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# Beyond Demographic Aging: Mortality Composition and Spending Growth in Healthcare Expenditure Projections

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# Beyond Demographic Aging: Mortality Composition and Spending Growth in Healthcare Expenditure Projections\*

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## Abstract

Population aging poses increasing fiscal challenges for publicly financed healthcare systems. Using comprehensive Danish administrative data, this paper develops a projection framework that extends standard demographic projections by allowing per capita healthcare expenditures to evolve heterogeneously across age groups. Mortality rate changes raise annual expenditure growth from 2.9% to 3.4%, with substantial heterogeneity across ages (0.5%–7.8%). Under these estimated growth patterns, demographic aging accounts for 19% of projected spending growth through 2035, while per capita expenditure growth explains the remaining 81%. Individuals aged 80 and above account for 46% of total growth despite comprising only 5% of the 2022 population. Relative to projections that impose uniform per

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capita expenditure growth, this framework implies higher total healthcare spending of DKK 52 billion in 2035.

**Keywords:** healthcare expenditure projections, population aging, time-to-death, age-heterogeneous growth, fiscal sustainability

**JEL Classification:** H51, I18, J11, C23

# 1 Introduction

Healthcare expenditure projections anchor fiscal policy across aging economies. Denmark allocates DKK 241 billion to healthcare in 2022 (8.0% of GDP), with the population aged 80 and older projected to nearly double by 2060 ([Statistics Denmark, 2025a,b](#)). This demographic shift concentrates fiscal pressure in a narrow age range: individuals aged 80+ consume healthcare at rates five times higher than the population average. Yet two critical questions remain unanswered for total publicly financed healthcare expenditures: whether per capita growth rates differ systematically across age groups when measured beyond hospital care alone, and if so, how incorporating such heterogeneity alters long-run fiscal projections.

Official healthcare expenditure projections produced by fiscal authorities such as the Ministry of Finance, the Danish Economic Councils (DØRS), and international organizations ([OECD, 2017](#); [DØRS, 2019](#); [Poisal et al., 2022](#); [Danish Ministry of Finance, 2024](#)) typically project population counts by age, sex, and time-to-death, then combine them with baseline per capita healthcare expenditures, sometimes augmented by a uniform real growth rate calibrated to macroeconomic assumptions. Under this approach, projected expenditure growth arises primarily from changes in population size and age composition. These frameworks typically maintain two simplifying assumptions that facilitate transparency. First, they often assume no or uniform expenditure growth across all ages. Second, the mechanical effect of declining mortality on measured per capita growth through compositional shifts is not always explicitly modeled. Despite the tractability these modeling choices may have quantitative implications in scenarios where mortality composition effects are substantial or expenditures evolve heterogeneously across age groups.

Two competing perspectives stand out in the literature relating healthcare expenditure and population aging. The Red Herring Hypothesis ([Zweifel et al., 1999](#)) argues that proximity to death, rather than chronological age, drives healthcare spending. Under this view, population aging may exert limited fiscal pressure if declining mortality postpones costly end-of-life care to older ages. Empirical support comes primarily from hospital expenditure studies ([Seshamani and](#)

Gray, 2004; Howdon and Rice, 2018), which consistently show that controlling for time-to-death substantially reduces or eliminates age effects. This finding implies that as survival improves, the mechanical shift in population composition away from high-cost decedents toward lower-cost survivors dampens measured expenditure growth. However, evidence for primary care, prescription drugs, and long-term care remains mixed (Kallestrup-Lamb et al., 2024), suggesting the Red Herring effect varies substantially across healthcare sectors.

The competing Steepening Hypothesis (Buchner and Wasem, 2006) posits that healthcare expenditure growth rates differ systematically across ages, with older individuals experiencing faster cost increases over time. This pattern creates a compositional amplification effect: as population aging shifts demographic weight toward older groups, aggregate expenditure growth accelerates mechanically. If expenditures for 80-year-olds grow at 6% annually while expenditures for 40-year-olds grow at 2%, then an aging population raises aggregate growth from higher average expenditures and an increasing population size. Evidence supporting steepening effects has emerged for hospital expenditures in Norway (Gregersen, 2014) and for combined hospital and physician care in Denmark (Kollerup et al., 2022), though findings remain heterogeneous across countries and healthcare sectors.

These mechanisms have traditionally been analyzed separately in both academic research and policy models. Some frameworks account for mortality composition effects on expenditure growth (the central insight of the Red Herring literature), while others focus on age-heterogeneous expenditure growth (the prediction of the Steepening Hypothesis). Our approach integrates both perspectives by jointly modeling mortality composition and differential growth rates across ages, extending the frameworks currently employed in policy settings.

We exploit comprehensive Danish administrative registers covering the entire population (2010–2022) to construct expenditure profiles spanning hospital care, primary care, prescription drugs, and long-term care disaggregated by age, sex, survival status, and geography across 98 municipalities. Measurement of healthcare expenditures by age, sex, and survival status is a data structure increasingly available across OECD countries with public healthcare systems.

Our empirical strategy follows [van Baal and Wong \(2012\)](#), leveraging geographic variation to estimate age-sex-specific growth rates, then projects aggregate expenditures through 2035 by applying these rates to official demographic projections. Beyond estimation, we provide the first decomposition separating projected expenditure increases into population aging, per capita growth, and interaction effects, a framework sharing similarities with [Oaxaca \(1973\)](#)-[Blinder \(1973\)](#) decomposition.

We advance healthcare expenditure projection methodology through three contributions. First, we quantify how accounting for mortality composition alters estimated healthcare expenditure growth rates. While [van Baal and Wong \(2012\)](#) demonstrate theoretically that time-to-death matters for expenditure projections, they restrict attention to hospital expenditures and do not formally quantify the specification difference for comprehensive healthcare spending. We show that accounting for mortality composition revises estimated average annual growth from 2.90% (Naïve specification) to 3.44% (mortality-corrected specification). This 0.5 percentage point difference compounds to 10% divergence in per capita expenditures over 13 years. The specification difference operates through a mechanical channel: as mortality declines, fewer individuals enter the high-cost decedent state each year, reducing observed per capita growth even when underlying costs rise. Specifications that do not separately identify this compositional shift may estimate lower underlying expenditure growth rates.

Second, we document pronounced heterogeneity in age-specific expenditure growth rates and demonstrate through formal hypothesis testing that uniform growth assumptions are rejected by the data ( $p < 0.001$ ). Estimated growth rates range from 0.5% annually for females aged 2–4 to 7.8% annually for males aged 90–94. This fifteenfold differential interacts with demographic shifts to amplify aggregate expenditures: as the population ages, demographic weight shifts toward fast-growing older age groups, mechanically accelerating aggregate growth beyond what would occur under uniform rates. Projections incorporating age-specific growth rates yield estimates for 2035 aggregate expenditures that differ by 22 percentage points from specifications imposing uniform growth, illustrating the quantitative importance of this modeling choice. This

compositional amplification effect represents a distinct mechanism from simple population aging. Projection models that apply a single growth rate to all ages may not fully capture this compositional dynamic.

Third, we provide the first comprehensive decomposition of projected aggregate expenditure increases, separating population aging effects (19% of total increase), per capita cost growth effects (67%), and interaction effects (14%). These mechanisms concentrate future expenditure growth among the oldest: individuals aged 80+ account for 46% of projected expenditure increases through 2035 despite representing only 5% of the 2022 population. This concentration arises from three reinforcing factors: (1) the 80+ population expands rapidly (population effect), (2) this age group experiences the fastest expenditure growth (per capita effect), and (3) these two forces interact multiplicatively (interaction effect).

These findings shift the emphasis of the policy challenge facing aging societies. Per capita cost growth contributes 3.5 times more than demographic changes to projected expenditure increases through 2035. Healthcare sustainability therefore depends less on managing population age structure and more on managing per capita expenditure growth through supply-side mechanisms. In Denmark's politically budgeted healthcare system, where expenditure levels are determined through annual parliamentary negotiations, this shifts the policy locus from demographic projection toward decisions about care provision intensity, treatment protocols, and capacity allocation. The projections reveal that even with complete success in reducing age inequality in healthcare expenditure growth, aggregate expenditure would still increase by 66.9% by 2035 in a uniform-growth scenario. Conversely, population demand for healthcare may itself be changing with population aging due to evolving morbidity patterns ([Carreras et al., 2018](#)) or new medical technologies that disproportionately benefit older individuals ([Chandra and Skinner, 2012](#)), affecting both the need for care and expenditure trajectories.

An important interpretational consideration is that in Denmark's politically budgeted healthcare system, observed expenditure growth reflects realized resource allocation decisions rather than unconstrained demand. Accordingly, the estimated age-specific growth rates describe

historically observed patterns of public resource allocation across age groups likely reflecting competing supply- and demand-driven expenditure responses within the set budget. The projections therefore reflect what future expenditure paths would look like if these allocation patterns persist, providing a benchmark against which alternative policy scenarios can be evaluated.

This paper proceeds as follows. Section 2 formalizes how mortality composition affects standard growth estimates and develops our projection and decomposition framework. Section 3 describes the Danish institutional context and construction of comprehensive expenditure profiles across healthcare sectors. Section 4 presents estimated age-sex-specific growth rates, aggregate projections through 2035, and decomposition results. Section 5 addresses identification assumptions and discusses policy implications for healthcare sustainability. Section 6 concludes.

