Learning from the Oldest: The Impact of Ageing on Healthcare Expenditure

Chiara Bersani* Paolo Berta† Sara Muzzì‡
Manuel Serrano-Alarcón§ Stefano Verzillo¶

April 8, 2026

Abstract

This paper estimates the causal impact of population ageing on healthcare expenditure. Using rich individual healthcare administrative records combined with historical demographic data from Lombardy, Italy's largest region, we build a highly granular panel covering all municipalities over 2011–2023. To address endogeneity, we exploit predicted variation in ageing across municipalities based on lagged local age structures and regional cohort-specific survival rates. Our instrumental-variable (IV) estimates show that population ageing significantly increases per-capita healthcare expenditure across major domains of care. A 1% increase in the share of the population aged 60 and above raises per-capita expenditure by 0.69% for hospitalizations, 1.29% for pharmaceutical consumption, and 0.47% for outpatient services. IV estimates are generally smaller than their OLS counterparts, by up to 30–40% for the oldest age ratio (75+). This indicates that conventional approaches that do not address endogeneity may overstate the true effect of ageing on healthcare expenditure due to reverse causality and healthcare-driven migration. Decomposing the ageing effect between older adults (aged 60–74) and the oldest-old (aged 75+) reveals that the latter group is the dominant driver of expenditure growth across all domains, accounting for 65–82% of total ageing-driven spending increases despite starting from a smaller population base. Our findings from one of the most advanced countries in the demographic transition provide credible causal insights into the fiscal pressures to be faced by healthcare systems across ageing societies

Keywords: Ageing, Healthcare Expenditure, Instrumental Variables

*University of Milan-Bicocca. Email: c.bersani3@campus.unimib.it
†University of Milan-Bicocca. Email: paolo.berta@unimib.it
‡University of Milan-Bicocca. Email: sara.muzzi@unimib.it
§European Commission, Joint Research Centre. Email: manuel.serrano-alarcon@ec.europa.eu
¶European Commission, Joint Research Centre. Email: stefano.verzillo@ec.europa.eu

Acknowledgements. The authors gratefully acknowledge the support and the provision of data by the Lombardy Health Authority and the Italian National Institute of Statistics (ISTAT). The views expressed in this paper are those of the authors and do not necessarily reflect those of the European Commission.

1 Introduction

Population ageing is widely regarded as a major driver of long-term healthcare expenditure growth. However, disentangling the causal effect of the ageing component from confounding trends -such as technological change, economic growth, migration, improvements in medical practice and health status, or policy reforms introduced to face both demographic and technological changes- remains empirically challenging. Standard projections performed by policy institutions typically rely on mechanical age-expenditure profiles and assume that today's age-specific spending patterns will hold in the future (Commission, 2024). These methods disregard the endogeneity of ageing, whereby health expenditure and longevity evolve jointly due to both reverse causality and common confounding trends. Furthermore, conventional projections rarely distinguish between types of care (hospital, outpatient, pharmaceutical) and diagnosis despite the fact that ageing may differentially affect specific services. This creates a crucial knowledge gap that limits healthcare planning and resource allocation.

In this paper, we examine the causal impact of ageing in healthcare expenditure in one of the most aged countries in the world: Italy. We build on Maestas et al. (2023)[1], and use a cohort-survival Bartik-style instrument to estimate the causal impact of healthcare expenditure and its core dimensions, using rich microdata from the largest region in Italy, Lombardy. This strategy allows to address key endogeneity concerns between population agein and healthcare expenditure, arising from reverse causality, selective migration and other unobserved local trends.

Our analysis relies on rich administrative data covering the universe of healthcare

[1] Maestas et al. (2023) use a cohort-survival Bartik-style instrument to estimate the causal impact of population ageing on economic growth in the US. We extend this methodology for the case of healthcare expenditure.

interactions for the Lombardy population over the period (2011-2023). This data allows us to track not only total healthcare expenditure, but also utilization and spending by major healthcare domains. This level of granularity is particularly relevant for healthcare planning as the burden of ageing on the healthcare system is unlikely to be be equally distributed across healthcare domains. Italy provides an unique informative case study for this analysis as with 25% of the population age 65+, it is among the most aged countries in the world[2]. As a consequence, this experience offers valuable insights for countries that are at earlier stages of the demographic transition.

Our instrumental variable estimates show that population ageing significantly increases per-capita healthcare expenditure across all major domains of care. For eight-year growth horizons over the pre-COVID period (2011–2019), a 1% increase in the share of the population aged 60 and above raises per-capita expenditure by approximately 0.69% for hospitalizations, 1.29% for pharmaceutical consumption, and 0.47% for outpatient services. These elasticities are economically meaningful and demonstrate substantial heterogeneity across healthcare domains, with pharmaceutical spending exhibiting the strongest response to demographic ageing. Importantly, these findings remain robust to alternative specifications, including older age ratios, longer instrumental variable lags, and extended time periods that include the COVID-19 pandemic.

Instrumental-variable estimates are generally smaller than their OLS counterparts, suggesting that simple correlations tend to overstate the effect of population ageing on healthcare expenditure. This pattern is consistent with upward bias in OLS estimates arising from reverse causality, selective migration, or endogenous adjustments in healthcare policy. The bias is particularly pronounced for older age thresholds, with IV estimates for the 75+ ratio running 30–40% below their OLS counterparts, suggesting that endogeneity concerns are most severe for the oldest segment of the population.

We estimate that population ageing over the period 2011–2019 contributed to expenditure increases of 8.0% for hospitalizations, 13.0% for pharmaceuticals, and 4.9% for outpatient services. Decomposing this effect between older adults (aged 60–74) and

[2]Italy is the 4th country in the World with the largest share of 65+ poplation. Only Monaco, Japan and Puerto Rico had a larger in 2024. Source: World Bank.

the oldest-old (aged 75+) reveals that, despite starting from a smaller population base, the oldest-old are the dominant driver of ageing-related expenditure growth across all healthcare domains. The oldest-old alone account for 5.7 percentage points of the 8.0% hospitalization increase, 8.4 of the 13.0% pharmaceutical increase, and 4.0 of the 4.9% outpatient increase. This accounts between 65% and 82% of the total ageing-driven expenditure growth depending on the healthcare dimension. Given that this group is projected to expand most rapidly in the coming decades, these findings point to an increasing concentration of the fiscal burden of demographic ageing among the very oldest segment of the population.

Our paper contributes to three main strands of the literature. First, we contribute to the literature that studies the determinants of healthcare expenditure using aggregate or panel data. Early contributions based on country-level or regional panels document a positive association between population ageing and healthcare spending, (Bech et al., 2011; Piscopo et al., 2024). However these studies are unable to address time-varying unobserved heterogeneity, including policy reforms, medical innovation, migration, etc. As a result, this literature provides limited causal evidence on the effect of ageing per se. We depart from this approach by exploiting plausibly exogenous variation in local demographic ageing to avoid confounding from contemporaneous economic and institutional factors. To the best of our knowledge, this paper is the first to provide causal evidence on the effect of population ageing on healthcare expenditure at regional level, and to do so separately by major healthcare domain.

Second, our paper relates to the micro-level literature that contrast the role of age vs proximity to death on healthcare use. Literature has shown that once accounted for time to death the individual effect of ageing on healthcare use attenuates, the so-called red-herring hypothesis (Howdon and Rice, 2018; Werblow et al., 2007; Costa-Font and Vilaplana-Prieto, 2020). While this literature is crucial for understanding individual-level spending patterns across time, it does not directly address the policy-relevant question of how shifts in the population age structure causally affect aggregate healthcare expenditure. Our contribution is complementary: rather than conditioning on time-to-death

to study individual-level healthcare pattern across time, we estimate the causal effect of population ageing at the municipality level, capturing the system-wide implications of demographic change across healthcare domains. This is an issue of central importance for healthcare planning.

Third, we contribute to the literature on the macroeconomic effects of population ageing. While earlier studies were not conclusive on the relation between population ageing and economic growth (Acemoglu and Restrepo, 2017; Sheiner, 2014), more recent causal studies using cohort-based instruments have found that population ageing reduces output per capita (Maestas et al., 2023). We extend this identification strategy to the case of healthcare utilization on expenditure. Taken together, our results imply that demographic ageing increases the fiscal burden of the healthcare system both directly (through higher healthcare expenditure) and indirectly (through lower GDP).

