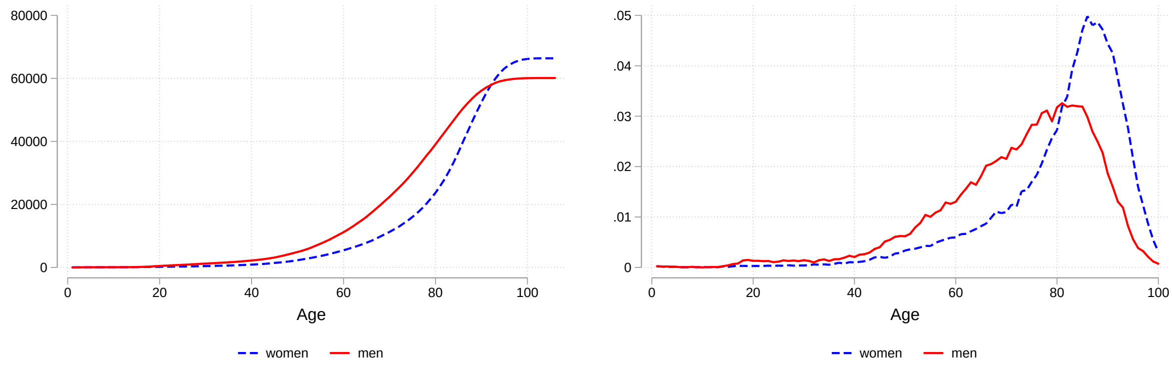
Notes: This table summarizes the development of cases and expenditures for disease groups of survivors. Column 1 shows the ICD-10 chapter or 3-digit code, column 2 the name of the disease group, column 3 the absolute number of cases, column 4 the annual growth rate of cases, column 5 the average annual HCE, column 6 the adjusted growth rate of cases calculated as column 4 minus 0.77, column 7 the growth rate of expenditures per case (β in equation 1 multiplied by 4), and column 8 the combined growth rate calculated as the sum of columns 6 and 7.

Table 6: Expenditure growth rates (GR) and increase in 5-year survival rates in 11 types of cancer

	last year		last 4 years		5-year survival rates (percent)				
	GR expenditures	GR per case	GR expenditures	GR per case	patients	2000-04	2010-14	change	
All neoplasms	6.05	5.44	5.59	5.24					
Group 1: Strong expenditure growth									
lung	7.35	6.13	5.99	5.24	56,130	15.4	19.7	4.3	
pancreas	7.16	5.46	7.92	6.55	18,371	6.7	10.5	3.8	
breast	7.53	5.70	9.16	5.52	74,818	81.7	84.8	3.1	
liver and intrahepatic bile ducts	7.44	5.45	8.84	5.29	10,570	11.2	14.8	3.6	
average (unweighted, weighted)								3.7	3.6
Group 2: Other frequent neoplasms									
skin					19,150	83.4	87.8	4.4	
leukaemia					31,583	57.6	63.3	5.7	
ovaries					11,567	40.9	41.0	0.1	
stomach					19,308	30.0	35.4	5.4	
colon					46,127	60.7	63.7	3.0	
rectum					23,360	60.2	64.2	4.0	
prostate					75,082	90.1	90.2	0.1	
average (unweighted, weighted)								3,2	2.7