## 2 Model and Methods

This section develops a projection framework that builds on [van Baal and Wong \(2012\)](#) that extends official Danish demographic projections in two key dimensions: (i) accounting for mortality–composition effects on observed expenditure growth, and (ii) allowing for age–heterogeneous growth rates. Our implementation differs from [van Baal and Wong \(2012\)](#) in scope and identification strategy. First, we analyze comprehensive government-financed healthcare, encompassing hospital care, long-term care, primary care, and pharmaceuticals, rather than hospital expenditures alone. Second, we exploit geographic variation across 98 municipalities to estimate model parameters, extending the time-series approach used in prior work.

### 2.1 Healthcare Expenditure Model

Aggregate national healthcare expenditures in year  $t$  are

$$H_t = \sum_{x \in \mathcal{X}} \sum_{s \in \mathcal{S}} C_{x,s,t} \cdot N_{x,s,t}, \quad (1)$$

where  $C_{x,s,t}$  denotes per capita expenditures and  $N_{x,s,t}$  the projected population in age group  $x$  and sex  $s$  where  $\mathcal{X}$  and  $\mathcal{S}$  denotes the set of age and sex groups, respectively. Official demographic projections provide  $N_{x,s,t}$  and the central task is therefore to model and project  $C_{x,s,t}$ .

Per capita expenditures,  $C_{r,x,s,t}$ , can be decomposed into per capita expenditures for survivors ( $C_{r,x,s,t}^0$ , those who live through year  $t$ ) and per capita expenditures of decedents ( $C_{r,x,s,t}^1$ , those who die) components:

$$C_{r,x,s,t} = (1 - M_{r,x,s,t}) C_{r,x,s,t}^0 + M_{r,x,s,t} C_{r,x,s,t}^1 \quad (2)$$

where  $r$  indexes municipalities and  $M_{r,x,s,t}$  is the mortality rate. Because  $C^1 \gg C^0$  at most ages (Lubitz and Riley, 1993), declines in mortality mechanically reduce per capita expenditures as the fraction with high end-of-life expenditures decrease.

The age-sex specific healthcare expenditure growth,  $\beta_{x,s}$ , with  $C_{r,x,s,t}^0 = C_{r,x,s,t-1}^0 (1 + \beta_{x,s})$  and  $C_{r,x,s,t}^1 = C_{r,x,s,t-1}^1 (1 + \beta_{x,s})$ , is a key parameter of interest as it bears large importance for future healthcare expenditures. Mortality changes, however, also impact how mean healthcare expenditures change over time. Following van Baal and Wong (2012), consider the log-differences of equation (2) between periods  $t$  and  $t - 1$

$$\Delta \log(C_{r,x,s,t}) = \log \left( \frac{(1 - M_{r,x,s,t}) C_{r,x,s,t}^0 + M_{r,x,s,t} C_{r,x,s,t}^1}{(1 - M_{r,x,s,t-1}) C_{r,x,s,t-1}^0 + M_{r,x,s,t-1} C_{r,x,s,t-1}^1} \right) \quad (3)$$

$$\approx \beta_{x,s} + \log \left( \frac{1 + M_{r,x,s,t} (R_{r,x,s,t} - 1)}{1 + M_{r,x,s,t-1} (R_{r,x,s,t-1} - 1)} \right), \quad (4)$$

using the approximation  $\log(1 + \beta_{x,s}) \approx \beta_{x,s}$  and the cost ratio  $R_{r,x,s,t} := \frac{C_{r,x,s,t}^1}{C_{r,x,s,t}^0}$ . The first term,  $\beta_{x,s}$ , captures actual expenditure growth. The second term present a mortality–composition effect. Since  $R > 1$ , mortality improvements generate negative composition effects, shifting population weight toward lower-cost survivors, and mechanically reduce observed per capita expendi-

tures even when  $\beta_{x,s} > 0$ .<sup>1</sup> Failing to account for mortality shifts systematically underestimates underlying cost growth. Equation (4) provides the basis for the empirical specification.

## 2.2 Empirical Specification and Estimation

We estimate age–sex-specific expenditure growth rates using a balanced panel covering 98 municipalities observed annually from 2010–2022, indexed by  $t \in \mathcal{T}$ . Our main specification implements equation (4) directly:

$$\Delta \log C_{r,x,s,t} = \beta_0 + \beta_{x,s} + \gamma_t + \log \left( \frac{1 + M_{r,x,s,t}(R_{r,x,s,t} - 1)}{1 + M_{r,x,s,t-1}(R_{r,x,s,t-1} - 1)} \right) + \varepsilon_{r,x,s,t}, \quad (5)$$

where  $\beta_0$  captures the mean growth rate across all groups and  $\beta_{x,s}$  represents the age–sex-specific deviation from this mean. Year fixed effects  $\gamma_t$  absorb aggregate shocks common to all municipalities and demographic groups. We employ effects coding such that  $\sum_{x \in \mathcal{X}} \sum_{s \in \mathcal{S}} \beta_{x,s} = 0$  and  $\sum_{t \in \mathcal{T}} \gamma_t = 0$  implying that  $\beta_0$  equals the unweighted mean growth rate across age–sex cells.<sup>2</sup> We allow arbitrary correlation of the conditional mean error term,  $\varepsilon_{r,x,s,t}$ , within municipalities over time and across demographic groups, assuming independence only across municipalities. Standard errors are therefore clustered at the municipality level using the [Cameron and Miller \(2015\)](#) heteroskedasticity- and autocorrelation-robust variance estimator.<sup>3</sup>

For comparison, we estimate a *Naïve Model* that omits the mortality-composition term:

$$\Delta \log(C_{r,x,s,t}) = \beta_0^{\text{Naïve}} + \beta_{x,s}^{\text{Naïve}} + \gamma_t^{\text{Naïve}} + \varepsilon_{r,x,s,t}^{\text{Naïve}}. \quad (6)$$

<sup>1</sup>This relationship may be modified if the survivor–decendent cost ratio evolves over time. In our empirical implementation, we allow for this channel by using observed cost ratios, but a structural analysis of their dynamics lies outside the scope of this paper. Using the observed cost ratio is a relaxation of the constant- $R$ -assumption in [van Baal and Wong \(2012\)](#) which their data requires them to make.

<sup>2</sup>Effects coding avoids reliance on an arbitrary omitted category and yields coefficients that are deviations from the mean rather than from a reference group.

<sup>3</sup>This accounts for persistent unobserved municipal characteristics (e.g., infrastructure, provider behavior) that generate correlated shocks across demographic groups.

Differences between estimates from (5) and (6) quantify the bias in  $\hat{\beta}_0$  arising from ignoring changes in mortality composition.

Both models are estimated by weighted least squares (WLS) using population weights  $w_{r,x,s,t} = N_{r,x,s,t}$  to address heteroskedasticity arising from variation in the size of demographic cells. Appendix A provides additional details on estimation and the construction of mortality-adjusted covariates.

### 2.3 Projection and Decomposition

Using the estimated growth rates,  $\hat{\beta}_{x,s}$ , from equation (5), we project per capita expenditures at a national level (dropping subscript,  $r$ ) from 2022 forward to year  $t$  as:

$$C_{x,s,t} = [(1 - M_{x,s,t}) \cdot C_{x,s,2022}^0 + M_{x,s,t} \cdot C_{x,s,2022}^1] \cdot (1 + \hat{\beta}_{x,s})^{t-2022} \quad (7)$$

Aggregate expenditures follow from equation (1) and incorporates three sources of expenditure growth: (1) per capita expenditure growth at rate  $\hat{\beta}_{x,s}$ , (2) demographic aging through changing population structure  $N_{x,s,t}$ , and (3) mortality composition effects through evolving  $M_{x,s,t}$ .

We decompose projected aggregate expenditure changes into three additive components clarifying the relative importance of demographic change versus expenditure dynamics. The change from base year  $t_0$  (2022) to future year  $t_1$  (2035),  $H_{t_1} - H_{t_0}$ , decomposes exactly as:

$$\underbrace{\sum_{x \in \mathcal{X}} \sum_{s \in \mathcal{S}} (N_{x,s,t_1} - N_{x,s,t_0}) C_{x,s,t_0}}_{\text{population effect}} + \underbrace{\sum_{x \in \mathcal{X}} \sum_{s \in \mathcal{S}} N_{x,s,t_0} (C_{x,s,t_1} - C_{x,s,t_0})}_{\text{expenditure growth effect}} + \underbrace{\sum_{x \in \mathcal{X}} \sum_{s \in \mathcal{S}} (N_{x,s,t_1} - N_{x,s,t_0}) (C_{x,s,t_1} - C_{x,s,t_0})}_{\text{interaction effect}}. \quad (8)$$

The *population effect* captures expenditure change if per capita costs remained at 2022 levels while the population change. The *expenditure growth effect* isolates rising per capita expenditures, holding population structure fixed. The *interaction effect* reflects joint operation of demographic and expenditure growth within age-sex cells. Our decomposition shares similarity

with the [Oaxaca \(1973\)-Blinder \(1973\)](#) method but address intertemporal changes rather than contemporaneous differences in observed outcomes.