The rest of the paper is organised as follows. Section 2 explains the data and the Italian demographic transition. Section 3 details the empirical strategy. Section 4.2 describes the main results. Section 5 provides robustness checks and Section 6 concludes.

2 Data

Our analyses focuses on the Lombardy region, the largest in Italia, with approximately 10 million inhabitants. We utilize two main data sources. Population data comes from the The Italian National Institute of Statistics (Istat). In particular, we use population data by age, sex and municipality of residence for the period 1952 to 2023[3].

Healthcare data includes individual administrative records provided by the Lombardy Region, regarding the individual healthcare consumption for the period 2011-2023. We consider three distinct health domains: hospitalizations, pharmaceutical consumption and outpatient services (including blood tests, diagnostic test and specialist visit). For each domain, we aggregate individual-level records to construct municipality-year measures of total real expenditure (inflation-adjusted) and calculate per-capita expenditure

[3]The Italian National Institute of Statistics (Istat) is the main producer of official statistics in Italy. Its online database is available here: https://demo.istat.it

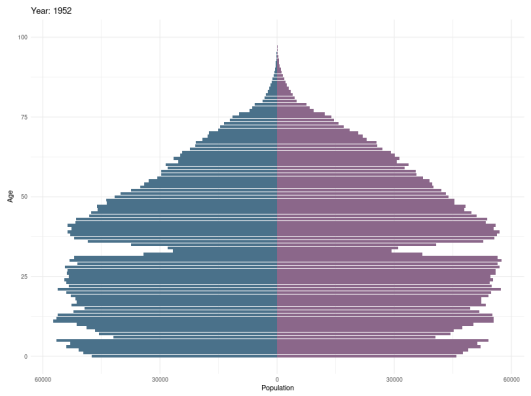
by dividing by the municipality's population aged 20 and above. Our main analysis uses data from 2011–2019 to avoid confounding effects from the COVID-19 pandemic, while robustness checks extend the sample through 2023.

2.1 Italy's demographic transition

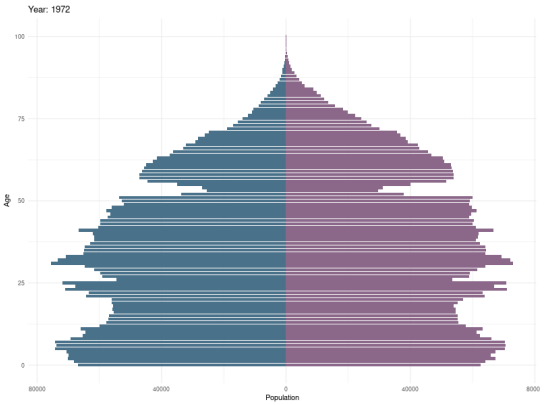
Figure 1 displays population pyramids for Lombardy at selected years from 1952 to 2050, illustrating the dramatic transformation of the population age structure across time.[4] The figure captures the post-World War II Baby Boom (1946–1964), reflected in the broad base of the 1952 and 1972 pyramids, followed by subsequent fertility declines. By 2011, Baby Boom cohorts had begun entering older age groups, accelerating the ageing process. This trend has been reinforced by continued declines in fertility rates and substantial increases in life expectancy driven by healthcare innovations. The share of population aged 65 or more reached 23.3% by 2023 (well above the EU average of 21.3%) and is expected to go well over 30% by 2050.

Figure 2 plots, for each municipality, the standardized 2011-2019 change in per-capita healthcare expenditure by category against the standardized observed change in population ageing. Each observation is weighted by resident population to account for differences in municipality size. Across all expenditure categories, the descriptive relationship is positive but limited in magnitude, being this correlation more evident for pharmaceutical and outpatient expenditures than for hospital spending. Panels (a)-(c) show a slightly upward slope, meaning that municipalities experiencing faster population ageing tend, on average, to exhibit higher growth in per-capita healthcare spending over the same period. However, the estimated associations are relatively weak and characterized by substantial dispersion, suggesting large heterogeneity across municipalities. Overall, these patterns indicate that simple cross-municipality correlations between ageing and healthcare expenditure growth have limited explanatory power.

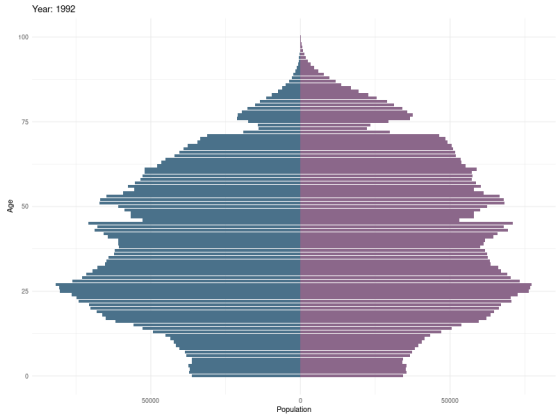
[4]To dynamically visualize the evolution of the population in Lombardy we created a *Shiny App* at (https://chiarabersani.shinyapps.io/hist_pop_1952_2080/). Importantly, the single age category of 100 years also includes people older than 100.