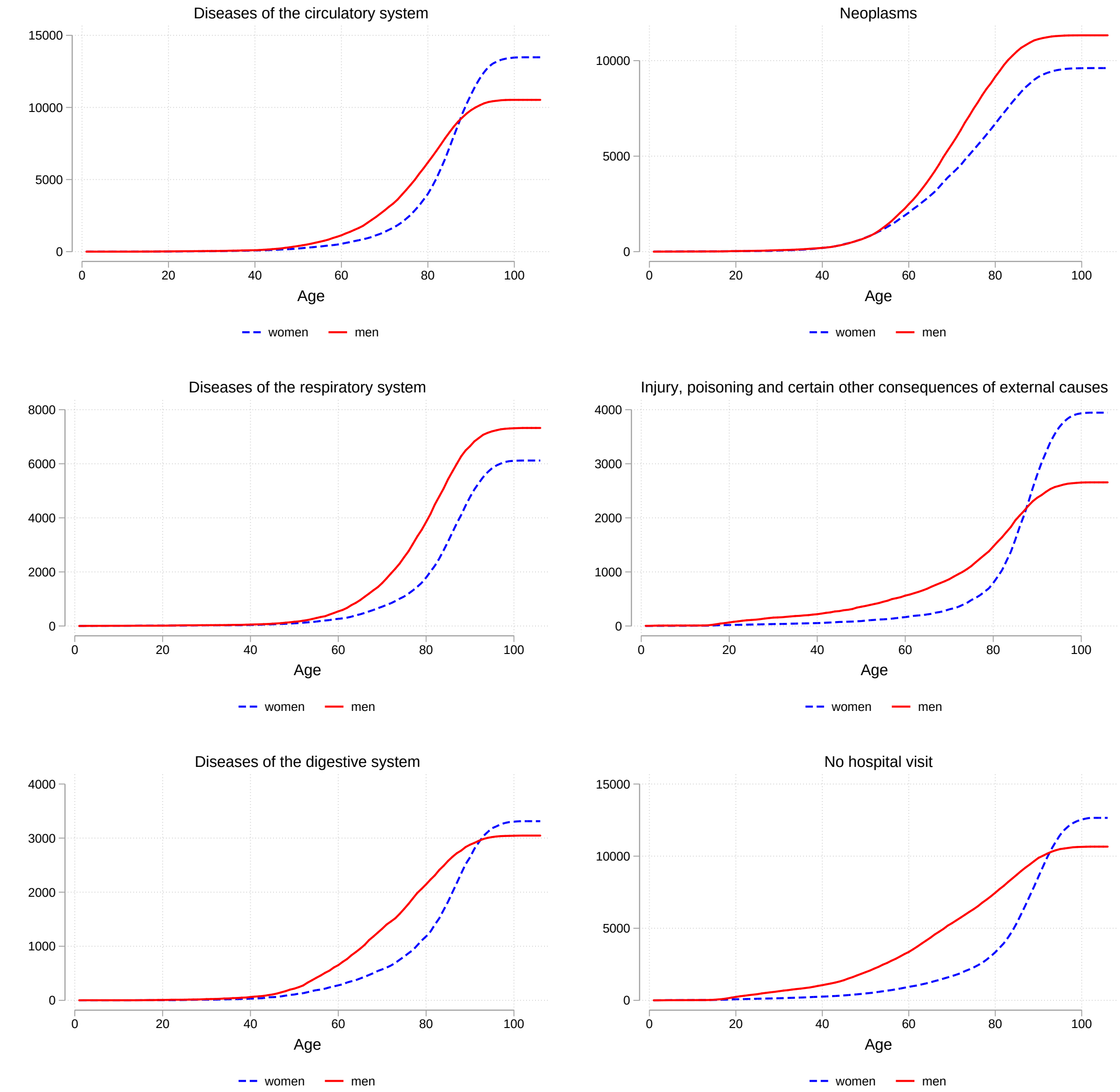
Notes: This table compares the growth rates in the 5-year survival rates for different cancer types as provided by CONCORD Working Group and others (2018). We distinguish cancer types with strong expenditure growth (Group 1) from other frequent cancers (Group 2). The growth rates (GR) of expenditures in columns 2-5 are replicated from Tables 3 and 4.