To address projection uncertainty, we perform  $B = 5,000$  bootstrap replications, drawing a growth rate vector  $\beta^{(b)} \sim N(\hat{\beta}, \widehat{\text{Var}}(\hat{\beta}))$  where  $\widehat{\text{Var}}(\hat{\beta})$  is the cluster-robust variance-covariance matrix. For each replication, we recalculate the decomposition. This captures parameter uncertainty in growth rate estimation while treating demographic projections as fixed. The 95% confidence intervals use the 2.5th and 97.5th percentiles of the resulting projection distributions.<sup>4</sup>

### 3 Institutional Background and Data

#### 3.1 The Danish Healthcare System

Denmark's universal, tax-financed healthcare system provides comprehensive coverage to approximately 6 million inhabitants with minimal cost-sharing. Administrative responsibility is distributed across three governmental levels: the national government maintains regulatory oversight and fiscal coordination; five regions operate hospitals and finance primary care providers (general practitioners, specialists, physiotherapists); and 98 municipalities deliver rehabilitation, long-term care, and public health services. Government expenditure finances 83.4% of all healthcare expenditures, with private insurance (2.7%), and out-of-pocket payments (13.9%, primarily drug copayments and dental care) comprising the remainder ([Statistics Denmark, 2025d](#)).

This institutional structure offers two advantages for expenditure analysis. First, comprehensive administrative registers capture essentially all publicly financed healthcare consumption across the entire population ([Ministry of Health, 2017](#)), eliminating selection bias from insurance coverage gaps and access to care that complicate cross-country comparisons. Second, the predominance of government financing ensures that our expenditure projections directly inform

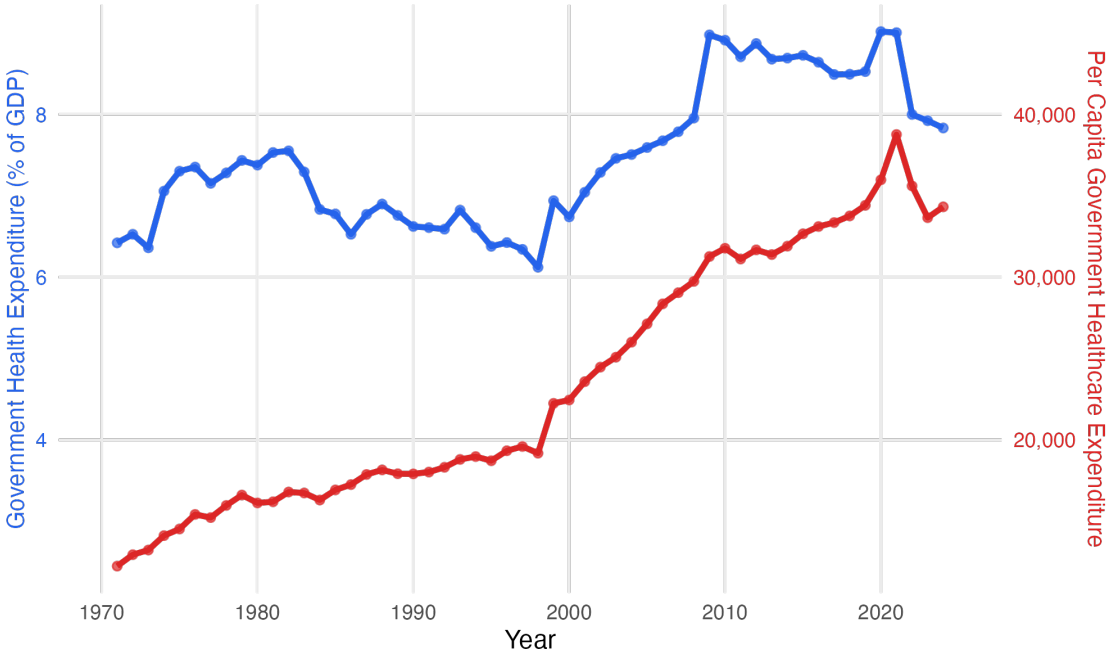
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<sup>4</sup>Total projection uncertainty incorporating demographic projection errors, technological shocks, and policy regime changes could exceed reported bounds.

fiscal policy, as private spending adjustments cannot substantially offset public expenditure trends.

**Health Expenditure Trends** Denmark’s government health expenditure exhibits two distinct growth patterns over 1971–2024. As a GDP share (Figure 1, blue line), spending follows a non-monotonic trajectory: rising from 6.4% (1971) to 7.6% (1982) during universal coverage expansion (Pedersen et al., 2005), stabilizing at 6.1–6.8% through the 1990s, then climbing to 8.0% by 2008 amid structural reforms (Christiansen, 2012). The 2008–2009 financial crisis temporarily elevated the ratio to 9.0% as GDP contracted while healthcare spending remained stable. The COVID-19 pandemic similarly produced a temporary spike, with expenditure reaching 9.1% of GDP in 2021 before normalizing.

Figure 1. Danish Government Health Expenditure, 1971–2024



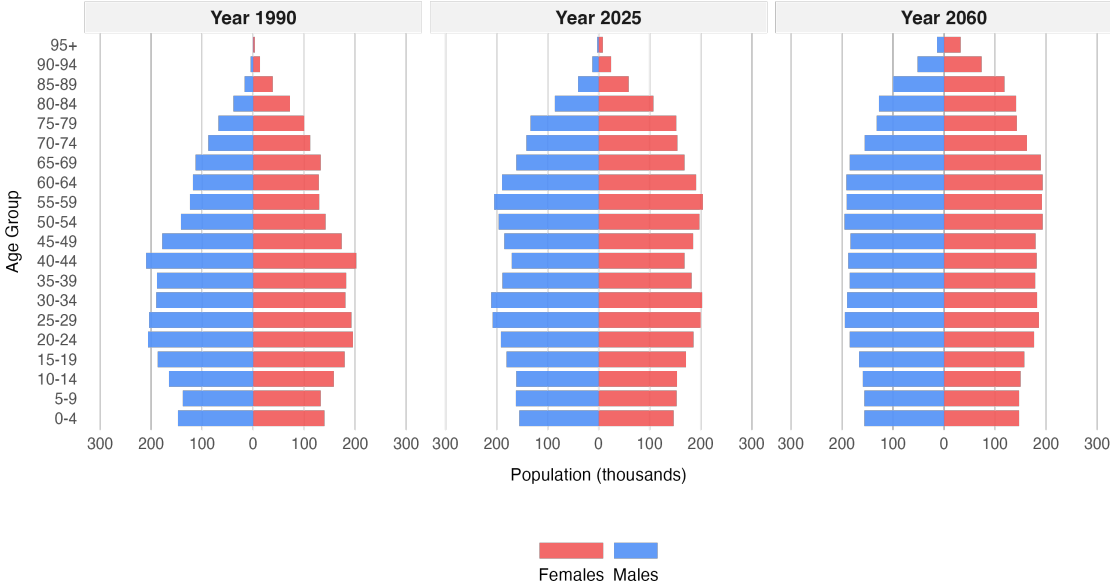
Note: Government health expenditure as share of GDP (left axis, blue) and per capita in constant 2020 DKK (right axis, red). Source: OECD Health Statistics (OECD, 2025).

In per capita terms (red line), growth is consistently positive. Real expenditure per person rose from DKK 12,246 (1971) to DKK 34,321 (2024) in constant 2020 prices, a 180% increase representing 2.0% average annual growth. Excluding the COVID-19 anomaly (2020–2021 peak at

DKK 38,764), healthcare expenditure generally grew across the period. This sustained real growth, exceeding both EU/EEA and WHO European Region averages (Birk et al., 2024), motivates our focus on expenditure projections, in particular, given the expected demographic changes in the coming years.

**Demographic Transformation** Denmark faces population aging that fundamentally reshapes its demographic composition. Figure 2 documents the age structure evolution across 1990 (past), 2025 (present), and 2060 (future).

**Figure 2.** Danish Population Structure: 1990, 2025, and 2060



*Note:* Population pyramids showing age-sex structure. Males (blue, left, negative), females (red, right, positive). *Source:* Statistics Denmark, BEFOLK1 (historical) (Statistics Denmark, 2025a) and FRDK125 (projections) (Statistics Denmark, 2025b).

In 1990, Denmark exhibited a broad-based age structure with substantial working-age cohorts (population: 5.14 million; 15.6% aged 65+). By 2025, aging effects become visible: large cohorts concentrate in pre-retirement ages (50–70) while entry cohorts shrink, producing the rectangular profile characteristic of mature economies (population: 5.99 million; 65+ population grew by 56.2% from 1990).

The 2060 projections reveal the demographic transformation’s expected scope. Total population reaches 6.23 million (21.3% above 1990, 3.9% above 2025), but compositional shifts

are large. The 65+ population expands to 1.62 million, with the 80+ cohort nearly doubling from 339,000 (2025) to 657,000 (2060). Simultaneously, the working-age population (20–64) stagnates, worsening old-age dependency ratios. As healthcare expenditure concentrates in old age ([Kallestrup-Lamb et al., 2024](#)), this demographic transformation carries severe fiscal implications for healthcare expenditures.

### **3.2 Data Sources and Construction**

For our empirical analyses we utilize comprehensive administrative registers covering Denmark’s entire population over 2010–2022. Individual level records link demographic information (population register BEF) with healthcare expenditures through pseudonymized identifiers. Death register (DOD) data enable classification of individuals as survivors or decedents and measurement of age-sex-specific mortality rates. Our healthcare expenditure measure captures the largest components of Denmark’s healthcare system: hospital care (somatic and psychiatric), primary care (general practitioners, specialists, health professionals), prescription drugs, and long-term care. This comprehensive scope is critical: while hospital and primary care dominate international healthcare analyses, long-term care represents a substantial and rapidly growing expenditure category in aging populations. Danish administrative data allow us to construct complete individual level expenditure profiles spanning these domains.