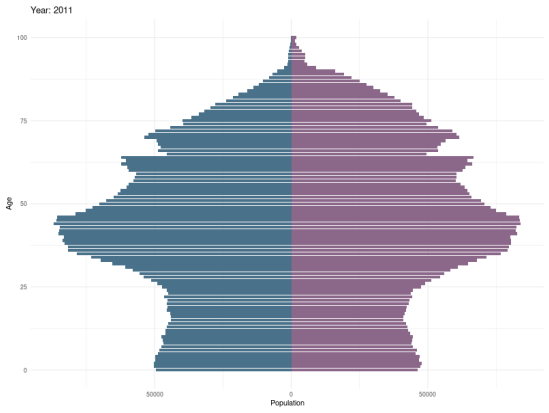
(a) Year: 1952



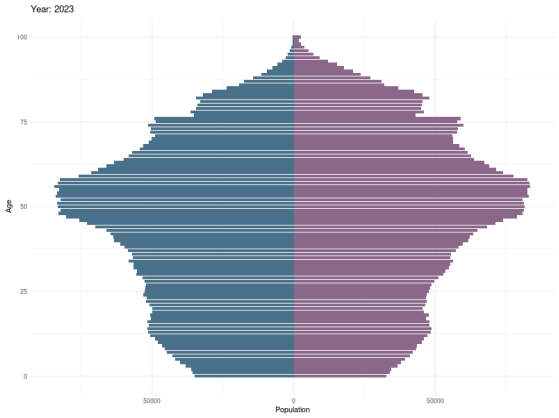
(b) Year: 1972



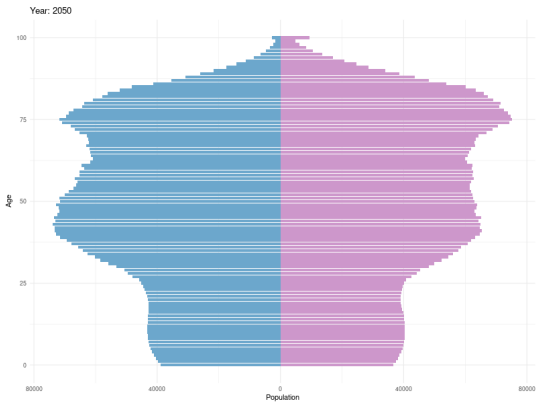
(c) Year: 1992



(d) Year: 2011

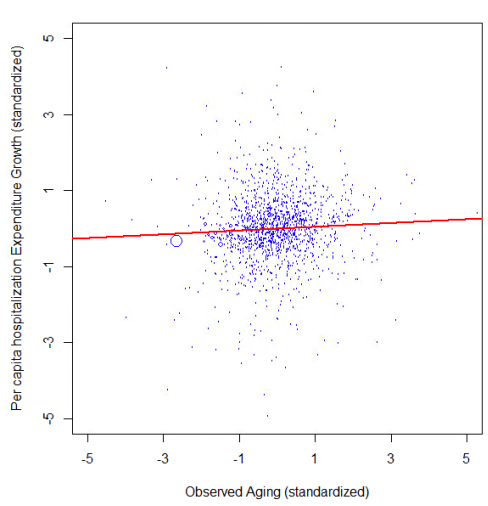


(e) Year: 2023

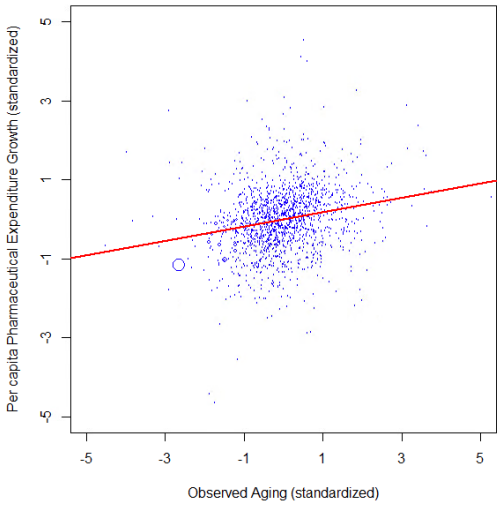


(f) Year: 2050

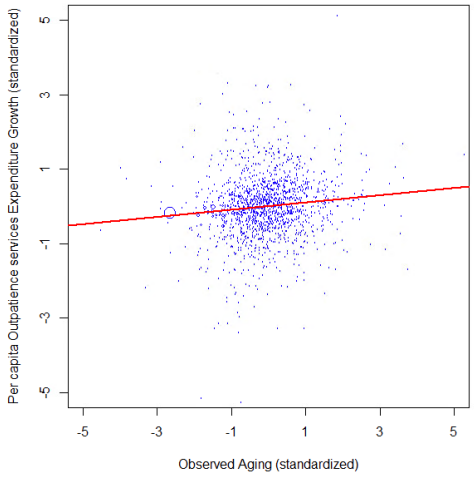
Figure 1: Population pyramids for Lombardy across selected years (1952–2050)



(a) Hospitalizations



(b) Pharmaceutical prescriptions



(c) Outpatient services

Figure 2: **Relationship between Observed Aging and Per-Capita Health Care Expenditure Growth (2011-2019)**

Notes: Size of bubbles reflects municipality population size.

3 Empirical Strategy

Our main model aims to estimate the casual effect of population ageing on healthcare expenditure growth. We measure population ageing as the change in the share of the population aged 60 and above (or alternatively 65+, 70+, or 75+) between year t and year $t+p$. Our main specification examines the effect of this demographic change on the growth rate in real per-capita healthcare expenditure over the same period:

$$\ln\left(\frac{Y_{m,t+p}}{N_{m,t+p}}\right)-\ln\left(\frac{Y_{m,t}}{N_{m,t}}\right)=\beta\left[\ln\left(\frac{\text{P60}_{m,t+p}}{N_{m,t+p}}\right)-\ln\left(\frac{\text{P60}_{m,t}}{N_{m,t}}\right)\right]+X'_{m,t}\delta_t+(\varepsilon_{m,t+p}-\varepsilon_{m,t}) \quad (1)$$

where $Y_{m,t}$ denotes real healthcare expenditure (i.e: adjusted for inflation) in municipality m in year t. Specifically, we examine three categories of healthcare expenditure: (i) hospitalizations, (ii) pharmaceutical consumption, and (iii) outpatient services. $N_{m,t}$ is the total population aged 20 years or older[5], and $\text{P60}_{m,t}$ is the older population (aged 60+). We estimate alternative specifications using different age thresholds (65+, 70+, and 75+) to assess how the effect varies with the definition of the elderly population.

Our main term of interest on the right hand side $\left[\ln\left(\frac{\text{P60}_{m,t+p}}{N_{m,t+p}}\right)-\ln\left(\frac{\text{P60}_{m,t}}{N_{m,t}}\right)\right]$ denotes the p-year growth in the 60+ share of the population, and intends to measure population ageing.

The coefficient β captures the effect of population ageing on the growth of the specific healthcare use indicator between t and $t+p$, and can be interpreted as elasticities.

In our main specification, we use an eight-year growth period ($p=8$) covering 2011–2019, which avoids the disruptive effects of the COVID-19 pandemic on both healthcare utilization and mortality patterns. We also include year fixed effects (γ_t). In future versions of the paper we will also include a vector of municipality-level controls ($X_{m,t}$) such as employment rates and other socieconomic indicators. Regressions are weighted by municipality population at time t, and standard errors are clustered at the municipality level to account for serial correlation within municipalities.

3.1 Endogeneity of Population Ageing and Instrumental Variable Strategy

Changes in the elderly population share may be endogenous to the evolution of healthcare utilization. For instance, better healthcare derived from higher expenditure may increase

[5]Following Maestas et al. (2023), we use as denominator only the 20+ population to allow the population at t to be predicted by the population structure some decades before, as explained in section 3.1

life-expectancy and therefore rise the share of elderly in a municipality (i.e. reverse causality). If this is the case, linear estimates would be biased upward. There may also be migration patterns related with healthcare access and expenditure which can bias linear estimates both upward and downward. On the one hand, older people, who are in more need of care, may migrate to municipalities with better access to healthcare. On the other hand, young people in working age may migrate to areas where there are more opportunities (mainly urban) and create scarcity of healthcare professionals and healthcare services, with the corresponding drop in healthcare expenditure. If any of these patterns arise, an OLS estimation of the coefficient β Equation 1 above could be biased.

To address these concerns, we construct an instrumental variable that predicts ageing based on the municipality's past population structure combined with common regional cohort survival rates following Maestas et al. (2023)[6]. Specifically, we use the age distribution in year $t-x$ to predict changes in the log share of the municipal population aged 60+ between periods t and $t+p$ (or aged 65+, aged 70+ and aged 75+ in our alternative specifications).

In our main model, we use a eight-year period to measure growth rates ($p = 8$) and a ten-year lag ($x = 10$) to predict the age structure at both t and $t + 8$. For instance, $x = 10$ and $p = 8$ imply that the age structure observed in 2001 ($t - 10$) is used to predict the elderly share of both 2011 (t) and 2019 ($t + 8$), and consequently the growth rate in the 60+ population during the period 2011-2019. In robustness checks presented in Section 5, we verify that results are robust to longer instrumental lags ($x = 15$) and extended sample periods including 2011–2023.

Our instruments are constructed as:

$$\ln\left(\frac{\widehat{P60}_{m,t+p}}{\widehat{N}_{m,t+p}}\right) - \ln\left(\frac{\widehat{P60}_{m,t}}{\widehat{N}_{m,t}}\right), \tag{2}$$

where $\widehat{P60}_{m,t+p}$ and $\widehat{P60}_{m,t}$ denote the *predicted* municipal population aged 60+ in years

[6]In a setting similar to ours, Maestas et al. (2023) examine the effect of population ageing on GDP per capita growth using state-level panel data from the US.

$t+p$ and t, respectively, constructed using national cohort survival rates and the municipal age structure at time $t-x$.

More precisely for our baseline specification of an eight-year growth period ($p = 8$) and a ten-year lag ($t = 10$):

$$\widehat{P60}_{m,t+p} = \sum_{j \geq 60-x-p} \underbrace{N^j_{m,t-x}}_{\substack{\text{Population age } j \\ \text{in municipality } m \text{ at } t-x}} \times \underbrace{\frac{N^{j+x+p}_{t+p}}{N^j_{t-x}}}_{\substack{\text{National survival rate} \\ \text{from } t-x \text{ to } t+p}} = \sum_{j \geq 42} N^j_{m,t-10} \times \frac{N^{j+18}_{t+8}}{N^j_{t-10}}$$

$$\widehat{P60}_{m,t} = \sum_{j \geq 60-x} \underbrace{N^j_{m,t-x}}_{\substack{\text{Population age } j \\ \text{in municipality } m \text{ at } t-x}} \times \underbrace{\frac{N^{j+x}_{t}}{N^j_{t-x}}}_{\substack{\text{National survival rate} \\ \text{from } t-x \text{ to } t}} = \sum_{j \geq 50} N^j_{m,t-10} \times \frac{N^{j+10}_{t}}{N^j_{t-10}}$$

The denominator terms $\widehat{N}_{m,t+p}$ and $\widehat{N}_{m,t}$ denote the predicted municipal population aged 20+ and are constructed analogously:

$$\widehat{N}_{m,t+9} = \sum_{j \geq 20-x-p} N^j_{m,t-x} \times \frac{N^{j+x+p}_{t+p}}{N^j_{t-x}} = \sum_{j \geq 6} N^j_{m,t-10} \times \frac{N^{j+18}_{t+8}}{N^j_{t-10}}$$

$$\widehat{N}_{m,t} = \sum_{j \geq 20-x} N^j_{m,t-x} \times \frac{N^{j+x}_{t}}{N^j_{t-x}} = \sum_{j \geq 10} N^j_{m,t-10} \times \frac{N^{j+10}_{t}}{N^j_{t-10}}$$

These expressions predict how the municipal older population would evolve if each cohort at time $t-10$ experienced the regional cohort-specific survival rates from $t-10$ up to t and $t+8$. Intuitively, the instrument leverages variation in municipalities' plausible exogenous and pre-determined historical age structures combined with common regional demographic forces captured by cohort survival rates.