Figure 1: Distribution of deaths



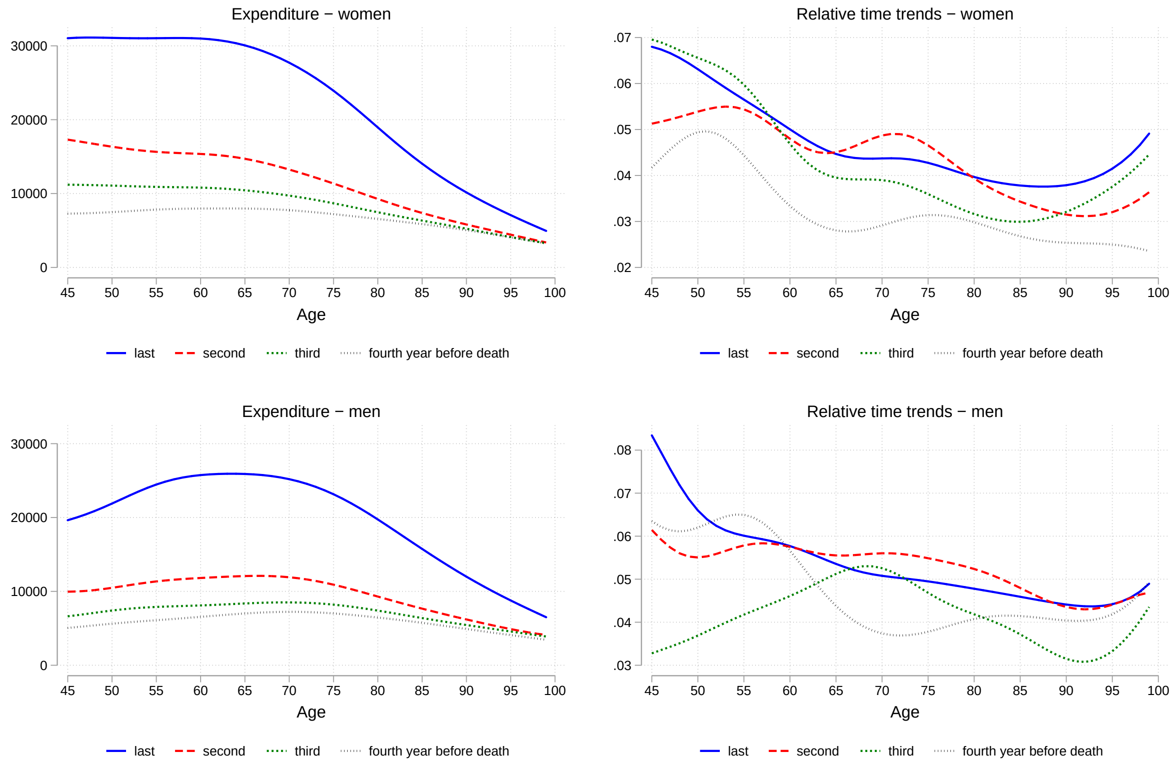
Notes: The figure shows the number of cumulative deaths (left) and the density of deaths (right) by sex and age.

