

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

By

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## Abstract

How much of projected healthcare expenditure growth reflects demographic aging, and how much reflects rising per capita costs? Using comprehensive Danish administrative data spanning hospital care, primary care, prescription drugs, and long-term care from 2010 to 2022, we develop a projection framework that extends standard demographic projections by allowing per capita expenditures to grow heterogeneously across age and sex groups, while correcting for mortality-driven compositional shifts in population spending. Failing to apply this correction leads to systematic underestimation of underlying cost growth: it raises estimated average annual growth from 2.9 % to 3.4 %. Age-specific growth rates range from 0.5 % to 7.8 % annually, and the uniform-growth assumption is decisively rejected by the data. Conditional on historical expenditure growth patterns continuing, demographic aging accounts for 19 % of projected expenditure increases through 2035, while per capita cost growth is attributable to 81 %. Individuals aged 80 and above generate 46 % of total projected growth despite comprising 5 % of the 2022 population.

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# 1. Introduction

Publicly financed healthcare systems across aging economies face a structural fiscal challenge. Denmark allocates DKK 241 billion to healthcare in 2022 (8.0 % of GDP), and the population aged 80 and older, the highest-cost demographic group, is projected to nearly double by 2060 (Statistics Denmark, 2025a; Statistics Denmark, 2025b). The aggregate fiscal pressure is clear. Less clear is how fast per capita healthcare costs are actually rising, whether that growth varies systematically across age groups, and how these dynamics interact with demographic aging to shape the long-run expenditure trajectory. The answers bear directly on whether fiscal pressure is primarily a problem of demographic management or of cost containment, and for whom.

Two hypotheses in the healthcare expenditure literature motivate our approach. The Red Herring Hypothesis (Zweifel et al., 1999) argues that proximity to death, rather than age itself, drives end-of-life spending; as mortality declines, the high-cost decedent share of any age group falls, mechanically dampening observed per capita growth. The Steepening Hypothesis (Büchner and Wasem, 2006) predicts that cost growth accelerates with age, so that population aging, by shifting demographic weight toward fast-growing older groups, amplifies aggregate expenditure growth beyond what simple population changes imply. Both mechanisms have been studied separately and primarily for hospital expenditures (Kallestrup-Lamb et al., 2024a). We integrate them within a unified projection framework applied to all four major sectors of Denmark's publicly financed system.

We exploit Danish administrative registers covering the entire population from 2010 to 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. Covering all four sectors is consequential: long-term care is the component most concentrated among the oldest old (Kallestrup-Lamb and Marin, 2024b) and among the fastest growing, yet it is routinely omitted from projection analyses. We implement the framework of van Baal and Wong (2012), extending their approach in two dimensions: we apply it to panel data across 98 municipalities rather than national time series, exploiting substantially more identifying variation in mortality rates, and we estimate growth rates for comprehensive publicly financed healthcare rather than hospital expenditures alone. Using the estimated age-sex-specific growth rates, we project aggregate expenditures through 2035 and decompose projected increases into population aging, per capita cost growth, and interaction effects, a framework that extends the Oaxaca (1973)-Blinder (1973) approach.

The paper establishes three findings. First, we show that failing to account for mortality composition leads to systematic underestimation of underlying per capita cost growth. As mortality declines, population composition shifts toward

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lower-cost survivors, creating a mechanical drag on observed expenditure growth that simple specifications absorb into the growth rate estimate. Correcting for this compositional shift raises estimated average annual growth from 2.9 % to 3.4 %, a difference that compounds to 10% divergence in per capita expenditures over 13 years. Second, we document that age-specific growth rates are strictly positive and vary substantially across groups, from 0.5 % annually (females aged 2-4) to 7.8 % (males aged 90-94), and we decisively reject both the hypothesis that growth rates are zero and the hypothesis that they are uniform across age-sex groups. Moreover, because growth rates rise with age, population aging shifts demographic weight toward faster-growing groups, leading projected aggregate expenditure under age-specific rates to exceed the uniform-growth projection by 22 percentage points by 2035. Third, we decompose projected expenditure increases into population aging (19 %), per capita cost growth (67 %), and interaction effects (14 %), with individuals aged 80 and above accounting for 46 % of total growth despite comprising only 5 % of the 2022 population.