The predicted growth in the old age share constructed in Equation (2) is then used as an instrument for the actual observed change in the municipal share of the population aged 60+, in a two-stage least square (IV-2SLS). The second stage is Equation (1) and the first stage is the Equation (3) below:

$$\ln\left(\frac{\text{P60}_{m,t+8}}{N_{m,t+8}}\right)-\ln\left(\frac{\text{P60}_{m,t}}{N_{m,t}}\right)=\alpha\left[\ln\left(\frac{\widehat{P60}_{m,t+8}}{\widehat{N}_{m,t+8}}\right)-\ln\left(\frac{\widehat{P60}_{m,t}}{\widehat{N}_{m,t}}\right)\right]+X'_{m,t}\theta+\mu_t+(\eta_{m,t+8}-\eta_{m,t}). \tag{3}$$

where the variables and subscripts are the same as those defined in 1. Regressions are weighted by municipality resident population at time t, and standard errors are clustered at municipality level.

The instrument is aimed to capture how the municipality's elderly share would have evolved if each initial cohort had grown according to national demographic trends. The main identifying assumption is that past age structure of a municipality affects healthcare expenditure growth only trough population ageing. Because the age distribution at time t is predetermined and national age-specific growth rates are driven primarily by common mortality at regional-level and cohort sizes, the instrument provides plausibly exogenous variation in predicted ageing across municipalities. We discuss this assumption and the validity of the instrument on detail in Section 4.1.

4 Results

This section presents the empirical analysis of the causal relationship between population aging and healthcare expenditure. Section 4.1 examines the validity of the instrumental variable and discusses potential threats to the exclusion restriction assumption. Section 4.2 reports the main estimates of the causal effect of population aging on healthcare expenditure across healthcare dimensions (hospitalizations, pharmaceutical and outpatient services).

4.1 First Stage and Instrument Validity

The instrumental variable relies in two main assumptions: a strong first-stage and a credible exclusion restriction. We address each in turn. Figure 3 illustrates the first-stage relationship underpinning our instrumental variable strategy. The predicted change in

the share of the population aged 60 and above -constructed by combining lagged municipal age structures with national cohort-specific survival rates- strongly predicts realized ageing at the municipality level. The figure shows a clear positive relationship, with little dispersion around the fitted line, indicating that the instrument captures substantial variation in demographic change across municipalities. The corresponding first-stage F-statistic is 3,062 (Table 1), far exceeding conventional thresholds for weak instrument concerns. Similarly strong first stages are obtained for alternative age thresholds.

The exclusion restriction assumption requires that the instrument affects healthcare expenditure growth only through its effect on population ageing, and not through any other channel. In other words, past age structure must influence current healthcare expenditure solely via its impact on the growth of the elderly population.

A potential threat to the validity of the exclusion restriction assumption would arise if historical age structures were correlated with long-run economic or demographic trends that themselves predict future healthcare expenditure (for example, persistent growth or decline in economic activity). To mitigate this concern, we exploit lagged population structure from sufficiently distant periods (15 and 20 years before the outcome, instead of 10) in robustness checks in section 5. Using older age distributions reduces the possibility that the instrument captures trends that may directly influence contemporary healthcare spending.

It is also important to note that healthcare expenditure is normatively determined at the regional level rather than at the municipal level. In Italy, regional governments' healthcare spending depends on regional and national revenues, and is therefore not linked to the economic dynamics of individual municipalities. In other words, higher (lower) municipality-specific economic growth will not directly translate into higher (lower) healthcare expenditure in that municipality, since healthcare budgets are financed and determined at the regional level. This institutional feature reinforces the plausibility of the exclusion restriction assumption.

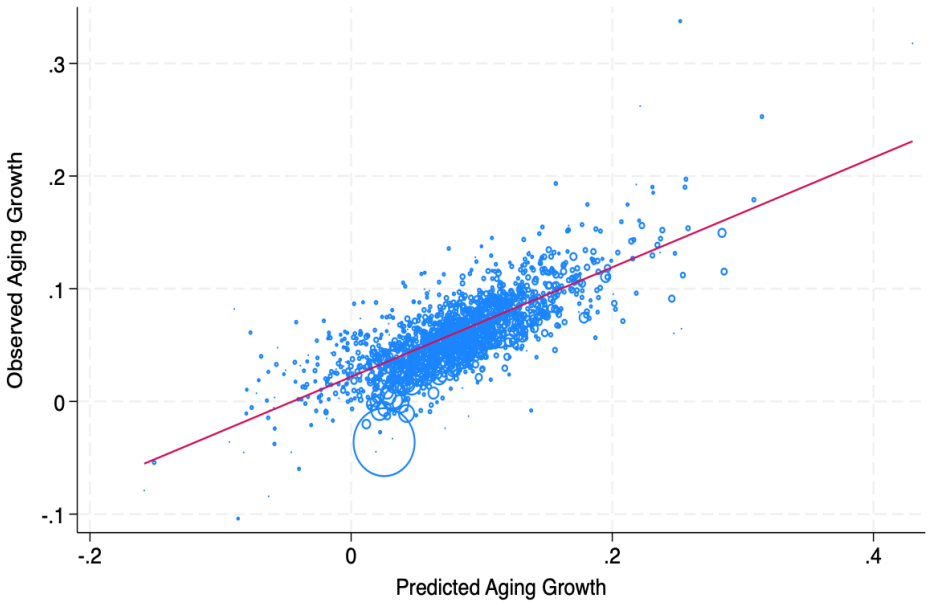


Figure 3: **Relationship between Predicted Aging and Observed Aging Growth**

Notes: Size of bubbles reflects municipality population size.

4.2 Main results

In this section we present the results of our main IV model next to the regular OLS model for each of the healthcare expenditure dimensions: hospitalization (Table 1), pharmaceutical (Table 2) and outpatient care (Table 3). We show estimates for four alternative old age ratios: over-60, over-65, over-70 and over-75.

The first-stage estimates (First columns of Tables 1, 2 and 3) are positive and highly significant across all age groups (60+/65+/70+). The positive coefficients indicate that higher predicted aging is systematically associated with a larger observed elderly population, as expected, confirming that the instrument strongly predicts variation in the elderly population. For the over-60 group, the coefficient is 0.761, implying that a 1% increase in the predicted aging measure is associated with a 0.761% increase in the observed share of the elderly population. The magnitude of the coefficient decreases with older age ratios, likely reflecting the fact that as cohorts age, mortality rates increase and municipal-level variation in mortality diverges more substantially from the regional trend. This suggests that prediction based on regional survival rates becomes less precise for the oldest age groups, where local mortality conditions may differ more markedly from

the regional average.

The IV estimates reveal economically meaningful and statistically significant effects of population ageing on healthcare expenditure across all domains. In our main model, 1 percent increase in the share of the population aged 60 and above raises per-capita healthcare expenditure by approximately 0.69 percent for hospitalizations, 1.29 percent for pharmaceutical prescriptions, and 0.47 percent for outpatient services. These elasticities demonstrate substantial heterogeneity across healthcare domains. Pharmaceutical consumption exhibits the strongest response to demographic ageing, with an elasticity exceeding unity, indicating that pharmaceutical spending grows more than proportionally with the elderly population share.

The elasticities decline systematically as we consider older age thresholds. For instance, the elasticity of hospital expenditure (Table 1) declines to 0.677, 0.646, and 0.486 for the over-65, over-70, and over-75 ratios, respectively. A similar pattern is observed for pharmaceutical and outpatient expenditure (Tables 2 and 3).

This declining pattern in elasticities has a straightforward interpretation. Relative percentage increases in older age ratios (e.g., 75+) correspond to much smaller absolute changes in population compared to younger age ratios (e.g., 60+). For instance, given baseline elderly shares in 2011 (32.3% for over-60, 11.8% for over-75; see Appendix Table A1), a 10% increase in the elderly ratio would yield an increase of 3.2 percentage points in the over-60 population but only 1.2 percentage points in the over-75 population. Consequently, smaller elasticities at higher age thresholds do not imply that the oldest elderly consume less healthcare; rather, they reflect the mechanical relationship between relative changes and absolute population shifts.