Figure 2: Cumulative deaths for ICD-10 chapters



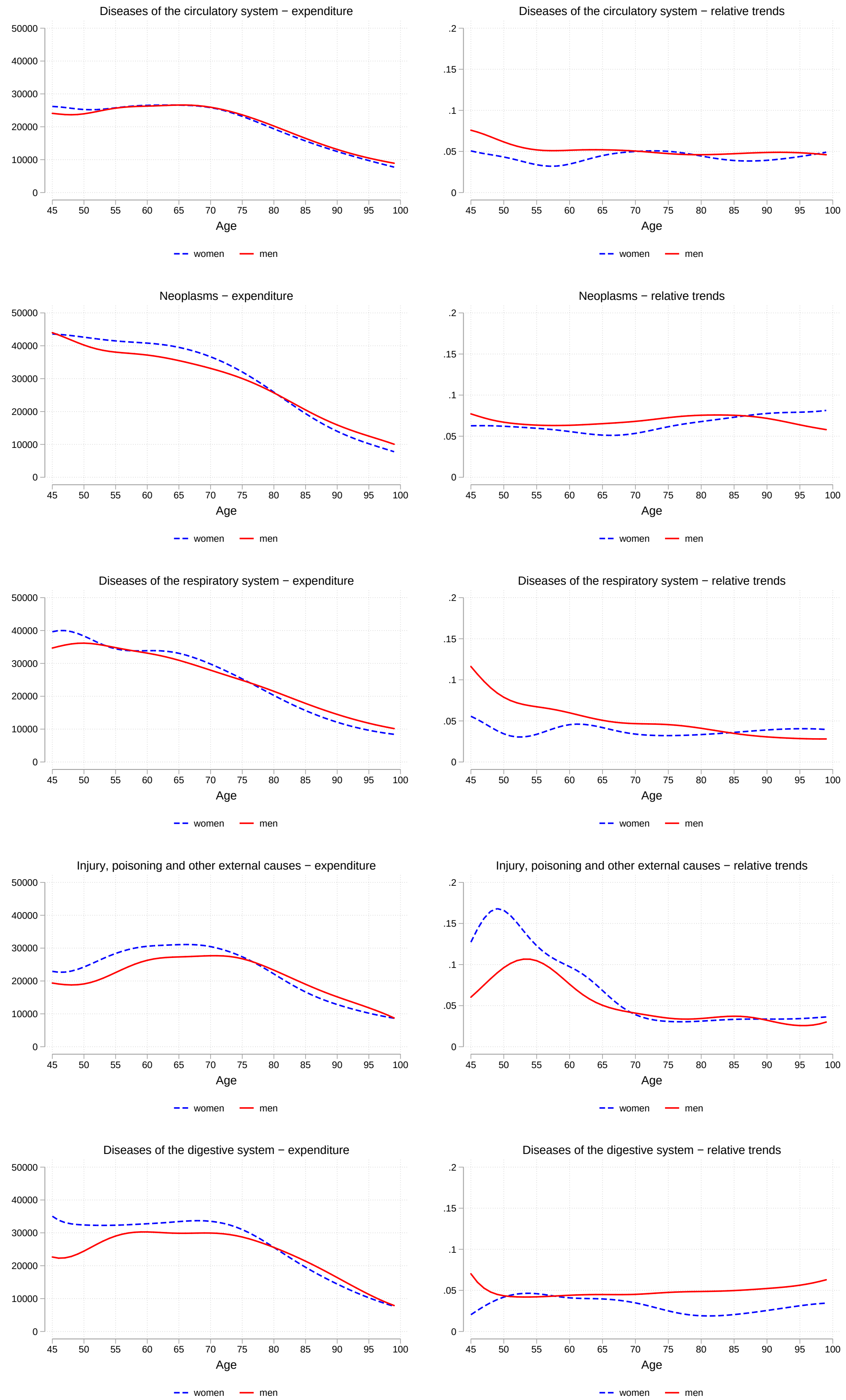
Notes: The figures show the number of cumulative deaths by sex and age for ICD-10 chapters.

Figure 3: Total HCE: Age profiles and growth rates for decedents



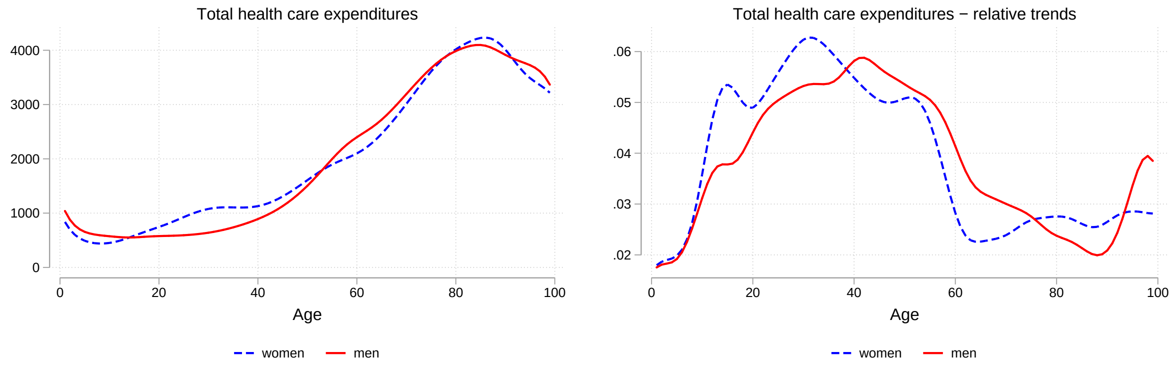
Notes: The figures show total HCE per year in € (left panels) and relative changes in total HCE per year in % (right panels) by age group for decedents in their last, second, third, and fourth year before death.