The findings suggest that the fiscal challenge is driven more by per capita expenditure growth than by demographic aging alone. Per capita cost growth contributes 3.5 times more to projected expenditure increases than demographic aging through 2035, conditional on historically observed expenditure growth persisting. In Denmark's politically budgeted healthcare system, where aggregate expenditure is determined through annual negotiations, the policy focus shifts from managing population age structure toward containing per capita cost growth. Our framework complements official demographic projection exercises (Danish Ministry of Finance, 2024) by quantifying what happens when per capita costs are allowed to grow heterogeneously across age groups, the component that demographic baselines, by construction, leave aside. The projections should therefore be interpreted as demand-side benchmarks rather than point forecasts of realized expenditure.

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 discusses policy implications for healthcare sustainability and addresses limitations. Section 6 concludes.

## 2. Model and Methods

This section develops a projection framework that extends official Danish demographic projections in two key dimensions, building on van Baal and Wong (2012): (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  $x$  and  $s$  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  $c^1 > c^0$  at most ages (Lubitz and Riley 1993), declines in mortality mechanically reduce per capita expenditures as the fraction with high end-of-life expenditures decreases.

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 given its central role in long-run expenditure projections. 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  $t - 1$  approximate annual percentage changes in per capita expenditure

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

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

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using the convention  $\log(1 + \beta_{x,s}) \approx \beta_{x,s}$  for small rates and the cost ratio  $R_{(r,x,s,t)} := C_{(r,x,s,t)}^1 / C_{(r,x,s,t)}^0$ . The first term,  $\beta_{x,s}$ , captures actual expenditure growth. The second term captures the 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 expenditures 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.<sup>3</sup> Standard errors are therefore clustered at the municipality level using the Cameron and Miller (2015) heteroskedasticity- and autocorrelation-robust variance estimator.<sup>4</sup>

1. 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.
2. Effects coding avoids reliance on an arbitrary omitted category and yields coefficients that are deviations from the mean rather than from a reference group.
3. Migration across municipalities could in principle violate the independence assumption if individuals systematically move toward municipalities with better healthcare infrastructure as health deteriorates. However, the stability of our estimates across municipality fixed effects specifications (Table 5, Appendix 10) suggests this channel does not materially affect our estimates.
4. This accounts for persistent unobserved municipal characteristics (e.g., infrastructure, provider behavior) that generate correlated shocks across demographic groups.

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

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

Differences between estimates from (5) and (6) quantify the bias in  $\beta_0$  arising from ignoring changes in mortality composition. Appendix 7 formalizes the relationship between these specifications and the Danish Ministry of Finance’s demographic baseline, which corresponds to equation (5) evaluated at  $\beta_{x,s} = 0$ . We show analytically that omitting per capita expenditure growth generates a level error of  $(1 + \beta_{x,s})^{-(t-t_0)}$  that compounds over the projection horizon, and that omitting the time-to-death correction attenuates  $\hat{\beta}_{x,s}$  downward via omitted-variable bias.

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 8 provides additional details on estimation.

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 changes. 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 follows the same additive logic as the Oaxaca (1973)–Blinder (1973) decomposition, partitioning a total change into component effects, but applies this to intertemporal expenditure changes rather than cross-sectional group differences and requires no regression framework.

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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>5</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, fiscal coordination, and regulate through agreements; 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 medical goods, dental care, and non-medical care) comprising the remainder (Statistics Denmark, 2025d).