Denmark employs a Diagnosis Related Group (DRG) system that assigns expenditures to hospital encounters based on diagnoses, procedures, and length of stay. We extract DRG expenditures for both somatic and psychiatric care across inpatient and outpatient settings from the Danish DRG registers. DRG expenditures reflect variable treatment expenditures and some fixed expenditures attributable to individual patients but exclude capital depreciation and infrastructure expenses that cannot be reliably allocated to individuals. This measurement choice is appropriate for expenditure projections: variable expenditures scale with utilization, while capital expenditures respond more slowly to demographic changes.

General practice and specialist care expenditures derive from provider reimbursements recorded in register SSSY at weekly frequency. The register captures all services subsidized by national health insurance (e.g., general practitioners, specialist physicians, physiotherapists, chiropractors, and psychologists) along with service details and provider characteristics. This fee-for-service data provides precise measurement of publicly-financed primary care consumption.

The Medication Purchase Register (LMDB) records monthly individual prescription drug expenditures, representing over 80% of pharmacy turnover in primary healthcare. The register includes both public subsidies for prescription medications but excludes over-the-counter drugs and hospital-administered medications (captured in DRG expenditures).

We construct individual level long-term care expenditures by combining administrative utilization records with aggregate expenditure data from Statistics Denmark's System of Health Accounts (SHA) ([Statistics Denmark, 2025d](#)). Our analysis encompasses personal home care, home nursing, and institutional nursing home care. Service quantities are measured through AEFV (home care minutes), HJSP and AEHJSP (home nursing visits), and AEPB (nursing home residence days).

Because administrative registers record utilization without prices, we employ a cost allocation methodology. Aggregate long-term care expenditures from SHA accounts ([Statistics Denmark, 2025d](#)) are allocated to calculate annual unit expenditures for each service category. Nursing home expenses derive from SHA account *2.1 Long-term nursing care facility*; combined home care and home nursing expenditures stem from account *3.5 Providers of home health care services*. We disaggregate home nursing from home care by setting home nursing unit expenditures 17.6% above home care, reflecting wage differentials reported by [Gørtz et al. \(2023\)](#). This methodology trades municipal price variation for aggregate consistency. While we cannot observe individual level price heterogeneity, our approach ensures that predicted expenditures align with SHA-reported aggregate spending, the relevant quantity for fiscal projections. The alternative of using only DRG and primary care data (which have individual level prices) would substantially

understate total healthcare expenditure and omit the component most concentrated among the elderly.

We aggregate individual healthcare expenditures to annual totals by age group, sex, survival status, and municipality. To ensure consistency with national accounts, we scale total healthcare expenditures to match SHA annual amounts using the accounts detailed in Online Appendix B. This calibration serves two purposes: it corrects for any coverage gaps in administrative registers, and it ensures our projections align with actual observed healthcare consumption levels in Denmark.

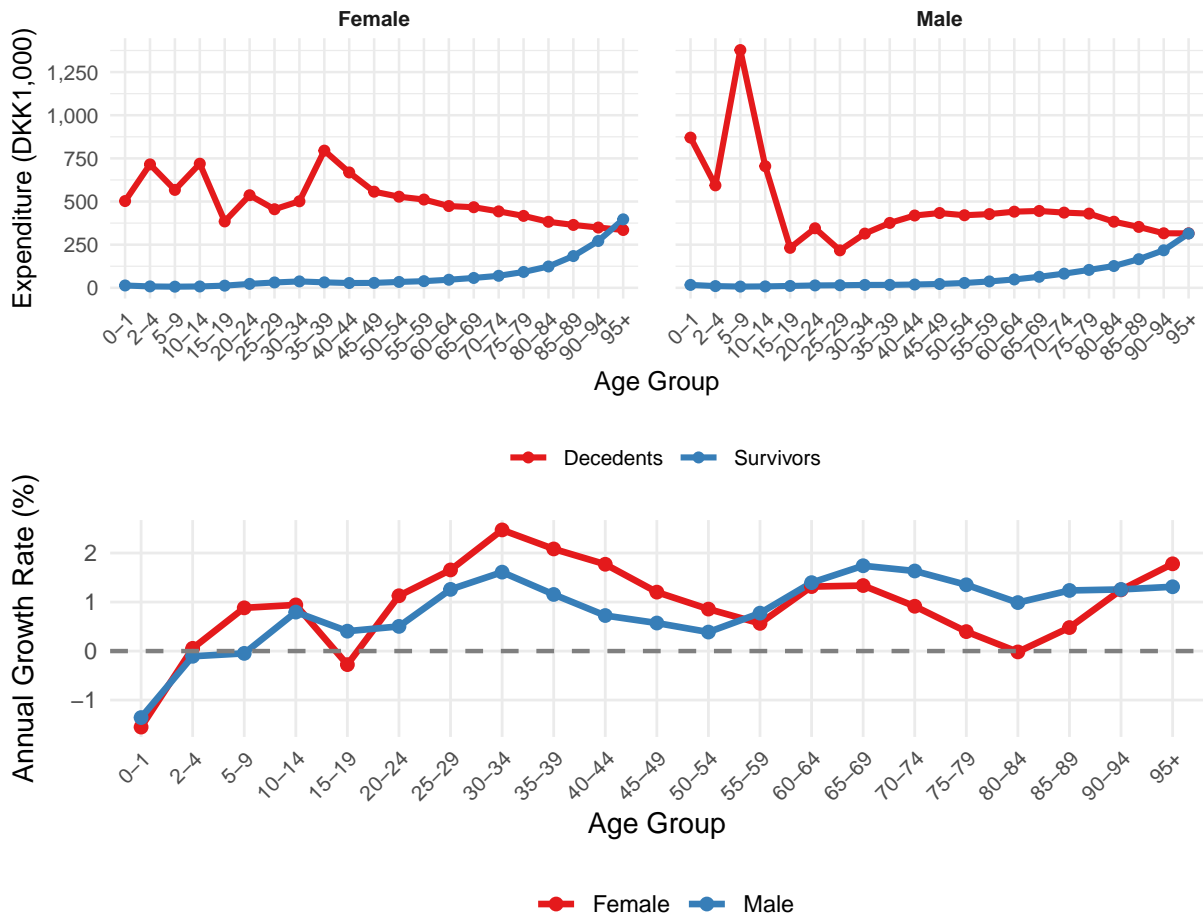
### 3.3 Descriptive Statistics

Figure 3 documents empirical patterns motivating our modeling approach: the concentration of expenditures near death and age-heterogeneous growth rates.

**Concentration of Healthcare Expenditures Near Death** The top panel reveals stark expenditure differentials between decedents and survivors. At ages 80–84, per capita expenditures reach DKK 383,000 for decedents versus DKK 124,000–126,000 for survivors, a threefold difference. This end-of-life concentration has been documented internationally ([Lubitz and Riley, 1993](#); [Zweifel et al., 1999](#)), but comprehensive Danish administrative data enable precise quantification across the entire population without insurance-induced selection.

The decedent-survivor ratio varies systematically by age. Among working-age adults (40–64), decedent expenditures exceed survivor expenditures by factors of 9–24. At ages 40–44, the ratio reaches 24-fold for females (DKK 668,000 vs DKK 28,000) and 22-fold for males (DKK 419,000 vs DKK 19,000). The gap narrows substantially at advanced ages: 1.3–1.5-fold at ages 90–94, nearly vanishing among the oldest old (95+). This convergence suggests end-of-life care becomes less exceptional as baseline health deteriorates and intensive long-term care dominates regardless of imminent mortality. Critically, survivor expenditures rise monotonically with age, reflecting increasing prevalence of chronic conditions, functional limitations, and long-term care

**Figure 3.** Healthcare Expenditures by Age, Sex, and Survival Status



*Note:* Top panels show 2022 per capita healthcare expenditures (DKK) by age for decedents (died within one year, red) and survivors (blue), separately by sex. Bottom panels display estimated annual growth rates by age and sex over 2010–2022. *Source:* Authors’ calculations from Danish administrative registers.

needs. Population aging therefore mechanically increases aggregate expenditures by shifting demographic weight toward high-survivor-cost age groups, independent of end-of-life care dynamics.

**Age-Heterogeneous Expenditure Growth** The bottom panel displays estimated annual growth rates by age and sex, comparing 2010 and 2022 per capita expenditures. Growth rates range from  $-1.6\%$  (females aged 0–1) to  $+2.5\%$  (females aged 30–34), with substantial heterogeneity challenging uniform-growth assumptions in standard fiscal models.

Three patterns emerge. First, pediatric expenditures show negative or minimal growth, declining  $1.4\text{--}1.6\%$  annually at ages 0–1 before stabilizing near zero. Growth turns modestly positive during school ages ( $0.8\text{--}0.9\%$  at ages 10–14), likely reflecting increased mental health and preventive care investments. Second, female healthcare expenditure growth systematically exceeds male growth across ages 20–64, peaking at ages 30–34 ( $2.5\%$  vs  $1.6\%$ ). While obstetric and gynecological services contribute during reproductive years, the differential persists beyond, pointing to broader sex differences in utilization patterns. Third, male growth matches or exceeds female growth after age 65. At ages 70–74, male expenditures grow  $1.6\%$  annually versus  $0.9\%$  for females, ages with intensive hospital care expenditures and rising long-term care expenses (Kallestrup-Lamb and Marin, 2024).

## 4 Results

### 4.1 Healthcare Expenditure Growth Rates

Table 1 presents our baseline regression results comparing the Naïve Model (Equation (6)) with the TTD model (Equation (5)). Both specifications include age-sex fixed effects and year fixed effects, with standard errors clustered at the municipality level. The key difference is that the TTD model accounts for the higher expenditures for decedents and the impact of changing mortality rates.