Figure 4: Total HCE for ICD chapters: Age profiles and growth rates for decedents



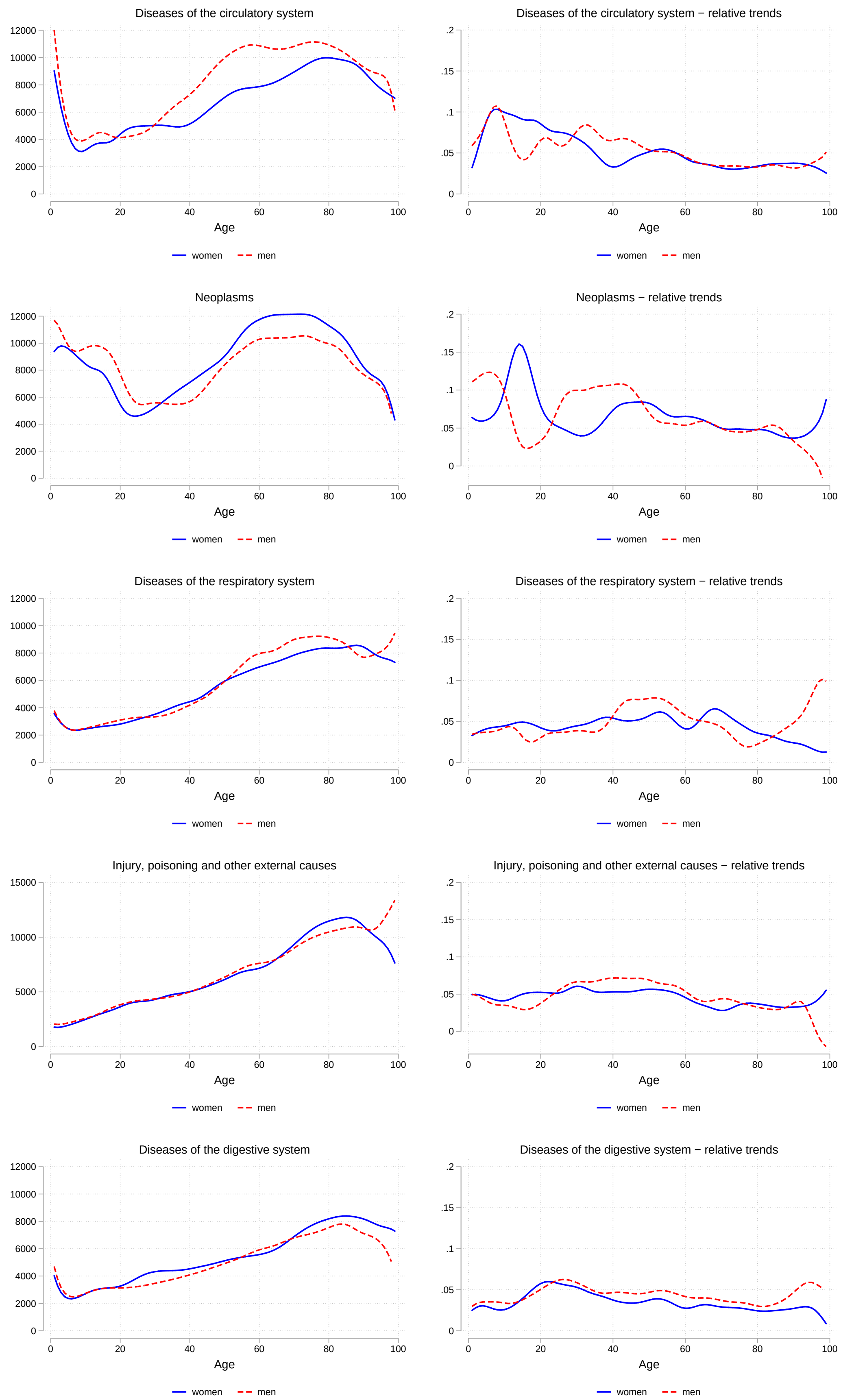
Notes: The figures show total HCE per year in € (left panels) and relative changes in total HCE per year in % (right panels) for different ICD chapters by age group for decedents in their last year before death.