A comparison between IV and OLS provides insight into the direction and magnitude of endogeneity bias. The magnitude of the differences between the two estimates for over-60 ratio are rather small while the direction of the bias depends on the healthcare domain. In particular, IV estimates are slightly smaller than OLS for hospitalization (Table 1) and pharmaceutical expenditure 2), while slightly larger for outpatient services (Table 3). This pattern for the over-60 ratio suggests that opposing sources of endogeneity bias may

partially offset each other. Specifically, reverse causality and healthcare-driven migration of the elderly would generate upward bias in OLS estimates, while selective migration of younger healthcare professionals to urban areas would generate downward bias. The close alignment between IV and OLS estimates indicates that these countervailing biases largely cancel out.

However, a different pattern emerges for older age ratios. IV estimates are consistently smaller in magnitude as we move from over-65 to over-70 to over-75. While IV estimates continue to be positive and significant at older ages, their magnitude is reduced around 30-40% with respect to the OLS estimates at the over-75 ratio. This increasing upward bias of OLS estimates indicates that endogeneity concerns become more relevant when aging is measured using the share of the oldest citizens. This suggests that reverse causality and healthcare-driven migration mechanisms are more pronounced for the oldest populations. Municipalities with higher-quality healthcare may disproportionately improve the health and survival of the oldest elderly. Furthermore, the oldest elderly may be particularly responsive to healthcare quality in their location decisions.

Table 1: Effect of Aging on Hospitalizations' Expenditure ($x = 10$)

	I Stage	**OLS**	**IV**
Over 60	0.761***	0.768***	0.691***
	(0.014)	(0.073)	(0.089)
Over 65	0.702***	0.677***	0.630***
	(0.012)	(0.059)	(0.071)
Over 70	0.576***	0.646***	0.485***
	(0.012)	(0.059)	(0.076)
Over 75	0.567***	0.486***	0.292***
	(0.009)	(0.052)	(0.063)
No. Obs.	1502	1502	1502

Notes: Significance levels: *10%, **5%, ***1%. Standard errors clustered at municipality level. Observations weighted by period-t population. Controls: year dummies, province FE.

F statistics: 3062, 3590, 2383 and 3237.

Table 2: Effect of Aging on Pharmaceutical Prescriptions' Expenditure ($x = 10$)

	I Stage	**OLS**	**IV**
Over 60	0.761***	1.310***	1.291***
	(0.014)	(0.056)	(0.068)
Over 65	0.702***	1.080***	1.005***
	(0.012)	(0.045)	(0.054)
Over 70	0.576***	0.928***	0.601***
	(0.012)	(0.047)	(0.061)
Over 75	0.567***	0.657***	0.357***
	(0.009)	(0.042)	(0.052)
No. Obs.	1502	1502	1502

Notes: Significance levels: *10%, **5%, ***1%. Standard errors clustered at municipality level. Observations weighted by period-t population. Controls: year dummies, province FE.

F statistics: 3062, 3590, 2383 and 3237.

Table 3: Effect of Aging on Outpatient Services' Expenditure ($x = 10$)

	I Stage	**OLS**	**IV**
Over 60	0.761***	0.414***	0.465***
	(0.014)	(0.062)	(0.076)
Over 65	0.702***	0.381***	0.427***
	(0.012)	(0.050)	(0.060)
Over 70	0.576***	0.349***	0.316***
	(0.012)	(0.050)	(0.064)
Over 75	0.567***	0.227***	0.158***
	(0.009)	(0.044)	(0.053)
No. Obs.	1502	1502	1502

Notes: Significance levels: *10%, **5%, ***1%. Standard errors clustered at municipality level. Observations weighted by period-t population. Controls: year dummies, province FE.

F statistics: 3062, 3590, 2383 and 3237.

4.3 Extended Period including Covid-19 (2011-2023)

Tables 4, 5, and 6 report the estimated effects of population aging on hospitalizations, pharmaceutical prescriptions, and outpatient services' expenditure for the period 2011–2023 ($p = 12$), which includes the years during and after the Covid-19 pandemic. First-stage results confirm that predicted aging strongly predicts variation in the observed elderly population, with stable coefficients across alternative lag specifications ($x = 10$ and $x = 15$), supporting the validity of the instrumental variable approach.

For comparison, these results show a broadly similar pattern in the responsiveness of healthcare expenditure to population aging, in particular for pharmaceutical and outpatient expenditure, as compared to the pre-COVID period 2011–2019 ($p = 8$). However, hospitalization expenditure shows a higher elasticity. This amplification likely reflects the severe impact of COVID-19 on the elderly population. The pandemic disproportionately affected older individuals both directly (through severe illness, and higher mortality) and indirectly through exacerbation of chronic conditions due to care disruptions and delayed treatments. Still, pharmaceutical expenditure remained the most responsive category across all age groups. Overall, the comparison between $p = 8$ and $p = 12$ suggests that the inclusion of the COVID-19 period slightly amplified the impact of population aging on hospital, while the effect on pharmaceutical and outpatient expenditure remained robust and stable. Importantly, results are very similar when using longer lags ($x = 15$)[7]

[7]We test and discuss further the robustness of our results to longers in subsection 5.

Table 4: Effect of Aging on Hospitalizations' Expenditure 2011-2023 (Lags $x = 10, 15$)

	I Stage ($x = 10$)	**I Stage** ($x = 15$)	**OLS**	**IV** ($x = 10$)	**IV** ($x = 15$)
Over 60	0.761***	0.708***	0.966***	0.923***	0.937***
	(0.013)	(0.012)	(0.058)	(0.069)	(0.070)
Over 65	0.709***	0.665***	0.819***	0.784***	0.798***
	(0.011)	(0.010)	(0.047)	(0.054)	(0.054)
Over 70	0.640***	0.597***	0.770***	0.687***	0.687***
	(0.010)	(0.010)	(0.043)	(0.051)	(0.052)
Over 75	0.584***	0.536***	0.602***	0.453***	0.437***
	(0.009)	(0.009)	(0.040)	(0.047)	(0.048)
No. Obs.	1502	1502	1502	1502	1502

Notes: Significance levels: *10%, **5%, ***1%. Standard errors clustered at municipality level. Observations weighted by period-t population. Controls: year dummies, province fixed effects, demographic structure.

Table 5: Effect of Aging on Pharmaceutical Prescriptions' Expenditure 2011-2023 (Lags $x = 10, 15$)

	I Stage ($x = 10$)	**I Stage** ($x = 15$)	**OLS**	**IV** ($x = 10$)	**IV** ($x = 15$)
Over 60	0.761***	0.708***	1.232***	1.208***	1.199***
	(0.013)	(0.012)	(0.048)	(0.056)	(0.057)
Over 65	0.709***	0.665***	1.011***	0.964***	0.965***
	(0.011)	(0.010)	(0.038)	(0.044)	(0.044)
Over 70	0.640***	0.597***	0.875***	0.721***	0.717***
	(0.010)	(0.010)	(0.037)	(0.043)	(0.044)
Over 75	0.584***	0.536***	0.645***	0.398***	0.375***
	(0.009)	(0.009)	(0.035)	(0.042)	(0.042)
No. Obs.	1502	1502	1502	1502	1502

Notes: Significance levels: *10%, **5%, ***1%. Standard errors clustered at municipality level. Observations weighted by period-t population. Controls: year dummies, province fixed effects, demographic structure.

Table 6: Effect of Aging on Outpatient Services' Expenditure 2011-2023 (Lags $x = 10, 15$)

	I Stage ($x = 10$)	**I Stage** ($x = 15$)	**OLS**	**IV** ($x = 10$)	**IV** ($x = 15$)
Over 60	0.761***	0.708***	0.525***	0.498***	0.476***
	(0.013)	(0.012)	(0.050)	(0.059)	(0.060)
Over 65	0.709***	0.665***	0.438***	0.404***	0.396***
	(0.011)	(0.010)	(0.041)	(0.047)	(0.047)
Over 70	0.640***	0.597***	0.379***	0.302***	0.296***
	(0.010)	(0.010)	(0.038)	(0.045)	(0.046)
Over 75	0.584***	0.536***	0.236***	0.113***	0.099***
	(0.009)	(0.009)	(0.035)	(0.041)	(0.042)
No. Obs.	1502	1502	1502	1502	1502

Notes: Significance levels: *10%, **5%, ***1%. Standard errors clustered at municipality level. Observations weighted by period-t population. Controls: year dummies, province fixed effects, demographic structure.