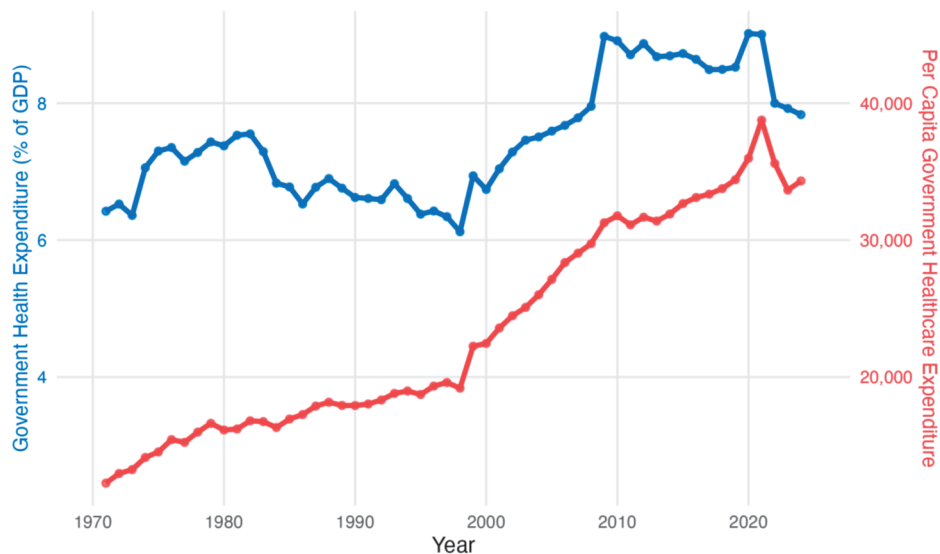
This institutional structure offers two advantages for expenditure analysis. First, comprehensive administrative registers capture essentially all publicly financed healthcare consumption across the entire population (Ministry of Health, 2017), eliminating selection bias from insurance coverage gaps and access to care that complicate cross-country comparisons. Second, with government financing covering 83.4 % of total healthcare expenditure, projections of publicly financed spending capture the dominant component of the system and are directly relevant to fiscal planning, irrespective of any changes in the smaller private segment.

5. Our decomposition includes the uncertainty of estimated parameters while the additional uncertainty incorporating demographic projection errors, technological shocks, and policy regime changes may exceed reported bounds.

### 3.1.1. 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 at 8.0 % in 2022.

**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 2025b).

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.

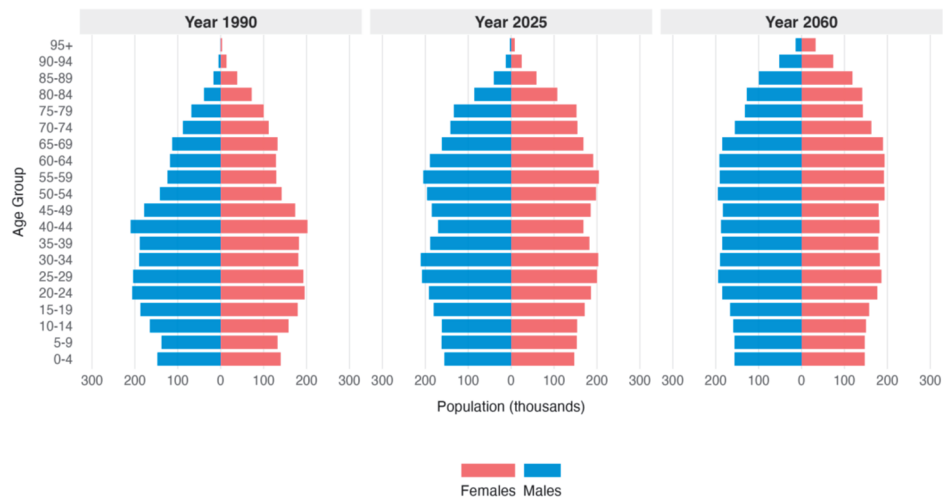
### 3.1.2. Demographic Transformation

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).

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., 2024a), this demographic transformation carries substantial fiscal implications for healthcare expenditures.

**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).

### 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, and other health professionals), prescription drugs, and long-term care. This comprehensive scope is consequential: while hospital and primary care dominate international healthcare analyses, long-term care represents a substantial and rapidly growing expenditure category in aging populations (OECD, 2025a), yet it is routinely omitted from projection analyses. 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 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).