**Table 1.** Healthcare Expenditure Growth: Main Regression Results

Dep.Var.: $\Delta \log(C_{r,x,s,t})$	Naïve Model	TTD Model
Average growth rate ( $\beta_0$ )	0.029*** (0.003)	0.034*** (0.003)
TTD composition effect	–	Included
Age-sex fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
Observations	49,729	49,729
$R^2$	0.153	0.161
Adjusted $R^2$	0.152	0.160

*Notes:* Robust standard errors clustered at municipality level in parentheses. All specifications estimated using weighted least squares with population weights. The Naïve Model (Column 1) corresponds to Equation (6), while Column 2 implements Equation (5). \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.10$ .

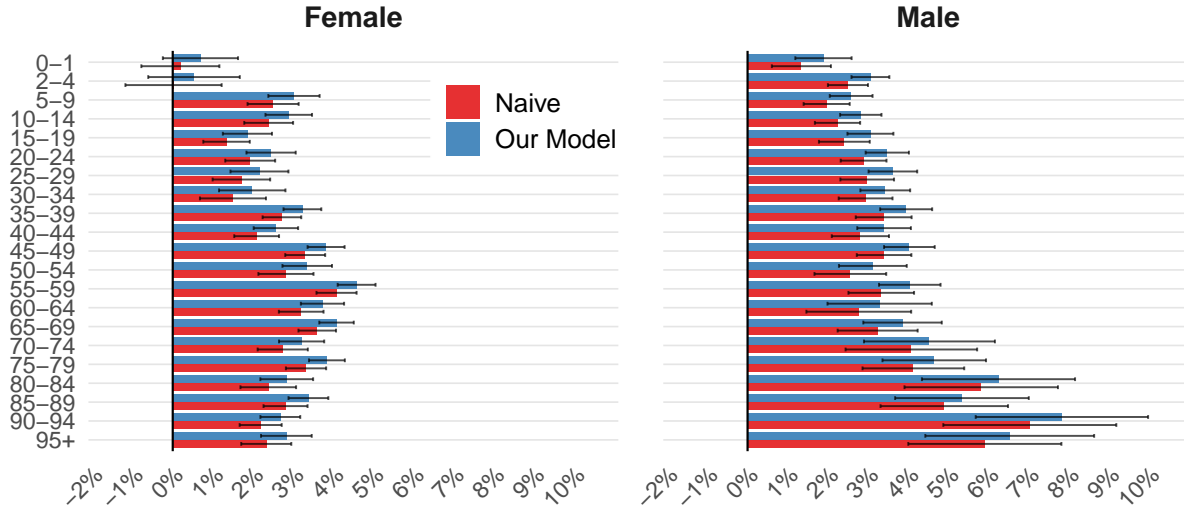
The Naïve Model estimates an average annual growth rate of 2.9% (Column 1), while the TTD Model yields 3.4% (Column 2), a 0.5 percentage point difference that appears modest but compounds substantially over projection horizons. This upward revision reflects the mechanical dampening effect of declining mortality rates: as fewer people die each year, the population shifts toward lower-cost survivors, artificially reducing observed per capita expenditure growth. The Naïve Model attributes this composition effect to slower underlying expenditure growth. When mortality composition effects are present, this specification may systematically estimate lower growth rates at which healthcare expenditures rise for survivors and decedents alike.

The TTD Model’s superior fit is evident from the higher  $R^2$  (0.161 vs 0.153), though both specifications explain a modest share of variation in expenditure growth. This limited explanatory power is unsurprising: healthcare expenditure growth reflects numerous factors beyond mortality composition and age-sex demographics, e.g., technological innovation, practice pattern evolution, policy changes, and idiosyncratic municipal shocks. Our focus is not comprehensive explanation of all variation but rather estimation of age-sex-specific growth rates purged of mortality composition bias.

**Growth Rates by Age and Sex** Figure 4 displays estimated age-sex-specific growth rates,  $\hat{\beta}_0 + \hat{\beta}_{x,s}$ , from both models, revealing substantial heterogeneity that standard fiscal projections ignore. Growth rates range from 0.5% annually (females aged 2–4, TTD model) to 7.8% annually (males aged 90–94, TTD model). For females, median growth is 2.9% under the TTD Model

versus 2.4% under the Naïve specification; for males, the corresponding rates are 3.6% and 3.0%. The TTD correction systematically shifts the estimated growth rates upward across nearly all age-sex groups, with the effect concentrated among working-age and elderly populations where mortality rates have declined most rapidly.

**Figure 4.** Estimated Annual Growth Rates by Age and Sex



*Note:* Bars show estimated age-sex-specific growth rates with 95% confidence intervals. The Naïve Model (red) omits mortality composition effects; TTD model (blue) includes time-to-death correction per Equation (5). Standard errors clustered at municipality level. *Source:* Authors' estimates from Danish administrative registers, 2010–2022.

Three patterns merit emphasis. First, we formally test whether age-sex-specific growth rates are necessary by examining whether deviations from the average rate are jointly zero. The null hypothesis  $H_0: \beta_{x,s} = 0$  for all  $(x, s)$  corresponds to the uniform growth assumption embedded in many official projections. An F-test decisively rejects uniform growth ( $F = 6.59, p < 0.001$ ), confirming that growth rates vary significantly across age-sex groups. The TTD correction increases estimated growth rates by an average of 0.50 percentage points for females and 0.58 percentage points for males. A paired  $t$ -test across all 42 age-sex groups yields  $t = 46.7$  ( $p < 0.001$ ), rejecting the null hypothesis of equal growth rates between models,  $H_0: \hat{\beta}_0^{\text{Naïve}} + \hat{\beta}_{x,s}^{\text{Naïve}} = \hat{\beta}_0 + \hat{\beta}_{x,s}$  for all  $(x, s)$ . Although average growth rates do not differ significantly at conventional levels (Naïve:  $\hat{\beta}_0^{\text{Naïve}} = 2.90\%$ ; TTD:  $\hat{\beta}_0 = 3.44\%$ ;  $t = 1.34, p = 0.181$ ), this aggregate comparison obscures the systematic underestimation within specific age-sex cells. The magnitude varies across age

groups, with maximum absolute differences ( $|\hat{\beta}_0^{\text{Naive}} + \hat{\beta}_{x,s}^{\text{Naive}} - \hat{\beta}_0 + \hat{\beta}_{x,s}|$ ) of 0.57 percentage points (females) and 0.80 percentage points (males). These differences appear small annually but compound exponentially: over 35 years (2022–2035), a 0.5 percentage point annual difference translates to a 10% divergence in projected per capita expenditures.

Second, male healthcare expenditures exhibit systematically higher growth rates than female expenditures. Under the TTD Model, male growth averages 4.04% annually (SD = 1.43%) versus 2.84% for females (SD = 1.01%), a 1.19 percentage point gap that is statistically significant ( $t = -3.12$ ,  $p = 0.004$ ). This differential persists across the age distribution but widens dramatically after age 70. At ages 70–74, male expenditures grow 4.5% annually versus 3.2% for females; at ages 80–84, the rates are 6.3% versus 2.8%; at ages 90–94, they reach 7.8% versus 2.7%. Hence, although female expenditures are higher on average, male expenditures are rising more quickly. This pattern partially confirms implications of the Steepening Hypothesis: faster expenditure growth for older individuals, although the pattern is more mixed, particularly for females.

Third, substantial within-sex heterogeneity suggests that fiscal projection models assuming uniform age-invariant growth may not fully capture age-specific dynamics. Among females, growth rates range from 0.5% (ages 2–4) to 4.6% (ages 55–59); among males, from 1.9% (ages 0–1) to 7.8% (ages 90–94). This heterogeneity implies that population aging generates compositional effects beyond simple demographic shifts: as the population ages, expenditure growth accelerates mechanically because demographic weight shifts toward high-growth age groups.

The confidence intervals in Figure 4 reveal reasonable precision. Although precision deteriorates at the extremes (ages 0–1, 95+) where smaller population sizes and higher mortality volatility generate noisier estimates, confidence bands at most age groups span 1.1–1.7 percentage points, providing sufficient precision for medium-run fiscal projections while acknowledging irreducible uncertainty in long-run projections. These estimated age-sex-specific growth rates form the foundation for our expenditure projections.

**Robustness Checks** We subject our baseline estimates to three specification tests. First, adding municipality fixed effects to absorb time-invariant local characteristics leaves estimates essentially unchanged: paired  $t$ -test  $t = -0.008$  ( $p = 0.994$ ), correlation = 0.999. Geographic variation in unobserved factors does not bias age-sex-specific growth rates. Second, re-estimating via OLS instead of WLS yields nearly identical point estimates ( $t = 0.546$ ,  $p = 0.588$ , correlation = 0.663), though standard errors increase as expected when ignoring heteroskedasticity. Findings reflect genuine expenditure dynamics rather than weighting artifacts. Third, controlling for age-sex-specific COVID-period effects (2020–2021 interaction terms) leaves remaining estimates statistically indistinguishable from baseline ( $t = -0.074$ ,  $p = 0.941$ , correlation = 0.904), suggesting our estimates capture structural trends rather than transient pandemic growth rate shocks. Given this insensitivity to alternative specifications, we retain the baseline TTD model (Equation (5)) for expenditure projections. Table 5, Appendix C collects the test results.