4.4 Is the effect driven by older adults or the oldest-old?

The effect of ageing on healthcare expenditure need not be homogeneous across the older population. Older adults (aged 60–74) and the oldest-old (aged 75+) differ substantially in their morbidity profiles, care needs, and proximity to death, suggesting that the two groups may exert differential pressure on healthcare spending. To test this, we augment the baseline specification to include both ageing indicators simultaneously:

$$\begin{aligned}\ln\left(\frac{Y_{m,t+p}}{N_{m,t+p}}\right) - \ln\left(\frac{Y_{m,t}}{N_{m,t}}\right) = \beta_1\left[\ln\left(\frac{\text{P6074}_{m,t+p}}{N_{m,t+p}}\right) - \ln\left(\frac{\text{P6074}_{m,t}}{N_{m,t}}\right)\right] \\ + \beta_2\left[\ln\left(\frac{\text{P75}_{m,t+p}}{N_{m,t+p}}\right) - \ln\left(\frac{\text{P75}_{m,t}}{N_{m,t}}\right)\right] \\ + X'_{m,t}\delta_t + (\varepsilon_{m,t+p} - \varepsilon_{m,t}).\end{aligned} \tag{4}$$

where $\text{P6074}_{m,t}$ and $\text{P75}_{m,t}$ denote the population aged 60–74 and 75 and above in municipality m at time t, respectively, and all remaining variables are defined as in Equation (1). The coefficients β_1 and β_2 capture the elasticity of per-capita healthcare expenditure with respect to the older adults and oldest-old population shares, respectively,

holding the other group constant.

The two endogenous regressors are jointly instrumented in a system of two first-stage equations. Each first stage includes both excluded instruments — the predicted growth in the young-old share $\left(\ln(\widehat{\text{P6074}}_{m,t+8}/\widehat{N}_{m,t+8}) - \ln(\widehat{\text{P6074}}_{m,t}/\widehat{N}_{m,t})\right)$ and the predicted growth in the oldest-old share $\left(\ln(\widehat{\text{P75}}_{m,t+8}/\widehat{N}_{m,t+8}) - \ln(\widehat{\text{P75}}_{m,t}/\widehat{N}_{m,t})\right)$ — constructed using the cohort-survival approach described in Section 3.1, applied separately to each age group. The two first-stage equations are:

$$\begin{aligned}\ln\left(\frac{\text{P6074}_{m,t+8}}{N_{m,t+8}}\right) - \ln\left(\frac{\text{P6074}_{m,t}}{N_{m,t}}\right) = \alpha_{11}&\left[\ln\left(\frac{\widehat{\text{P6074}}_{m,t+8}}{\widehat{N}_{m,t+8}}\right) - \ln\left(\frac{\widehat{\text{P6074}}_{m,t}}{\widehat{N}_{m,t}}\right)\right] \\ &+ \alpha_{12}\left[\ln\left(\frac{\widehat{\text{P75}}_{m,t+8}}{\widehat{N}_{m,t+8}}\right) - \ln\left(\frac{\widehat{\text{P75}}_{m,t}}{\widehat{N}_{m,t}}\right)\right] \\ &+ X'_{m,t}\theta_1 + \mu_{1t} + (\eta_{1,m,t+8} - \eta_{1,m,t}). \qquad (5)\end{aligned}$$

$$\begin{aligned}\ln\left(\frac{\text{P75}_{m,t+8}}{N_{m,t+8}}\right) - \ln\left(\frac{\text{P75}_{m,t}}{N_{m,t}}\right) = \alpha_{21}&\left[\ln\left(\frac{\widehat{\text{P6074}}_{m,t+8}}{\widehat{N}_{m,t+8}}\right) - \ln\left(\frac{\widehat{\text{P6074}}_{m,t}}{\widehat{N}_{m,t}}\right)\right] \\ &+ \alpha_{22}\left[\ln\left(\frac{\widehat{\text{P75}}_{m,t+8}}{\widehat{N}_{m,t+8}}\right) - \ln\left(\frac{\widehat{\text{P75}}_{m,t}}{\widehat{N}_{m,t}}\right)\right] \\ &+ X'_{m,t}\theta_2 + \mu_{2t} + (\eta_{2,m,t+8} - \eta_{2,m,t}). \qquad (6)\end{aligned}$$

where $\widehat{\text{P6074}}_{m,t}$ and $\widehat{\text{P75}}_{m,t}$ denote the predicted populations of the respective age groups, constructed by applying regional cohort-specific survival rates to the municipal age structure at time $t-10$.

Results are reported in Table 7. Both age groups exert a positive and statistically significant effect on healthcare expenditure across all domains, but important heterogeneity emerges between them. For hospitalizations, the elasticities of the young-old and oldest-old are similar in magnitude (0.320 and 0.324, respectively), indicating that both groups contribute comparably to hospitalization expenditure growth for a given percentage increase in their population share. For outpatient services, the oldest-old exhibit a

larger elasticity (0.225) than the young-old (0.127), suggesting that the demand for specialist visits and diagnostic tests is more concentrated among the very old. The contrast is sharpest for pharmaceutical expenditure, where the young-old display a substantially larger elasticity (0.635) than the oldest-old (0.475), consistent with the dominant role of chronic disease management and long-term prescribing among the 60–74 age group.

To quantify the contribution of each group to aggregate expenditure growth during 2011–2019, we combine these elasticities with the observed demographic changes.[8]

Demographic ageing alone accounts for expenditure increases of 8.0% for hospitalizations, 13.0% for pharmaceuticals, and 4.9% for outpatient services over the period. This reflect the growth in healthcare expenditure that would have occurred due to population ageing, in the absence of any changes in healthcare legislation, technological innovation, or other concurrent shocks that affect healthcare expenditure. Despite starting from a smaller population base, the oldest-old emerge as the dominant driver across all domains: they account for 5.7 percentage points of the 8.0% hospitalization increase, 8.4 of the 13.0% pharmaceutical increase, and 4.0 of the 4.9% outpatient increase.

Taken together, these results reveal that despite starting from a smaller population base, the oldest-old are the dominant driver of ageing-related healthcare expenditure growth across all domains, owing to the combination of their faster demographic expansion and their elevated healthcare needs. Given that this group is projected to grow most rapidly in the coming decades, these findings point to an increasing concentration of the fiscal burden of demographic ageing among the very oldest segment of the population.

[8]The young-old share rose from 0.2047 to 0.2199, a log-change of $\ln(0.2199/0.2047) = 0.0721$ (7.21%), while the oldest-old share increased from 0.1179 to 0.1407, a log-change of $\ln(0.1407/0.1179) = 0.1760$ (17.60%). Multiplying each log-change by the corresponding IV elasticity yields the predicted percentage increase in per-capita expenditure attributable to each group, as reported in Panel B of Table 7.

Table 7: Effects of Older Age Groups on Expenditure per Capita and Implied Expenditure Contributions (2011–2019)

	Hospitalizations	**Pharmaceutical**	**Outpatient Services**
Panel A: IV Estimates			
ln(Ages 60–74/N)	0.320***	0.635***	0.127**
	(0.066)	(0.051)	(0.058)
ln(Ages 75+/N)	0.324***	0.475***	0.225***
	(0.060)	(0.046)	(0.053)
Observations	1,502	1,502	1,502
Panel B: Implied Expenditure Contributions from Demographic Change (2011–2019)			
Total ageing contribution	8.0%	13.0%	4.9%
Of which: oldest-old (75+)	5.7%	8.4%	4.0%
Of which: older adults (60–74)	2.3%	4.6%	0.9%

Notes: Panel A reports IV estimates from Equation (4), instrumenting both age-group regressors jointly using predicted cohort-survival growth rates for the 60–74 and 75+ groups ($x = 10$). Standard errors clustered at municipality level in parentheses. Observations weighted by period-t population. Controls: year dummies, province fixed effects. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Panel B translates the IV elasticities into implied expenditure contributions by multiplying each elasticity by the observed % change in the corresponding age group's population share between 2011 and 2019 (see Table A1).