Figure 5: Total HCE: Age profiles and growth rates for survivors



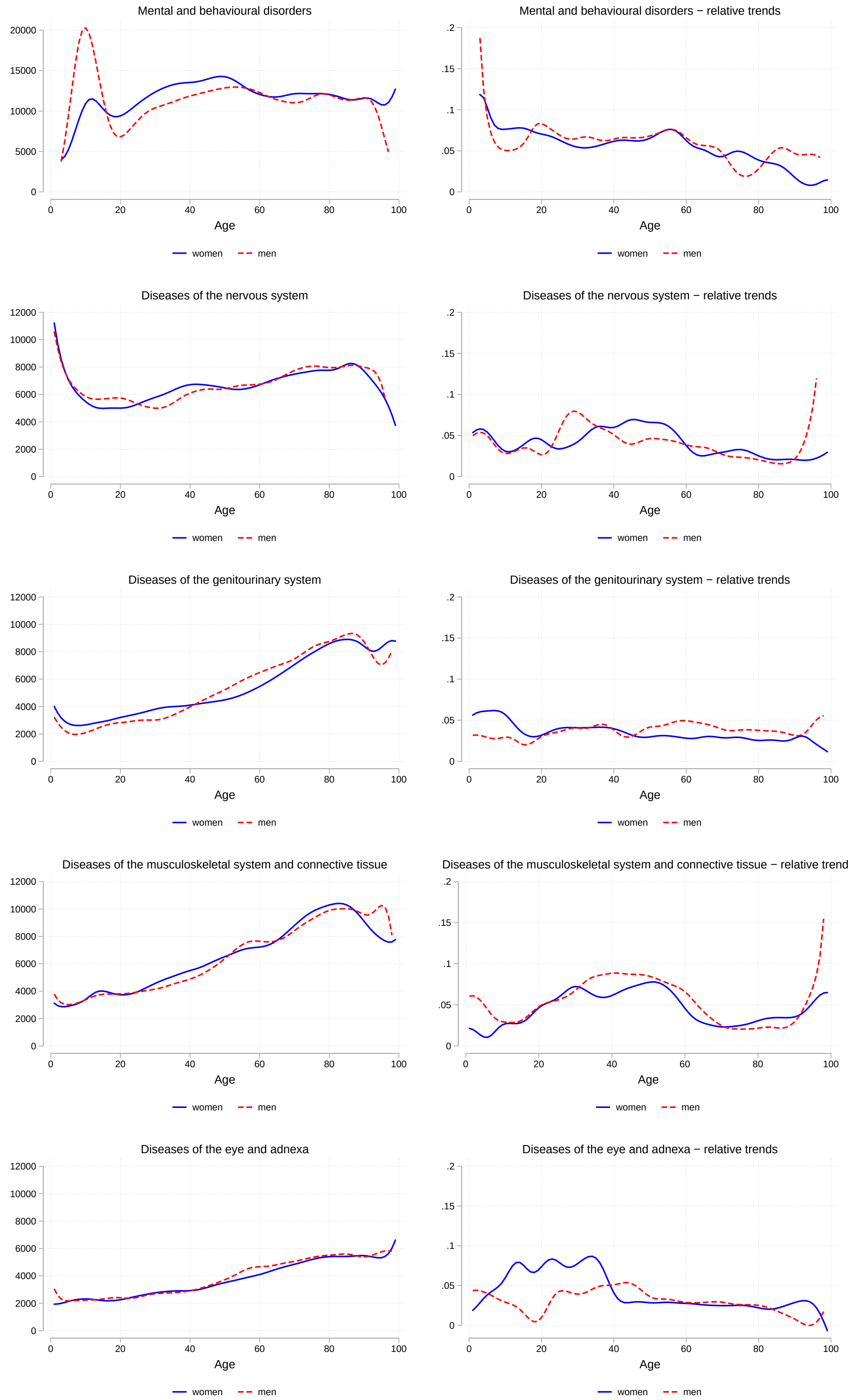
Notes: The figures show total HCE per year in € (left panels) and relative changes in total HCE in % (right panels) by age group for survivors.