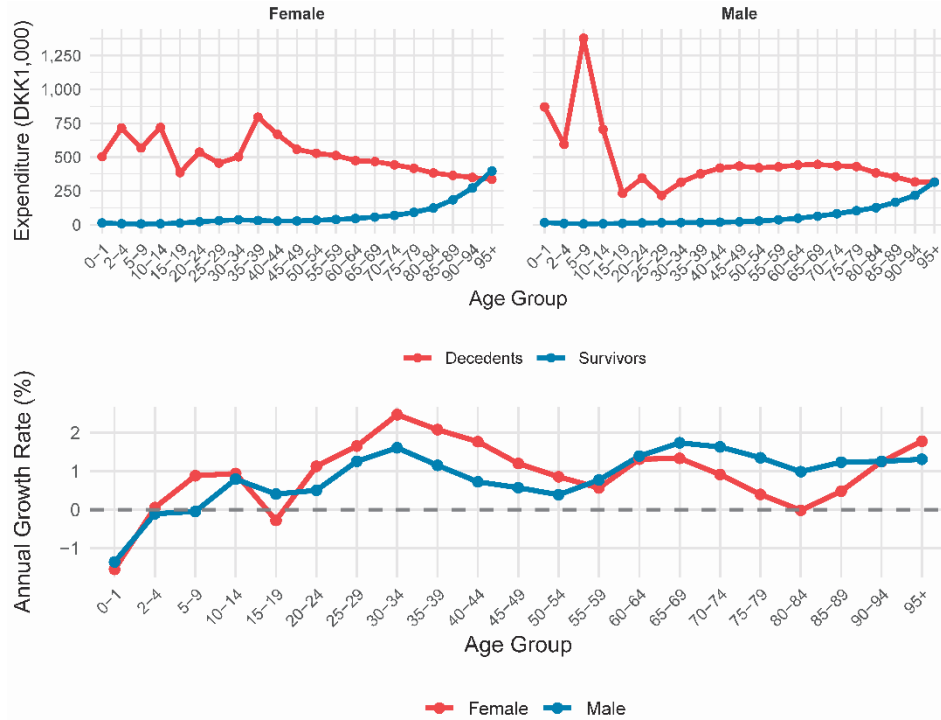
Because administrative registers record utilization without prices, we employ a cost allocation methodology. Aggregate long-term care expenditures from SHA accounts (Statistics Denmark, 2025d) are allocated to calculate annual unit expenditures for each service category. Nursing home expenses derive 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 as described in Appendix 9. 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.

**Figur. 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.

#### 3.3.1. 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 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.

### 3.3.2. *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 1.4-1.6 % annually at ages 0-1 before stabilizing near zero. Growth turns modestly positive during school ages (0.8-0.9 % 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 services associated with pregnancy and birth contribute during reproductive years, the differential persists beyond these ages, 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, 2024b).

## 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.

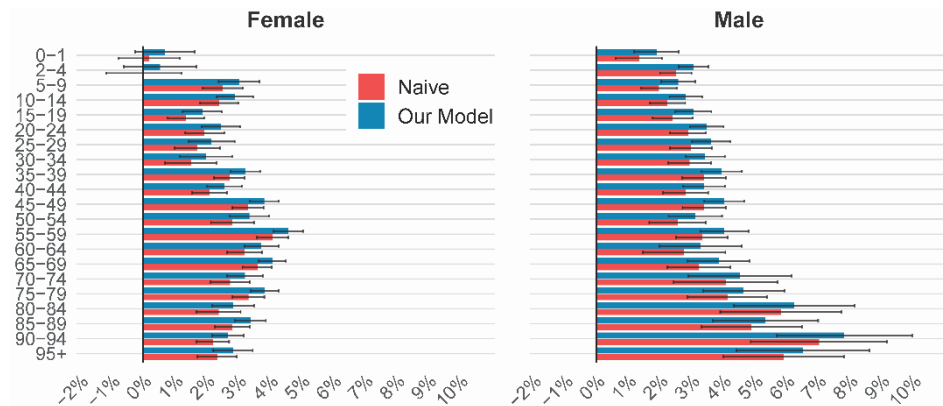
The TTD Model’s superior fit is evident from the higher  $R^2$  (0.161 vs 0.153), though both specifications explain a modest share of variation in expenditure growth. This limited explanatory power is unsurprising: healthcare expenditure growth reflects numerous factors beyond mortality composition 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.