5 Robustness Checks

In this section, we provide the following robustness analysis to our main findings: i) we utilize longer lags (x=15,20) to predict population ageing, ii) we drop Milan and the province capitals from the analysis.

5.1 Alternative IV lag: Fifteen-Years and Twenty-Years

To address potential concerns that predetermined age structures might be correlated with slowly-evolving local trends, we reconstruct the instrument using age structures from fifteen years prior ($x = 15$) and twenty years prior ($x = 20$) rather than ten years prior. By using longer lags, we reduce the probability of the instrument to be correlated with local trends that affect contemporaneous healthcare expenditure growth Maestas et al. (2023). Tables A2-A4 in Appendix present the results obtained using this alternative

lags ($x = 15$ and $x = 20$). First-stage estimates remain strong and statically significant, whereas the IV elasticities are very similar to those of our main models. Overall, this supports the assumption that there are no long-term local trends affecting our results providing strong support for the validity of the exclusion restriction.

5.2 Dropping Milan and Province Capitals

To assess whether our results are driven by the distinctive demographic and healthcare dynamics of large urban centres, we re-estimate the main model after sequentially dropping Milan (the regional capital, accounting for 13.7% of Lombardy's population) and all 12 province capitals, which together represent 22.7% of the population. Results are reported in Tables A5–A10 in the Appendix.

Two patterns emerge from this exercise. First, first-stage coefficients are consistently lower when large urban centres are excluded. This likely reflects the role of migration: over recent decades, working-age individuals have increasingly relocated to cities in search of labour opportunities, while city-born residents tend to remain. As a result, lagged cohort structures predict future age compositions more accurately in urban settings, where population turnover is lower, than in smaller municipalities where net out-migration of younger cohorts introduces greater prediction error.

Second, and more importantly for our purposes, the IV estimates are very similar across both exercises and do not differ statistically from the main specification, as confirmed by the overlapping standard errors. This stability indicates that our findings are not driven by idiosyncratic dynamics in urban centres, and that the causal effect of population ageing on healthcare expenditure is broadly consistent across the urban-rural spectrum of Lombardy municipalities.

5.3 Aging-driven migration

THINK where to put

A further concern is that municipalities ageing more rapidly — as predicted by the instrument — may attract in-migrants seeking better healthcare access, or conversely

lose younger residents. Either pattern would represent a migration response to predicted ageing that could confound our estimates. Following Maestas et al. (2023), we assess this directly by replacing the healthcare expenditure outcome with migration flows as the dependent variable and re-estimating both OLS and the 2SLS specification. We use ISTAT inter-municipal migration data to construct the log-change in per-capita in-migration between 2011 and 2019, both for total in-migration (from any Italian municipality) and for intra-regional in-migration within Lombardy — the most plausible channel for healthcare-quality-driven mobility. Table XXX reports these estimates for all four age thresholds and....

6 Discussion and Conclusions

This paper investigates the causal impact of population ageing on healthcare expenditure using rich administrative data from the largest region in Italy, Lombardy, and a municipality-level instrumental variable panel design. We exploit plausible exogenous variation in demographic ageing generated by lagged municipal age structures combined with national cohort-specific survival rates, and provide evidence that population ageing leads to statistically significant increases in per-capita healthcare spending across all major domains of care (hospitalizations, pharmaceutical consumption and outpatient care).

Our instrumental variable results indicate economically meaningful and persistent effects. For the pre-COVID period (2011–2019), a 1% increase in the share of the population aged 60 and above raises per-capita expenditure by approximately 0.69% for hospitalizations, 1.29% for pharmaceutical consumption, and 0.47% for outpatient services. These findings demonstrate substantial heterogeneity in how different healthcare domains respond to demographic ageing, with pharmaceutical spending exhibiting more-than-proportional responses while outpatient services show more modest elasticities. This differential responsiveness across healthcare domains has important implications for healthcare planning and resource allocation

Decomposing the aggregate ageing effect between older adults (60–74) and the oldest-old (75+) reveals that the fiscal pressure is disproportionately driven by the latter group. Although the two groups display similar elasticities for hospitalizations (0.320 and 0.324, respectively), the oldest-old exhibit higher elasticities for outpatient services (0.225 vs 0.127), while the young-old dominate pharmaceutical spending (0.635 vs 0.475), reflecting the central role of chronic disease management among this group. The faster demographic expansion of the oldest-old that makes them the dominant contributor to total ageing-driven expenditure growth across all domains. The oldest-old account for 5.7 of the 8.0% hospitalization increase, 8.4 of the 13.0% pharmaceutical increase, and 4.0 of the 4.9% outpatient increase attributable to ageing over the period. As the oldest-old are projected to be the fastest-growing demographic segment in the coming decades, these results suggest that the fiscal burden of ageing on healthcare systems will intensify beyond what aggregate elderly population shares alone would imply.

Importantly, instrumental-variable estimates are generally smaller than their OLS counterparts, suggesting that ordinary linear models that do not account for the endogeneity of population ageing tend to overstate the effect of population ageing on healthcare expenditure. This pattern is consistent with upward bias in OLS estimates arising from reverse causality (healthcare-improved longevity), healthcare driven migration of the elderly towards better services, or other endogenous adjustments in healthcare supply. This bias is particularly present when considering older age thresholds (70+, 75+), as IV estimates around become 30% to 40% smaller than OLS. The IV results therefore provide more conservative and credible estimates of the causal impact of demographic ageing on healtchare expenditure.

Extending our sample to the COVID-19 pandemic years (2011–2023) reveals that the core findings persist even in the presence of a massive health shock, though with some important modifications. On the one hand, hospitalization elasticities slightly increase consistent with the disproportionate impact of the pandemic on elderly populations, who experienced both higher direct infection burdens and indirect effects from delayed care for chronic conditions. On the other hand, pharmaceutical and outpatient spending

elasticities remain stable. Overall, the lack of a systematic increase in elasticities when considering longer periods discards the presence of a cumulative amplification of the ageing effects. This pattern suggests that while demographic ageing exerts sustained pressure on healthcare systems, adjustment mechanisms or offsetting forces may partially dampen expenditure growth in the longer run.

Overall, our findings highlight the substantial and sustained pressure that population ageing places on publicly financed healthcare systems, with heterogeneous impacts across healthcare domains. As demographic ageing is projected to intensify in the coming decades, understanding its causal impact on healthcare expenditure is crucial for designing sustainable health policies. Our findings from Italy, a country at an advanced stage of demographic transition, offer valuable insights for countries and regions at earlier stages of ageing, providing a preview of the fiscal challenges the their healthcare systems are likely to confront.

References

Acemoglu, D. and Restrepo, P. (2017). Secular stagnation? the effect of aging on economic growth in the age of automation. *American Economic Review*, 107(5):174–179.

Bech, M., Christiansen, T., Khoman, E., Lauridsen, J., and Weale, M. (2011). Ageing and health care expenditure in eu-15. *The European Journal of Health Economics*, 12(5):469–478.

Commission, E. (2024). 2024 ageing report: Economic & budgetary projections for the eu member states (2022–2070).

Costa-Font, J. and Vilaplana-Prieto, C. (2020). 'more than one red herring'? heterogeneous effects of ageing on health care utilisation. *Health Economics*, 29:8–29.

Howdon, D. and Rice, N. (2018). Health care expenditures, age, proximity to death and morbidity: Implications for an ageing population. *Journal of health economics*, 57:60–74.

Maestas, N., Mullen, K. J., and Powell, D. (2023). The effect of population aging on economic growth, the labor force, and productivity. *American Economic Journal: Macroeconomics*, 15(2):306–332.

Piscopo, J., Groot, W., and Pavlova, M. (2024). Determinants of public health expenditure in the eu. *Plos one*, 19(3):e0299359.

Sheiner, L. (2014). The determinants of the macroeconomic implications of aging. *American Economic Review*, 104(5):218–223.

Werblow, A., Felder, S., and Zweifel, P. (2007). Population ageing and health care expenditure: a school of 'red herrings'? *Health economics*, 16(10):1109–1126.