## 4.2 Healthcare Expenditure Projections

We project Danish healthcare expenditures through 2035 under three growth scenarios, comparing outcomes from the Naïve Model and the TTD Model. Future population size and mortality rates are drawn from Statistics Denmark ([Statistics Denmark, 2025b,c](#)) like official demographic projections ([DØRS, 2019](#); [Danish Ministry of Finance, 2024](#)). Our preferred projection employs the age-sex-specific growth rates estimated in Section 4.1, while alternative scenarios illustrate the mechanical effects of demographic change (zero growth) and uniform expenditure growth (2.9% across all groups). These scenarios isolate the separate contributions of demographic aging, expenditure growth, and their interaction, providing fiscal planners with precise quantification of expenditure drivers. Table 2 presents projected expenditure growth relative to the 2022 baseline of DKK 241 billion. Three patterns emerge that challenge standard assumptions about healthcare cost dynamics under population aging.

**The Modest Role of Pure Demographics** Demographic aging alone, absent any cost growth, drives expenditures up 15.1% by 2035 under the TTD model, reaching DKK 277 billion in constant 2022 prices. This represents substantial but manageable fiscal pressure: approximately 1.1% annual growth attributable purely to demographic composition shifts, increasing the population size at the highest-cost age group. The TTD model projects 2 percentage points lower demographic impact than the Naïve approach (15.1% versus 16.9% by 2035). This difference reflects a subtle but important compositional mechanism: mortality improvements shift population composition toward lower-cost survivors within each age group. As life expectancy rises, fewer individuals at any given age are near death, mechanically reducing average per capita expenditures even as the population ages.

Incorporating uniform 2.9% annual cost growth (calibrated to match the Naïve model's average historical trend from Table 1) yields dramatically higher projections: 66.9% growth under the TTD model versus 69.5% under the Naïve specification by 2035. Expenditures reach DKK 402 billion (TTD) and DKK 408 billion (Naïve), levels 2.4 times the zero-growth scenario and 67% above the 2022 level. The slightly lower cost in the TTD Model reaffirms the mortality mechanism, shifting population weight to lower-cost survivor. The most striking finding is the huge increase in expenditure growth once growth rates are accounted for, amounting to 40.8 percentage points higher expenditure growth compared to the zero-growth scenario, reflecting the importance of expenditure growth in healthcare expenditure projections.

**Amplification Under Age-Heterogeneous Growth** Our preferred specification with age-sex-specific growth rates under the TTD Model, projects 88.6% expenditure growth by 2035, reaching DKK 454 billion in constant 2022 prices, a 5.0% increase in aggregate healthcare expenditures annually. This substantially exceeds both the uniform growth scenario (+22 percentage points) and the Naïve model's age-specific projection (79.6%), generating a DKK 22 billion projection divergence by 2035.

**Table 2.** Healthcare Expenditure Projections: 2022–2035

Model	2025		2030		2035	
	Naive	TTD	Naive	TTD	Naive	TTD
<i>Panel A: Growth relative to 2022 baseline (%)</i>						
Zero growth	4.5	3.9	11.0	9.8	16.9	15.1
Uniform 2.9%	13.8	13.2	39.6	38.0	69.5	66.9
Age-sex specific	14.9	16.0	43.9	48.1	79.6	88.6
	(12.7/17.1)	(13.9/18.0)	(36.3/52.0)	(40.9/55.8)	(64.0/97.4)	(73.4/106.4)
<i>Panel B: Expenditure levels (Billion DKK, 2022 prices)</i>						
Zero growth	251	250	267	264	281	277
Uniform 2.9%	274	272	336	332	408	402
Age-sex specific	277	279	346	357	432	454
	(271/282)	(274/284)	(328/366)	(339/375)	(395/475)	(417/497)
Baseline 2022	241 billion DKK					

*Notes:* Healthcare expenditure projections using the method from Section 2.3. Panel A shows percentage growth from 2022 baseline aggregate healthcare expenditures; Panel B shows absolute expenditure levels by projection horizon. Uniform scenario applies 2.9% annually to all age-sex groups is from Table 1 and age-sex specific scenario uses estimated growth rates from Figure 4. 95% bootstrap confidence intervals in parentheses based on 5,000 replications of random age-sex growth rates.

This amplification reflects the interaction between rapid elderly cost growth and demographic aging. Estimated growth rates reach 4-8% annually for individuals aged 80+, compared to 2-4% for working-age adults as illustrated in Figure 4. As the 80+ population share rises, aggregate growth increasingly reflects high-growth elderly cohorts rather than low-growth working-age groups.

The Naïve model underestimates this amplification mechanism for a key reason. By conflating healthcare expenditure growth with mortality composition dampening, it estimates lower growth rates for all age-sex groups which is particularly important for the older age-groups which increase in size. Meanwhile, the Naïve model's inability to accommodate mortality changes has the opposite effect, increasing expenditure projections, as it does not account for mortality improvements shifting the population share between individuals incurring less expensive survivor healthcare expenditures and the more expensive decedent expenses. Yet, the growth rate effect dominates the effect of mortality rate changes.

Notably, the confidence intervals, accounting for the growth rate parameter estimation error, reveal substantial uncertainty in projections. For the age-sex-specific TTD model, the 95% interval spans DKK 417-497 billion by 2035, overlapping with projection in the Naïve model. The DKK 80 billion range representing 18% of the point projection. This uncertainty reflects

only parameter estimation error in the growth rates; total projection uncertainty, incorporating demographic projection errors, policy changes, and technological shocks, substantially exceeds these bounds. These confidence intervals should, thus, be interpreted as lower bounds on total projection uncertainty.

### 4.3 Decomposing Healthcare Expenditure projections

Table 3 implements the decomposition framework from Section 3.3, partitioning the DKK 213 billion projected increase (2022–2035) into population effects, per capita cost growth effects, and interaction effects. This accounting reveals two findings that provide additional perspective on healthcare sustainability discussions.

**Table 3.** Decomposition of Healthcare Expenditure Growth (2022–2035)

Category	Group	Total Change (Bn DKK)	Population Change (Bn DKK)	Expenditure Growth (Bn DKK)	Interaction Effect (Bn DKK)
<b>Panel A: Overall Decomposition (TTD Model)</b>					
Total	All	213.1 (176.2/254.1) [100.0%]	41.0 (41.0/41.0) [19.3%]	142.4 (113.1/174.8) [66.8%]	29.7 (21.6/38.9) [13.9%]
<b>Panel B: By Age Category and Sex</b>					
0–19	Female	1.5 (1.1/2.0) [0.7%]	-0.1 (-0.1/-0.1) [-8.7%]	1.7 (1.2/2.2) [112.5%]	-0.1 (-0.1/-0.0) [-3.8%]
	Male	2.6 (2.0/3.2) [1.2%]	-0.1 (-0.1/-0.1) [-2.4%]	2.7 (2.1/3.3) [104.0%]	-0.0 (-0.1/-0.0) [-1.6%]
20–64	Female	28.2 (23.9/32.7) [13.2%]	-0.0 (-0.0/-0.0) [-0.1%]	28.6 (24.2/33.1) [101.4%]	-0.4 (-0.5/-0.2) [-1.3%]
	Male	23.0 (17.0/29.6) [10.8%]	-0.8 (-0.8/-0.8) [-3.3%]	24.2 (18.1/31.0) [105.5%]	-0.5 (-0.6/-0.4) [-2.1%]
65–79	Female	25.6 (22.4/28.9) [12.0%]	3.0 (3.0/3.0) [11.7%]	20.9 (18.0/24.0) [81.6%]	1.7 (1.5/2.0) [6.7%]
	Male	34.3 (23.1/47.0) [16.1%]	4.3 (4.3/4.3) [12.6%]	27.2 (17.1/38.7) [79.2%]	2.8 (1.8/4.0) [8.2%]
80+	Female	42.8 (38.6/47.1) [20.1%]	19.7 (19.7/19.7) [46.0%]	14.3 (11.6/17.1) [33.4%]	8.8 (7.3/10.4) [20.6%]
	Male	55.1 (39.7/72.7) [25.9%]	15.0 (15.0/15.0) [27.2%]	22.8 (14.0/32.8) [41.4%]	17.3 (10.7/24.9) [31.4%]

*Notes:* Decomposition based on TTD model with 5,000 bootstrap replications. Point estimates shown in first row of each group. 95% confidence intervals in parentheses (second row). Percentage contributions in brackets (third row for Panel A; total change only for Panel B). Population effect: expenditure change due to population size/structure changes, holding 2022 per capita expenditures constant. Cost growth effect: expenditure change due to per capita cost growth, holding 2022 population structure constant. Interaction effect: expenditure change due to covariance between population and cost changes.

**Cost Growth, Not Aging, Drives Expenditure Increases** Per capita cost growth contributes DKK 142.4 billion (66.8%) of total expenditure growth, dwarfing the DKK 41.0 billion (19.3%) attributable to demographic change alone. If per capita expenditures remained frozen at 2022 levels, population aging would increase expenditures substantially, but manageable. Instead, secular expenditure growth generates pressures 3.5 times larger than demographic forces.

This finding complements existing policy discussions on demographic management by highlighting the substantial role of per capita expenditure growth. Political discourse emphasizes capacity expansion, more hospital beds, long-term care facilities, and recruitment, to accommodate aging populations. While these supply adjustments address real constraints, they target only 19.3% of projected expenditure growth. The remaining 81.7% (66.8% direct cost growth plus 13.9% interaction effects) stems from rising per capita expenditures within age groups, driven by forces not explained by the model, e.g., technological diffusion, practice pattern evolution, pharmaceutical innovation, morbidity patterns, and wage growth. Effective fiscal strategy requires dual-track intervention: capacity planning for demographic change and cost containment mechanisms addressing why per capita expenditures rise 2–8% annually within stable cohorts.