#### 4.1.1. Growth Rates by Age and Sex

Figure 4 displays estimated age-sex-specific growth rates,  $\widehat{\beta}_0 + \widehat{\beta}_{x,s}$ , 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 time-to-death 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 time-to-death 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 ( $|(\hat{\beta}_0^{\text{Naïve}} + \hat{\beta}_{x,s}^{\text{Naïve}}) - (\hat{\beta}_0 + \hat{\beta}_{x,s})|$ ) of 0.57 percentage points (females) and 0.80 percentage points (males). These differences appear small annually but compound exponentially: over 13 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.

#### 4.1.2. *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 2, Appendix D 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); Statistics Denmark, 2025c) consistent with official demographic projections (DØRS, 2019; Danish Ministry of Finance, 2024).<sup>6</sup> Our preferred projection employs the age-sex-specific growth rates estimated in Section 3.1, 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.

The projections apply historically estimated age-sex-specific growth rates forward from the 2022 baseline, treating past patterns of public resource allocation as the conditioning assumption. They are demand-side benchmarks, not forecasts of realized expenditure, which will ultimately reflect future budgetary decisions by governments and regions.

Table 2 presents projected expenditure growth relative to the 2022 baseline of DKK 241 billion. Three patterns emerge from Table 2.

### 4.2.1. *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 (the Naïve model's 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

6. Both our projections and the Danish Ministry of Finance's demographic component use Statistics Denmark's official population forecast (FRDK125) as the demographic input.

TTD Model reaffirms the mortality mechanism, shifting population weight to lower-cost survivors. Incorporating uniform cost growth adds 40.8 percentage points to the projected expenditure increase relative to the zero-growth scenario, illustrating the quantitative importance of per capita cost dynamics.

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

Model	2025		2030		2035	
	Naïve	TTD	Naïve	TTD	Naïve	TTD
<i>Panel A: Growth relative to 2022 base line (%)</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	136.0	43.9	84.1	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 corresponding to the Naïve estimate in Table 1 and age-sex specific scenario uses estimated growth rates presented in Figure 4. 95% bootstrap confidence intervals in parentheses based on 5,000 replications of random age-sex growth rates.

#### 4.2.2. 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. 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 the amplification mechanism through two offsetting channels. First, by failing to separate the mortality-composition dampening from underlying expenditure growth, the Naïve model attributes the mechanical decline in average costs (as fewer individuals are near death) to slower real cost growth. This attenuates estimated growth rates across all age-sex groups, with the largest absolute attenuation at older ages where mortality improvements have been most rapid. Second, because the Naïve model does not project population shares of survivors and decedents separately, it cannot account for the cost reduction that accompanies declining mortality under the TTD framework: lower mortality shifts population weight toward lower-cost survivors, reducing projected aggregate expenditure relative to a model that holds survivor and decedent shares constant. These two effects work in opposite directions. The first lowers projected expenditure through attenuated growth rates; the second raises it by overstating the decedent share. The net result is that the Naïve age-sex-specific projection (79.6 %) lies below the TTD preferred projection (88.6 %), indicating that the growth-rate attenuation effect dominates.

Notably, the confidence intervals that account for growth-rate parameter uncertainty, 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 represents 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) under our preferred model 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)**

Age Group	Sex	Total Change (Bn DKK)	Population Change (Bn DKK)	Expenditure Growth (Bn DKK)	Interaction Effect (Bn DKK)
<i>Panel A: Overall Decomposition (TTD Model)</i>					
All	Both	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 %]
<i>Panel B: By Age Category and Sex</i>					
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.

#### 4.3.1. *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. The remaining 13.9 % reflects interaction effects, arising where rapid population growth coincides with rapid per capita cost growth within the same age-sex cells. Taken together, demographic aging accounts for less than one-fifth of projected expenditure increases through 2035, with per capita cost dynamics driving the rest.

#### 4.3.2. *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).

This interaction term captures the additional expenditure growth generated when a rapidly growing population coincides with rapidly rising per capita costs. 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 interaction term captures the additional expenditure growth that arises when a rapidly expanding population coincides with rapidly rising per capita costs, a joint contribution that neither the population effect nor the expenditure growth effect captures individually.

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.

#### 4.3.3. *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, reflecting the combination of faster per capita cost growth and rapid population expansion in this group.