Figure 6: Total HCE for ICD chapters: Age profiles and growth rates for survivors



Notes: The figures show total HCE per year in € (left panels) and relative changes in total HCE per year in % (right panels) for different ICD-10 chapters by age group for survivors.

Figure 6 (continued):



Notes: The figures show total HCE per year in € (left panels) and relative changes in total HCE per year in % (right panels) for different ICD-10 chapters by age group for survivors.

Web Appendix

This Web Appendix (not for publication) provides additional material discussed in the manuscript ‘Looking into the Black Box of Medical Progress: Rising Health Expenditures by Illness Type and Age’ by Friedrich Breyer, Normann Lorenz, Gerald J. Pruckner and Thomas Schober.

A.1 End-of-life diagnosis and official death records

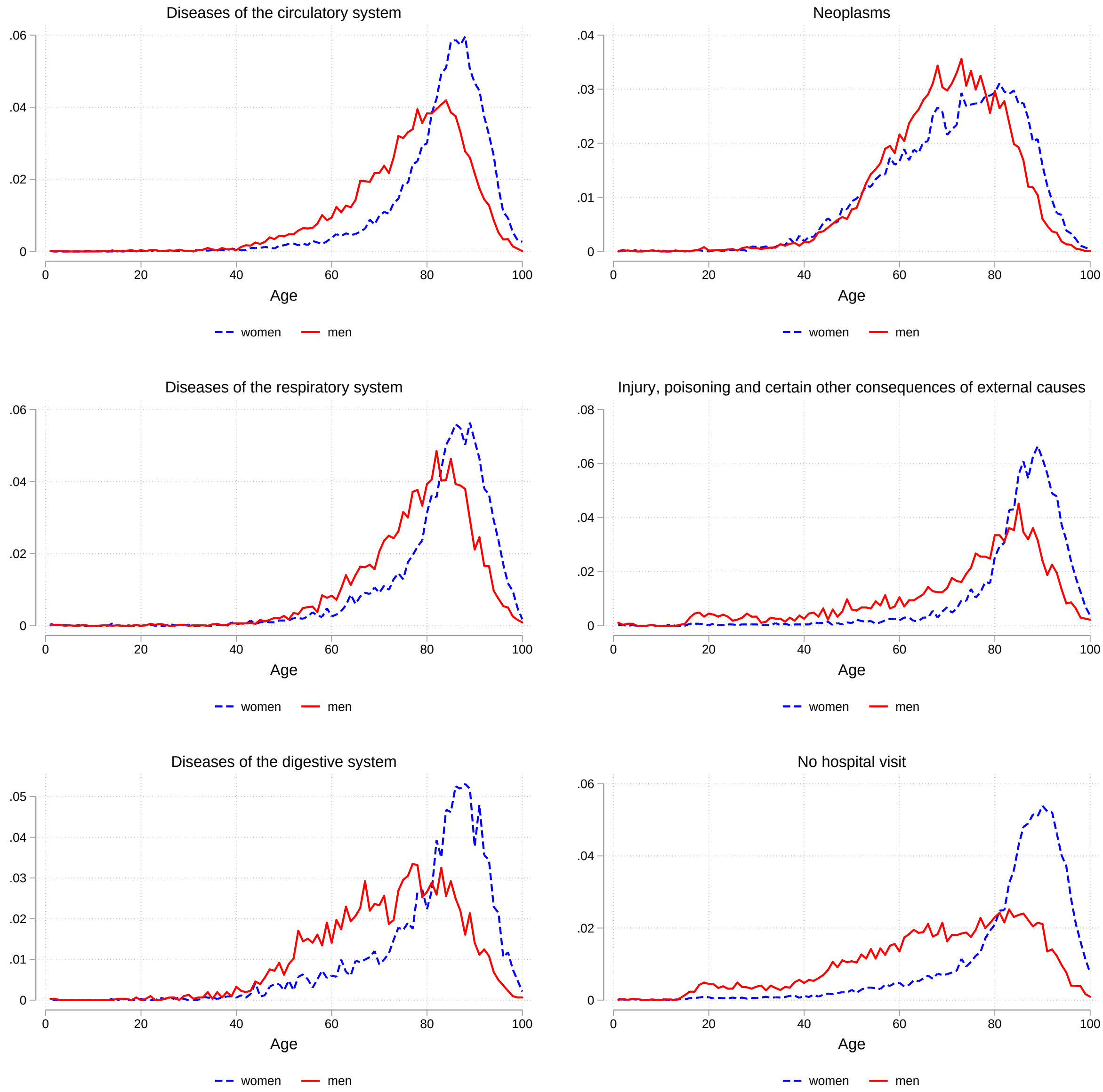
For deaths between 2005 and 2010, we can match the hospital data to the Austrian death records to compare decedents’ end-of-life diagnosis with the official cause of death. There are 28,201 deaths where diagnoses from both data sources are available. The ICD-10 3-digit code matches in 6,919 (24.5 %) of the cases, the ICD-10 chapter in 14,017 (49.7 %) of the cases. Table A.1 shows the cross table for diagnoses according to ICD-10 chapters from both data sources.