**Expenditure Pressures Concentrate Among the Oldest Old** Individuals aged 80+ account for 46.0% of total expenditure growth (DKK 97.9 billion) despite representing 5.0% of the 2022 population. Males aged 80+ alone contribute 25.9% (DKK 55.1 billion), with females contributing 20.1% (DKK 42.8 billion). This concentration reflects three reinforcing mechanisms documented in Section 3.3: high baseline expenditures (DKK 124,000–271,000 for survivors aged 80–84), elevated growth rates (6–8% annually for males versus 2–3% for working-age adults), and rapid population expansion (males +68.0%, females +54.8% over 2022–2035).

Interaction effects, the amplification when population and cost growth coincide, concentrate heavily in this segment. For males aged 80+, interactions contribute DKK 17.3 billion (31.4% of the group's total), nearly matching the direct population effect (27.2%) and rivaling the cost growth effect (41.4%). This amplification captures the increasing healthcare expenditures fused

by the increased population in the age-segment which neither the population nor expenditure parts account for. In contrast, working-age populations exhibit minimal or negative interaction effects. Females aged 20–64 experience population decline (-0.2%) offsetting modest cost growth, generating DKK -0.4 billion interaction effects. Youth populations (0–19) contribute negligibly (1.9% of total growth), with declining birth cohorts providing slight fiscal relief (DKK -0.2 billion population effect) overwhelmed by cost growth in other age groups.

**Divergent Sex-Specific Pathways** Sex differences in decomposition components reflect distinct biological and treatment trajectories. Among females aged 80+, population effects dominate (46.0% of group contribution), reflecting female longevity advantage. Cost growth contributes 33.4% and interactions 20.6%, with moderate expenditure growth rates (2–3% annually) limiting amplification effects. Males aged 80+ exhibit a more balanced decomposition: population (27.2%), cost growth (41.4%), and interaction (31.4%) effects contribute comparably. This pattern stems from males' higher expenditure growth rates at advanced ages (6–8% annually). The larger interaction term (31.4% versus 20.6% for females) indicates that male expenditure growth amplifies more strongly with demographic aging, suggesting cost containment strategies targeting male-dominant high-intensity conditions may yield disproportionate aggregate savings.

Working-age males (20–64) exhibit negative population effects (DKK -0.8 billion) as declining cohort sizes partially offset cost growth (DKK 24.2 billion). For working-age females, cost growth dominates (101.4% of group contribution) with negligible demographic effects, reflecting stable population size but persistent expenditure growth. These patterns underscore that among nonelderly populations, fiscal pressure stems almost entirely from rising per capita expenditures rather than demographic change.

## 5 Discussion

### 5.1 Policy Implications

Ignoring mortality composition and age-heterogeneous growth leads to systematic underestimation of healthcare expenditure growth. In our setting, these specification choices shift projected 2035 spending by 22 percentage points (DKK 52 billion). Our results differ materially from some official projections. The Danish Ministry of Finance’s “healthy aging” scenario projects 6.5% expenditure growth by 2030 for healthcare and 11.0% for long-term care ([Folketingets Finansudvalg, 2024](#); [Danish Ministry of Finance, 2024](#)); our preferred specification projects 8.9%, a substantial 7.8 to 8.25 percentage point gap. Similarly, OECD ([OECD, 2024](#)) estimates average annual growth of 2.1% compared to our 5.0%. The methodological extension of existing models is straightforward: estimate age-sex-specific growth rates using panel methods controlling for mortality composition, then apply these heterogeneous rates to official demographic projections.

Beyond quantifying specification differences, our decomposition reframes the policy challenge. Per capita cost growth contributes 67% of projected expenditure increases through 2035 while demographic aging contributes 19%, a 3.5-to-1 ratio. This suggests sustainability depends less on demographic management—which fiscal authorities cannot readily control—and more on per capita expenditure trajectories. While capacity expansion (hospital beds, long-term care facilities, workforce recruitment) remains necessary, it addresses less than one-fifth of projected growth. The remaining four-fifths stems from rising per capita consumption within age groups driven by technological diffusion, practice pattern evolution, pharmaceutical innovation, and potentially changing morbidity patterns.

The concentration of expenditure growth among individuals aged 80+, who account for 46% of projected increases through 2035 despite representing 5% of the 2022 population, creates both challenge and opportunity. This concentration arises from three reinforcing factors: high baseline expenditures (DKK 124,000–271,000 for survivors aged 80–84), elevated growth rates (6–8% annually for males), and rapid population expansion (males +68%, females +55% over

2022–2035). Long-term care represents the largest expenditure component while hospital care decreases beyond age 80 (Kallestrup-Lamb and Marin, 2024). Interventions targeting elderly care efficiency could substantially affect the fastest-growing component.

Substantial projection uncertainty demands explicit acknowledgment in fiscal planning. Our 95% confidence intervals widen from  $\pm 2$  percentage points (2025) to  $\pm 17$  percentage points (2035). By 2035, the DKK 80 billion uncertainty band exceeds Denmark’s entire long-term care budget yet reflects only parameter estimation error in growth coefficients. Total uncertainty incorporating demographic projection errors, technological shocks, and policy regime changes substantially exceeds reported bounds. Prudent policy design must acknowledge this uncertainty explicitly, developing scenario planning with contingency mechanisms for high-growth realizations (automatic expenditure caps, revenue triggers) while maintaining flexibility to expand access under alternative outcomes.

## 5.2 Limitations

Three substantive limitations affect interpretation. First, we treat mortality improvements as exogenous to healthcare expenditure. If healthcare investments drive mortality decline, our framework omits feedback whereby expenditure growth generates survival gains that reshape future costs. However, Kallestrup-Lamb et al. (2020) show Denmark’s mortality improvements during 2010–2022 were driven primarily by non-healthcare factors (smoking cessation, education, income growth).

Second, our framework captures reduced-form expenditure growth but cannot decompose growth into structural drivers. The estimated age-sex-specific rates reflect combined effects of technological change, pharmaceutical innovation, practice patterns, and morbidity trends. We cannot identify the relative contribution of each mechanism, which matters for policy: if growth reflects beneficial technological innovation improving health outcomes, constraining expenditure may sacrifice welfare gains.

Third, generalizability depends on institutional context. The mortality composition effect and age-heterogeneous growth patterns likely reflect fundamental demographic mechanics that generalize broadly across aging societies. However, magnitudes may differ: Denmark’s politically budgeted healthcare system may exhibit different growth dynamics than demand-driven systems where utilization directly determines spending.

## 6 Conclusion

Population aging creates substantial fiscal pressures for healthcare systems across developed economies. In Denmark, the population aged 80+ is projected to nearly double by 2060 while using healthcare at the highest per capita expenditures. Official projections currently employed by ministries of finance and international institutions reflect modeling choices that balance multiple objectives. Our empirical analysis suggests that alternative specifications incorporating mortality composition and age-specific growth patterns present two complementary mechanisms affecting healthcare expenditure growth.

This paper develops a projection framework that jointly incorporates mortality composition effects and age-heterogeneous growth rates. First, we quantify the specification difference arising from mortality composition effects using comprehensive Danish register data. As mortality declines, population weight shifts from high-cost decedents toward lower-cost survivors, mechanically dampening observed expenditure growth. Specifications that fail to separate this compositional shift may erroneously attribute it to slower underlying growth. Accounting for mortality composition revises estimated average growth from 2.9% to 3.4% annually, a 0.5 percentage point difference compounding to 10% divergence over 13 years. Second, we document pronounced heterogeneity in age-specific growth rates (0.5%–7.8% annually) and demonstrate through formal testing that uniform growth assumptions are decisively rejected. This heterogeneity creates compositional amplification: as demographic weight shifts toward fast-growing older age groups, aggregate expenditure growth accelerates mechanically beyond what uniform-

growth models predict. Projections imposing uniform growth yield 2035 expenditure estimates 22 percentage points lower than age-specific specifications.

Three findings inform the policy challenge. First, decomposing projected growth through 2035 reveals demographic aging contributes 19% while the remaining 81% relates to per capita growth rates. Healthcare sustainability therefore depends more on managing per capita expenditure growth through supply-side mechanisms such as pharmaceutical price regulation, gatekeeping, health technology assessment, and payment system redesign. Policy discourse that disproportionately emphasizes capacity expansion (hospital beds, long-term care facilities, workforce recruitment) thus addresses 19% of projected growth while per capita trajectories account for the remainder.

Second, individuals aged 80+ account for 46% of projected expenditure increases through 2035 despite representing 5% of the 2022 population. This concentration arises from three reinforcing factors: high baseline expenditures, elevated growth rates (6–8% annually for males), and rapid population expansion (+68% for males, +55% for females over 2022–2035). Third, our results differ materially from some official projections through three modeling choices. Some projection exercises focus primarily on demographic change without modeling per capita expenditure growth explicitly, yielding 17% increases by 2035 while our preferred specification projects 89%, a 72 percentage point difference. Finally, imposing uniform growth across ages when heterogeneity exists yields estimates 22 percentage points lower. Combined, these three specification choices generate substantially different fiscal projections, with important implications for sustainability assessments and policy planning.

As Denmark and similar aging societies confront these fiscal challenges, projection accuracy matters for sound policy planning. Official projections currently employed by ministries of finance and international institutions reflect modeling choices that available data reject empirically. The tools for methodological extension exist and are implementable with data routinely collected. Our analysis demonstrates that fiscal authorities can construct projections incorporating mortality composition and age-heterogeneous growth using existing data infrastructure.