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

The decomposition establishes that per capita cost growth, not demographic aging, is the dominant driver of projected healthcare expenditure increases. This has a direct implication for how fiscal policy should be framed. Public debate in aging societies typically focuses on demographic management: expanding hospital capacity, increasing the healthcare workforce, and building long-term care infrastructure to accommodate a larger elderly population. These responses address the 19 % of projected growth attributable to demographic change. The remaining 81 % reflects rising costs per person within stable age cohorts, driven by forces that capacity expansion alone does not address. Effective fiscal planning therefore requires understanding not just how many people will need care, but why the cost of that care rises persistently year after year.

The concentration of projected growth among individuals aged 80 and above points toward a specific part of the system. Long-term care becomes the increasingly dominant expenditure component at advanced ages, even as hospital care remains substantial, with the relative weight of institutional and home-based care rising sharply beyond age 80 (Kallestrup-Lamb and Marin, 2024b). The fiscal pressure implied by our projections is likely not uniform across healthcare sectors: it falls disproportionately on long-term care, shifting the planning focus toward the organization, pricing, and staffing of home care and nursing home services alongside continued attention to acute hospital capacity.

Our framework and the Danish Ministry of Finance's demographic baseline are related but answer distinct questions. Both are grounded in the same aggregate expenditure identity and use the same official population forecast as demographic input, and both incorporate a time-to-death correction for healthy aging.

The key structural difference is that the Ministry's baseline holds real expenditure per user constant within age-sex-survival cells by design, isolating the fiscal effect of demographic change alone (Danish Ministry of Finance, 2024). Our zero-growth scenario is the analogous calculation in our framework, and the two yield comparable figures (9.8 % versus 6.5 % expenditure growth by 2030), with residual differences attributable to population forecast vintages, expenditure coverage, and the time-to-death threshold.<sup>7</sup> The question this paper is designed to answer, what happens when per capita costs are allowed to grow heterogeneously across age groups, lies entirely outside the scope of either demographic baseline by construction. The 38 percentage point gap between our zero-growth scenario and our preferred projection by 2030 quantifies the fiscal consequence of that extension.

Projection uncertainty is large. The 95 % confidence intervals on the 2035 projection span DKK 80 billion on parameter estimation uncertainty alone, a range that exceeds Denmark's entire long-term care budget in 2022. These bounds capture only uncertainty in the estimated growth coefficients; they do not reflect uncertainty in demographic forecasts, future policy decisions, or structural breaks in expenditure patterns. The projections are best understood as conditional benchmarks: they describe the fiscal trajectory implied by continuing historically observed patterns of public resource allocation, not a prediction of what expenditure will actually be. Just as the estimated growth rates reflect past budgetary decisions about how resources have been distributed across age groups, the projected trajectory will ultimately depend on the budgetary decisions of future governments.

### 5.1. Limitations

Three limitations affect the interpretation of the results. First, the framework treats mortality changes as exogenous to healthcare expenditure. If sustained healthcare investment itself drives mortality decline, this creates a feedback channel whereby expenditure growth generates survival gains that in turn reshape future costs. The empirical relevance of this channel in our setting appears limited: Kallestrup-Lamb et al. (2020) document that Danish mortality improvements over the sample period were driven primarily by behavioural and socio-economic factors rather than healthcare intensity. The feedback channel cannot be ruled out in principle, but it is unlikely to materially affect the growth rate estimates.

7. The FM baseline disaggregates expenditure profiles by origin (Danish-born, immigrant, descendant), which our framework does not. Appendix 7 formalizes the structural relationship between the two frameworks.

Second, the estimated growth rates are reduced-form and cannot be attributed to specific drivers. They reflect the combined influence of many factors, including technological change, pharmaceutical innovation, evolving clinical practice, changing morbidity patterns, and wage growth in the healthcare sector. Distinguishing these mechanisms lies beyond the scope of this paper and would require a different research design and data structure than the one employed here. The distinction matters: cost growth reflecting innovation that extends healthy life years is qualitatively different from growth reflecting practice variation or administrative cost inflation, and the two carry different implications for whether the historical expenditure growth pattern should be expected to persist.