Table A.1: Comparison of end-of-life diagnosis (EOL) and cause of death

	Cause of death																
EOL	1	2	3	4	5	6	9	10	11	12	13	14	15	17	18	19	Total
1	92	205	5	79	3	28	328	105	114	9	10	42	0	2	8	21	1051
2	8	5641	11	15	4	11	186	41	30	0	2	3	0	0	3	47	6002
3	4	66	12	6	2	4	63	3	7	0	2	2	0	1	3	2	177
4	1	87	1	135	9	17	277	31	27	0	4	11	0	1	15	14	630
5	8	73	1	51	50	46	357	51	30	0	1	10	0	1	15	165	859
6	5	97	0	31	13	157	355	34	17	1	3	2	0	1	6	43	765
7	2	17	1	19	4	3	93	11	3	0	0	1	0	0	2	13	169
8	1	1	0	3	1	0	10	0	1	0	0	0	0	0	0	1	18
9	38	608	5	523	22	96	5509	385	176	5	18	74	1	10	47	135	7652
10	30	564	8	165	32	185	1526	988	92	4	13	45	0	9	36	78	3775
11	44	459	4	62	23	35	537	81	696	1	3	29	0	2	11	51	2038
12	3	39	0	35	5	12	165	21	6	9	1	12	0	0	4	11	323
13	4	48	0	27	5	2	163	29	13	3	22	6	0	0	6	49	377
14	15	207	4	123	6	34	466	55	41	5	7	108	0	0	10	26	1107
15	0	0	0	0	1	0	1	0	1	0	0	0	1	0	0	3	7
16	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	4
17	0	2	0	0	0	0	10	1	1	0	0	0	0	5	0	0	19
18	20	364	1	85	11	47	575	111	67	3	4	25	0	2	18	58	1391
19	9	154	3	64	31	44	737	69	53	3	18	20	0	0	34	574	1813
20	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	2
21	1	10	0	0	1	0	6	2	0	0	0	0	0	0	0	2	22
Total	285	8642	56	1423	223	721	11367	2020	1375	43	108	390	2	34	218	1294	28201

Notes: 1=Certain infectious and parasitic diseases 2=Neoplasms 3=Diseases of the blood and blood-forming organs 4=Endocrine, nutritional and metabolic diseases 5=Mental and behavioural disorders 6=Diseases of the nervous system 7=Diseases of the eye and adnexa 8=Diseases of the ear and mastoid process 9=Diseases of the circulatory system 10=Diseases of the respiratory system 11=Diseases of the digestive system 12=Diseases of the skin and subcutaneous tissue 13=Diseases of the musculoskeletal system and connective tissue 14=Diseases of the genitourinary system 15=Pregnancy, childbirth and the puerperium 16=Certain conditions originating in the perinatal period 17=Congenital malformations, deformations and chromosomal abnormalities 18=Symptoms, signs and abnormal clinical and laboratory findings 19=Injury, poisoning and certain other consequences of external causes 20=External causes of morbidity and mortality 21=Factors influencing health status and contact with health services.

Figure A.1: Distribution of deaths for ICD chapters



Notes: The figures show the density of deaths by sex and age for ICD-10 chapters.