Recognition that alternative specifications yield materially different fiscal trajectories encourage ongoing methodological refinement in long-run fiscal planning.

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## A Online Appendix Estimation

**Matrix Notation and Estimators** We can express all three specifications compactly in matrix form. Let  $\mathbf{y}$  denote the  $n \times 1$  vector of dependent variables  $\Delta \log(C_{r,x,s,t})$ , and let  $\mathbf{X}$  denote the  $n \times k$  matrix containing all right-hand-side variables (age-sex dummies, year dummies, municipality dummies where applicable, and the time-to-death transformation). Let  $\boldsymbol{\theta}$  represent the  $k \times 1$  parameter vector. The WLS estimator is given by:

$$\hat{\boldsymbol{\theta}} = (\mathbf{X}'\mathbf{W}\mathbf{X})^{-1}\mathbf{X}'\mathbf{W}\mathbf{y}, \quad (9)$$

where  $\mathbf{W} = \text{diag}(w_{r,x,s,t})$  is the  $n \times n$  diagonal matrix of weights.

For Specification 1 (equation (6)), the matrix  $\mathbf{X}$  contains: 42 age-sex group indicators  $\mathbb{1}_{x,s}$  (effects coded: 21 age groups  $\times$  2 sexes, with one category serving as reference such that coefficients sum to zero), and 13 year indicators  $\mathbb{1}_\tau$  for  $\tau \in \{2010, \dots, 2022\}$  (effects coded). Under Specification 2 (equation (5)), we augment  $\mathbf{X}$  with the time-to-death transformation:

$$\text{TTD}_{r,x,s,t} = \log\left(\frac{1 + M_{r,x,s,t}(R_{r,x,s,t} - 1)}{1 + M_{r,x,s,t-1}(R_{r,x,s,t-1} - 1)}\right). \quad (10)$$

This term enters linearly in the regression, with the cost ratios  $R_{r,x,s,t}$  directly observed from the data rather than estimated as parameters.

**Standard Error Estimation** Given the panel structure of our data, standard errors must account for potential correlation patterns. Our primary concern is within-municipality correlation over time, as unobserved municipality characteristics (healthcare infrastructure, demographic composition, local health policies) likely generate persistent effects across years.

We compute cluster-robust standard errors at the municipality level, permitting arbitrary within-cluster correlation while maintaining independence across municipalities. The cluster-robust variance-covariance matrix estimator is:

$$\widehat{\text{Var}}(\hat{\boldsymbol{\theta}}) = (\mathbf{X}'\mathbf{W}\mathbf{X})^{-1} \left( \sum_{r=1}^{98} \mathbf{X}'_r \mathbf{W}_r \hat{\boldsymbol{\epsilon}}_r \hat{\boldsymbol{\epsilon}}'_r \mathbf{W}_r \mathbf{X}_r \right) (\mathbf{X}'\mathbf{W}\mathbf{X})^{-1}, \quad (11)$$

where  $\mathbf{X}_r$  denotes the matrix rows corresponding to municipality  $r$ ,  $\mathbf{W}_r$  the corresponding weight matrix, and  $\hat{\boldsymbol{\epsilon}}_r$  the vector of residuals for municipality  $r$ . This approach yields valid inference under heteroskedasticity and within-municipality autocorrelation of arbitrary form (Cameron et al., 2011).

We do not cluster by time period for three reasons. First, year fixed effects  $\{\gamma_\tau\}$  explicitly control for common aggregate shocks affecting all municipalities in a given year, absorbing the primary source of cross-sectional correlation. Second, with only 13 time periods, clustering by time would yield too few clusters for asymptotic approximations to provide reliable inference (Cameron and Miller, 2015). Third, our identification strategy exploits cross-sectional variation in mortality rates across municipalities within years rather than time-series variation, making municipality-level clustering the natural approach for addressing correlation patterns relevant to our research design.

**Calculating Age-Sex-Specific Growth Rates and Standard Errors** The WLS estimation yields 41 explicitly estimated age-sex-specific deviation parameters  $\{\hat{\beta}_{x,s}\}_{i=1}^{41}$  plus an intercept  $\hat{\beta}_0$  representing the average growth rate across all groups. Under effects coding, the 42nd age-sex group's deviation is implicitly defined by the constraint  $\sum_{x,s} \beta_{x,s} = 0$ , yielding  $\hat{\beta}_{42} = -\sum_{i=1}^{41} \hat{\beta}_i$ . The full growth rate for each age-sex group is then constructed as  $\hat{g}_{x,s} = \hat{\beta}_0 + \hat{\beta}_{x,s}$  for  $i = 1, \dots, 42$ . Standard errors for the 41 explicitly estimated growth rates are computed directly from the cluster-robust variance-covariance matrix (equation 11), accounting for covariances between the intercept and age-sex deviation terms:  $SE(\hat{g}_i) = \sqrt{\text{Var}(\hat{\beta}_0) + \text{Var}(\hat{\beta}_i) + 2\text{Cov}(\hat{\beta}_0, \hat{\beta}_i)}$  for  $i = 1, \dots, 41$ . For the omitted 42nd group, the standard error accounts for the sum constraint:  $SE(\hat{g}_{42}) = \sqrt{\text{Var}(\hat{\beta}_0) + \sum_{i,j=1}^{41} \text{Cov}(\hat{\beta}_i, \hat{\beta}_j) - 2\sum_{i=1}^{41} \text{Cov}(\hat{\beta}_0, \hat{\beta}_i)}$ . These calculations ensure that confidence intervals appropriately reflect both parameter estimation uncertainty and the restrictions imposed by effects coding, with all standard errors incorporating the municipality-level clustering structure that accounts for within-municipality correlation over time.

## **B Online Appendix - Data - SHA Expenditures by Category**

Table 4 shows the mapping of SHA expenditures to our expenditure categories [Statistics Denmark \(2025d\)](#). Total expenditures is the sum of these expenditures. We scale the cost categories in year 2022 before the projection to match the official aggregates in the economy. Note that we are only considering government financed expenses.

**Table 4.** Mapping of Danish Administrative Registers to SHA Functions and Providers

Your Data Source	SHA Function	SHA Provider	Coverage Notes
<b><i>Hospital Care (DRG registers)</i></b>			
Somatic hospital inpatient	1.1 Inpatient curative care	1.1 General hospitals	Acute + elective
Somatic hospital outpatient	1.3 Outpatient curative care	1.1 General hospitals	Day surgery, clinics
Psychiatric hospital inpatient	1.1 Inpatient curative care	1.2 Mental health hospitals	Psychiatric wards
Psychiatric hospital outpatient	1.3 Outpatient curative care	1.2 Mental health hospitals	Psychiatric clinics
<b><i>Long-Term Care</i></b>			
Nursing homes (AEPB)	3.1 Inpatient long-term care (health)	2.1 Long-term nursing care facilities	Residential care
Home nursing (HJSP/AEHJSP)	3.4 Home-based long-term care (health)	3.5 Providers of home health care services	Nursing visits
Home care - personal (AEFV)	3.4 Home-based long-term care (health)	3.5 Providers of home health care services	Personal care only <sup>a</sup>
<b><i>Primary Care (SYSI/SSSY registers)</i></b>			
General practitioners	1.3.1 General outpatient curative care	3.1.1 Offices of general medical practitioners	All GP services
Medical specialists	1.3.9 Other outpatient curative care	3.1.3 Offices of medical specialists	Specialist consultations
Dentists	1.3.2 Dental outpatient curative care	3.2 Dental practice	Dental services
Physiotherapists	2.3 Outpatient rehabilitative care	3.3 Other health care practitioners	Physical therapy
Chiropractors	2.3 Outpatient rehabilitative care	3.3 Other health care practitioners	Chiropractic
Psychologists	1.3.9 Other outpatient curative care	3.3 Other health care practitioners	Psychological services
<b><i>Prescription Drugs (LMDB register)</i></b>			
Prescription drugs	5.1.1 Prescribed medicines	5.1 Pharmacies	Primary care pharmacy <sup>b</sup>

Notes: <sup>a</sup>Practical home help (cleaning, shopping) excluded per SHA guidelines (Eurostat and Organization, 2017). <sup>b</sup>Excludes hospital-dispensed medications and over-the-counter drugs not in LMDB.

## C Online Appendix Results

**Table 5.** Robustness Checks: Alternative Specifications

Alternative Specification	Comparison with Baseline TTD Model		
	<i>t</i> -statistic	<i>p</i> -value	Correlation
<i>Panel A: Municipality Fixed Effects</i>			
Municipality FE included	−0.008	0.994	0.999
<i>Panel B: Unweighted Estimation</i>			
OLS (no population weights)	0.546	0.588	0.663
<i>Panel C: COVID-Period Interactions</i>			
Age-sex × COVID interaction	−0.074	0.941	0.904

*Notes:* Each row reports results from paired *t*-tests comparing age-sex-specific growth rate estimates ( $\{\hat{\beta}_{x,s}\}$  in Panel A,  $\{\hat{\beta}_0, \hat{\beta}_{x,s}\}$  in Panel B and Panel C) from alternative specifications against baseline estimates from Equation (5). Panel A adds municipality fixed effects. Panel B estimates via OLS without population weights. Panel C includes age-sex-specific COVID-period effects (interaction terms for years 2020–2021). Correlation column shows Pearson correlation between baseline and alternative point estimates across parameter estimates.