Third, the framework is calibrated to a politically budgeted system in which aggregate healthcare spending is determined through annual negotiations between the central government, the regions, and the municipalities. The estimated growth rates therefore describe historically realized patterns of public resource allocation rather than unconstrained demand. Researchers applying this framework in systems where utilization directly determines spending should account for the different institutional constraints on expenditure growth.

## 6. Conclusion

This paper set out to ask three questions: how fast are per capita healthcare costs rising in Denmark, whether that growth differs systematically across age groups, and how the interaction between age-heterogeneous cost growth and demographic aging shapes the long-run fiscal trajectory. The answers are consequential. Per capita cost growth, not demographic aging, accounts for the dominant share of projected expenditure increases through 2035, with demographic change contributing 19 % and cost growth the remaining 81 %. Conditional on estimated expenditure growth rates persisting, aggregate Danish healthcare expenditure would reach DKK 454 billion by 2035, an 89 % increase from the 2022 baseline. The fiscal challenge is less about how many older people there will be, and more about how rapidly the cost of caring for them is rising.

Two features of the analysis bear emphasis for researchers building on this framework. First, failing to account for mortality composition leads to systematic underestimation of underlying cost growth: as mortality declines, the population shifts toward lower-cost survivors, and specifications that do not separate this compositional shift absorb it into the growth rate estimate. Second, growth rates vary substantially across age and sex groups, and the uniform-growth assumption embedded in simpler projection frameworks is strongly rejected by the data. These are not minor technical adjustments: together they account for a DKK 173 billion difference in projected 2035 expenditure relative to a zero-growth demographic baseline.

The concentration of projected growth among individuals aged 80 and above, who account for 46 % of total expenditure increases despite comprising 5 % of the 2022 population, is among the most striking findings. Within a politically budgeted system, sustained elevated growth rates for this age group imply that incrementally more public resources have been directed toward older individuals year after year. Whether this pattern reflects rising clinical need, technological change, or shifting allocative priorities is not identified here, and that question lies beyond what the present results can support. What the results do establish is that this concentration is the central feature of the projected fiscal trajectory, and understanding why it has emerged is as important for long-run fiscal planning as the projection numbers themselves.

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## 7. Appendix: Model Comparison and Specification Differences.

This appendix formalizes the relationship between our projection framework and the Danish Ministry of Finance’s (FM’s) demographic baseline (Danish Ministry of Finance, 2024), and derives the implied projection differences from the two modeling choices that distinguish simpler specifications from our preferred TTD Model. The key takeaway is that the FM baseline is a nested special case of our framework: our model reduces to the FM baseline when all per capita growth rates are set to zero.

### The FM Demographic Baseline as a Nested Special Case

Both frameworks build on the aggregate expenditure identity in equation (1). The FM demographic component projects changes in per capita expenditure as

$$\Delta \log C_{x,s,t}^{\text{FM}} = \log \left( \frac{1 + M_{x,s,t}(R_{x,s,t} - 1)}{1 + M_{x,s,t-1}(R_{x,s,t-1} - 1)} \right), \quad (9)$$

which is equation (4) evaluated at  $\beta_{x,s} = 0$ . The FM baseline allows population composition to shift as mortality changes (capturing the »healthy aging« correction whereby fewer people are near death in any given year) but assumes that the real cost of treating a person of given age, sex, and survival status does not change over time.<sup>8</sup>

The two modeling dimensions, whether per capita growth is estimated freely or constrained to zero ( $\beta_{x,s}=0$ ), and whether mortality composition is explicitly controlled for, define a natural  $2 \times 2$  taxonomy of projection approaches:

	No TTD correction	TTD correction	
$\beta_{x,s} = 0$	Pure demographics	FM	(10)
$\hat{\beta}_{x,s} \neq 0$	Naïve (ours)	TTD (ours)	

The FM baseline occupies the upper-right cell: it incorporates the time-to-death composition effect but imposes zero per capita growth. Our preferred time-to-death specification, in the lower-right cell, is the only approach that addresses both dimensions simultaneously. The two frameworks are therefore complements: the FM baseline answers what spending would look like if only population structure changed, while our TTD Model additionally asks how spending evolves when per capita costs grow heterogeneously across age groups.

8. DØRS (2019) applies an analogous structure using a ten-year terminal window rather than three years used by the Ministry, generating a somewhat larger healthy-aging adjustment. The structural form is identical.