Appendices

Appendix A Additional Tables

Year	share60	share65	share70	share75	share60-74
2011	0.3226	0.2425	0.1806	0.1179	0.2047
2012	0.3274	0.2482	0.1839	0.1202	0.2072
2013	0.3312	0.2528	0.1862	0.1229	0.2083
2014	0.3356	0.2584	0.1885	0.1267	0.2089
2015	0.3409	0.2643	0.1915	0.1312	0.2097
2016	0.3458	0.2696	0.1926	0.1348	0.2110
2017	0.3512	0.2742	0.1980	0.1378	0.2134
2018	0.3559	0.2780	0.2022	0.1394	0.2165
2019	0.3606	0.2814	0.2068	0.1407	0.2199
2020	0.3665	0.2856	0.2114	0.1426	0.2239
2021	0.3701	0.2872	0.2132	0.1405	0.2296
2022	0.3752	0.2904	0.2156	0.1440	0.2312
2023	0.3803	0.2932	0.2175	0.1464	0.2339

Table A1: Share of population by year

Table A2: Effect of Aging on Hospitalizations' Expenditure: Alternative Lags Comparison

	I Stage $x = 15$	**I Stage** $x = 20$	**OLS**	**IV** $x = 15$	**IV** $x = 20$
Over 60	0.707***	0.667***	0.768***	0.727***	0.721***
	(0.013)	(0.013)	(0.073)	(0.089)	(0.092)
Over 65	0.660***	0.626***	0.677***	0.645***	0.647***
	(0.011)	(0.011)	(0.059)	(0.071)	(0.071)
Over 70	0.535***	0.515***	0.646***	0.472***	0.486***
	(0.011)	(0.011)	(0.059)	(0.077)	(0.076)
Over 75	0.517***	0.491***	0.486***	0.296***	0.300***
	(0.010)	(0.009)	(0.052)	(0.064)	(0.064)
No. Obs.	1502	1502	1502	1502	1502

Notes: Significance levels: *10%, **5%, ***1%. Standard errors clustered at municipality level. Observations weighted by period-t population. Controls: year dummies, province FE, demographic structure.

Table A3: Effect of Aging on Pharmaceutical Prescriptions' Expenditure: Alternative Lags Comparison

	I Stage $x = 15$	**I Stage** $x = 20$	**OLS**	**IV** $x = 15$	**IV** $x = 20$
Over 60	0.707***	0.667***	1.310***	1.296***	1.250***
	(0.013)	(0.013)	(0.056)	(0.068)	(0.070)
Over 65	0.660***	0.626***	1.080***	1.013***	0.992***
	(0.011)	(0.011)	(0.045)	(0.054)	(0.054)
Over 70	0.535***	0.515***	0.928***	0.581***	0.598***
	(0.011)	(0.011)	(0.047)	(0.062)	(0.061)
Over 75	0.517***	0.491***	0.657***	0.332***	0.339***
	(0.010)	(0.009)	(0.042)	(0.053)	(0.053)
No. Obs.	1502	1502	1502	1502	1502

Notes: Significance levels: *10%, **5%, ***1%. Standard errors clustered at municipality level. Observations weighted by period-t population. Controls: year dummies, province FE, demographic structure.

Table A4: Effect of Aging on Outpatient Services' Expenditure: Alternative Lags Comparison

	I Stage $x = 15$	**I Stage** $x = 20$	**OLS**	**IV** $x = 15$	**IV** $x = 20$
Over 60	0.707***	0.667***	0.414***	0.445***	0.427***
	(0.013)	(0.013)	(0.062)	(0.076)	(0.078)
Over 65	0.660***	0.626***	0.381***	0.414***	0.411***
	(0.011)	(0.011)	(0.050)	(0.059)	(0.060)
Over 70	0.535***	0.515***	0.349***	0.282***	0.281***
	(0.011)	(0.011)	(0.050)	(0.065)	(0.064)
Over 75	0.517***	0.491***	0.227***	0.146***	0.136***
	(0.010)	(0.009)	(0.044)	(0.054)	(0.054)
No. Obs.	1502	1502	1502	1502	1502

Notes: Significance levels: *10%, **5%, ***1%. Standard errors clustered at municipality level. Observations weighted by period-t population. Controls: year dummies, province FE, demographic structure.

Table A5: Effect of Aging on Hospitalizations' Expenditure ($x = 10$) without Milan

	I Stage	**OLS**	**IV**
Over 60	0.589***	0.605***	0.558***
	(0.011)	(0.104)	(0.127)
Over 65	0.565***	0.580***	0.553***
	(0.009)	(0.081)	(0.096)
Over 70	0.515***	0.507***	0.417***
	(0.008)	(0.073)	(0.086)
Over 75	0.531***	0.344***	0.232***
	(0.008)	(0.058)	(0.067)
No. Obs.	1501	1501	1501

Notes: Significance levels: *10%, **5%, ***1%. Standard errors clustered at municipality level. Observations weighted by period-t population. Controls: year dummies, province FE, demographic structure. Fstatistics: 3018, 3644, 3761 and 4810.

Table A6: Effect of Aging on Pharmaceutical Prescriptions' Expenditure ($x = 10$) without Milan

	I Stage	**OLS**	**IV**
Over 60	0.589***	0.956***	1.086***
	(0.011)	(0.078)	(0.096)
Over 65	0.565***	0.796***	0.810***
	(0.009)	(0.061)	(0.072)
Over 70	0.515***	0.562***	0.436***
	(0.008)	(0.056)	(0.066)
Over 75	0.531***	0.342***	0.237***
	(0.008)	(0.045)	(0.052)
No. Obs.	1501	1501	1501

Notes: Significance levels: *10%, **5%, ***1%. Standard errors clustered at municipality level. Observations weighted by period-t population. Controls: year dummies, province FE, demographic structure. Fstatistics: 3018, 3644, 3761 and 4810.

Table A7: Effect of Aging on Outpatient services' Expenditure ($x = 10$) without Milan

	I Stage	**OLS**	**IV**
Over 60	0.589***	0.467***	0.524***
	(0.011)	(0.088)	(0.108)
Over 65	0.565***	0.445***	0.487***
	(0.009)	(0.069)	(0.082)
Over 70	0.515***	0.507***	0.417***
	(0.008)	(0.073)	(0.086)
Over 75	0.531***	0.183***	0.139**
	(0.008)	(0.050)	(0.057)
No. Obs.	1501	1501	1501

Notes: Significance levels: *10%, **5%, ***1%. Standard errors clustered at municipality level. Observations weighted by period-t population. Controls: year dummies, province FE, demographic structure. Fstatistics: 3018, 3644, 3761 and 4810.

Table A8: Effect of Aging on Hospitalizations' Expenditure ($x = 10$) without province capitals

	I Stage	**OLS**	**IV**
Over 60	0.529***	0.525***	0.487***
	(0.011)	(0.120)	0.152)
Over 65	0.511***	0.548***	0.522***
	(0.009)	(0.093)	(0.113)
Over 70	0.481***	0.470***	0.390***
	(0.008)	(0.080)	(0.095)
Over 75	0.506***	0.301***	0.192***
	(0.007)	(0.063)	(0.073)
No. Obs.	1490	1490	1490

Notes: Significance levels: *10%, **5%, ***1%. Standard errors clustered at municipality level. Observations weighted by period-t population. Controls: year dummies, province FE, demographic structure.

Table A9: Effect of Aging on Pharmaceutical Prescriptions' Expenditure ($x = 10$) without province capitals

	I Stage	**OLS**	**IV**
Over 60	0.529***	0.716***	0.892***
	(0.011)	(0.089)	0.113)
Over 65	0.511***	0.622***	0.666***
	(0.009)	(0.069)	(0.084)
Over 70	0.481***	0.398***	0.318***
	(0.008)	(0.061)	(0.071)
Over 75	0.506***	0.208***	0.127**
	(0.007)	(0.048)	(0.055)
No. Obs.	1490	1490	1490

Notes: Significance levels: *10%, **5%, ***1%. Standard errors clustered at municipality level. Observations weighted by period-t population. Controls: year dummies, province FE, demographic structure.

Table A10: Effect of Aging on Outpatient services' Expenditure ($x = 10$) without province capitals

	I Stage	**OLS**	**IV**
Over 60	0.529***	0.436***	0.488***
	(0.011)	(0.102)	(0.129)
Over 65	0.511***	0.446***	0.486***
	(0.009)	(0.079)	(0.096)
Over 70	0.481***	0.329***	0.287***
	(0.008)	(0.068)	(0.081)
Over 75	0.506***	0.153***	0.103***
	(0.007)	(0.054)	(0.062)
No. Obs.	1490	1490	1490

Notes: Significance levels: *10%, **5%, ***1%. Standard errors clustered at municipality level. Observations weighted by period-t population. Controls: year dummies, province FE, demographic structure.