### Implied Projection Difference from Imposing $\beta_{x,s} = 0$

When per capita expenditures grow at rate  $\beta_{x,s} > 0$ , conditioning projections on equation (9) generates a compounding level difference relative to a model that allows growth. Iterating equation (4) forward from base year  $t_0$ , the ratio of the FM projection to the true per capita expenditure path is:

$$\frac{C_{x,s,t}^{\text{FM}}}{C_{x,s,t}} = \frac{1}{(1 + \beta_{x,s})^{t-t_0}}. \quad (11)$$

This ratio is less than one whenever  $\beta_{x,s} > 0$ , and it shrinks as the horizon lengthens. Intuitively: if real costs per patient rise each year but the projection assumes they do not, the gap between projected and actual expenditures widens with each passing year.

At the estimated average growth rate  $\beta_0 = 0.034$  over the 13-year horizon to 2035, equation (11) gives  $(1.034)^{-13} \approx 0.65$ . A zero-growth projection therefore captures approximately 65% of projected per capita expenditures, a 35 % shortfall relative to a model that allows observed growth rates to continue. Whether this shortfall is realized depends on whether historical growth rates persist, which is itself uncertain; the FM baseline's value is precisely that it does not require this assumption. The quantitative importance of the growth assumption is nonetheless large: the zero-growth restriction is decisively rejected by the data, and the aggregate gap between our zero-growth scenario and the age-sex-specific projection amounts to DKK 173 billion by 2035 (Table 2).

## 8. 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:

$$\hat{\boldsymbol{\theta}} = (\mathbf{X}'\mathbf{W}\mathbf{X})^{-1}\mathbf{X}'\mathbf{W}\mathbf{y}, \quad (12)$$

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:

$$\text{TTD}_{r,x,s,t} = \log\left(\frac{1 + M_{r,x,s,t}(R_{r,x,s,t} - 1)}{1 + M_{r,x,s,t-1}(R_{r,x,s,t-1} - 1)}\right). \quad (13)$$

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:

$$\widehat{\text{Var}}(\hat{\boldsymbol{\theta}}) = (\mathbf{X}'\mathbf{W}\mathbf{X})^{-1} \left( \sum_{r=1}^{98} \mathbf{X}'_r \mathbf{W}_r \hat{\boldsymbol{\varepsilon}}_r \hat{\boldsymbol{\varepsilon}}_r' \mathbf{W}_r \mathbf{X}_r \right) (\mathbf{X}'\mathbf{W}\mathbf{X})^{-1}, \quad (14)$$

where  $\mathbf{x}_r$  denotes the matrix rows corresponding to municipality  $r$ ,  $\mathbf{w}_r$  the corresponding weight matrix, and  $\hat{\boldsymbol{\varepsilon}}_r$  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 as-

ymptotic 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 14), accounting for covariances between the intercept and age-sex deviation terms:

$$SE(\hat{g}_i) = \sqrt{\text{Var}(\hat{\beta}_0) + \text{Var}(\hat{\beta}_i) + 2\text{Cov}(\hat{\beta}_0, \hat{\beta}_i)} \text{ for } i = 1, \dots, 41.$$

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.

## 9. Appendix: Data – SHA Expenditures by Category

Table A1 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 A1. Mapping of Danish Administrative Registers to SHA Functions and Providers**

Your Data Source	SHA Function	SHA Provider	Coverage Notes
<i>Hospital Care (DRG registers)</i>			
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
<i>Long-Term Care</i>			
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 on-ly <sup>a</sup>
<i>Primary Care (SYSI/SSSY registers)</i>			
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
<i>Prescription Drugs (LMDB register)</i>			
Prescription drugs	5.1.1 Prescribed medicines	5.1 Pharmacies	Primary care pharmacy <sup>b</sup>

Notes:

- Practical home help (cleaning, shopping) excluded per SHA guidelines (WHO 2017).
- Excludes hospital-dispensed medications and over-the-counter drugs not in LMDB.

## 10. Appendix: Results

**Table A2. Robustness Checks: Alternative Specifications**

2-4 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,  $\{\widehat{\beta}_0, \hat{\beta}_{x,s}\}$  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.