Title: **Demographic Moderation of Healthcare Expenditure Associated with Home-Based Deaths: A Longitudinal Ecological Study in Japanese Municipalities (2015–2022)**

A short running title: Home-Based Deaths and Healthcare Costs in Ageing Japan

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Conflict of interest statement

The authors declare no conflict of interest.

Data availability

The data used in this study were assembled from publicly available government statistics in Japan and processed into a structured panel dataset. The final research dataset, including documentation of variable definitions and data sources, is openly available via the Open Science Framework: Ishikawa T. Municipality-level Healthcare and Long-Term Care Dataset in Japan (2015–2022). OSF, 2025. https://doi.org/10.17605/OSF.IO/9E7PT

Abstract

Introduction: Home-based end-of-life care is promoted in Japan, yet its fiscal consequences remain unclear. Rising healthcare costs and rapid population ageing heighten the policy relevance of such evidence.

Objectives: To assess how the municipal home-based death rate relates to per-capita medical and long-term care insurance (LTCI) spending, and whether ageing modifies these links.

Methods: We analysed a panel data of 1,741 municipalities (2015–2022). Outcomes were log-transformed total and inpatient medical spending per resident and LTCI spending per certified individual. The exposure was the one-year-lagged home-based death rate, defined as home deaths divided by all deaths. Fixed-effects regressions controlled for year, ageing rate, population density, income-tax revenue, and health- and long-term care resources. Cluster-robust standard errors addressed within-municipality serial correlation. All analyses were implemented in Python 3.11 with the linearmodels package.

Results: The mean home-based death rate was 12.3% (SD = 5.72). Each one-percentage-point increase predicted 0.062 (95 % CI: 0.010–0.113) and 0.091 (95 % CI: 0.001–0.182) log-point rises in total and inpatient spending, with no association for LTCI. Ageing moderated this relation; at ageing 39.5%, higher home-based death rates predicted lower medical costs. Greater population density, lower taxable income and more home-visit nursing agencies were also linked to higher medical spending.

Conclusion: The fiscal impact of home-based deaths is context dependent. In highly aged municipalities, encouraging home dying may yield medical savings, whereas younger areas could face initial cost growth. Distinct cost dynamics between medical and LTCI systems call for locally tailored end-of-life policies.

Keywords: home-based death, healthcare expenditure, ageing population, end-of-life care, panel data analysis, fixed-effects model, municipal-level study

Highlights

- Fixed-effects models used 2015–2022 data from 1,741 municipalities in Japan.
- Home death rates raised costs in younger areas but lowered them in older ones.
- No link found between home deaths and LTCI costs, showing fiscal separation.
- End-of-life care policy must reflect ageing to ensure fiscal sustainability.

I. Introduction

Japan has one of the highest proportions of older people in the world, with more than 28% of its population now aged 65 years or older. In response to this demographic trend, increasing attention has been directed towards maintaining the health and quality of life of older adults while sustaining the national healthcare system over the long term [1]. As part of this policy direction, the Japanese government has promoted the development of a Community-based Integrated Care System, designed to support people to remain in familiar settings while receiving appropriate care, particularly in the final stages of life [2]. Within this policy framework, increasing efforts have been made to support home-based end-of-life care as part of a broader shift toward community-based services. To this end, the Japanese government has promoted Community-based Integrated Care Centres and 24-hour home-visiting physician services to strengthen the capacity for home-based care and death in familiar surroundings [2]. Despite global trends showing that 25–60% of deaths occur at home depending on income level, only 17.4% of deaths in Japan took place at home in 2022, with 64.5% still occurring in hospitals [3]. Although the government has strongly promoted home-based care, Japan has been slow to shift toward home-based deaths. Correspondingly, nationwide data from Japanese municipalities demonstrate that areas with more extensive home-care resources, such as clinics that offer 24-hour services and visiting nursing agencies, are associated with higher rates of home deaths [4,5]. While the primary aim of such care is to honour the preferences and dignity of individuals, it has also been discussed in the context of potentially reducing healthcare expenditure [6]. As population ageing continues to accelerate in Japan, healthcare costs are rising sharply, posing a serious challenge to the sustainability of the system [7]. In Japan, healthcare expenditure per capita remains moderately low (approximately USD 3,900) compared with the OECD average (around USD 5,000) [8,9], largely due to the government's centralised control of medical fees through a national fee schedule. However, the proportion of GDP spent on healthcare reaches 10–11%, exceeding the OECD average, and public funding accounts for about 83% of total health spending [10]. This high public dependency highlights the urgency of ensuring cost-effective care delivery. The idea that enabling people to remain at home until death may lead to more efficient use of healthcare resources has therefore received growing attention.

Several studies have examined the proposition that home-based end-of-life care may be associated with lower healthcare expenditure in the final stages of life.

Kato and Fukuda (2017) found that the total medical expenditure per patient was approximately USD 7,523 lower for those receiving home-based palliative care than for those admitted to hospital [11]. In the United States, Lustbader et al. (2017) demonstrated that home-based palliative care was associated with savings of around USD 12,000 in the final three months of life, alongside a higher likelihood of dying at home [12]. However, Takahashi et al. (2024) analysed claims data and found that, although total costs for patients receiving end-of-life care at home were lower than for those in general or palliative wards, spending increased during the last week of life, whereas it decreased for hospitalised patients [13].

Systematic reviews have also suggested that home-based palliative care may be effective in enabling individuals to die in their preferred place and in improving satisfaction among patients and their families. However, the evidence concerning cost-effectiveness remains inconclusive, and further research has been recommended [14]. Most existing studies, however, have focused primarily on patients with terminal cancer or on specific care programmes, limiting the generalizability of their cost findings to broader populations. Consequently, relatively few have comprehensively investigated the association between overall home-based death rates and aggregate healthcare expenditure at a population level, which is crucial for informing national health policies. In addition, Tomita et al. (2020) reported that families providing care at home often bear substantial indirect costs, such as time and lost income, which are typically excluded from analyses of public healthcare spending [15]. These findings suggest the need for a broader perspective when considering the economic implications of home-based end-of-life care.

However, from a public policy and national financial sustainability standpoint, understanding the direct impact on public healthcare expenditure at a population level remains paramount. Addressing these critical knowledge gaps, particularly in the context of a rapidly ageing society like Japan, is imperative. Despite growing policy emphasis on home-based end-of-life care in Japan, evidence regarding its relationship with overall public healthcare expenditure at the population level remains notably limited. This gap could hinder evidence-based policymaking, as it is crucial to ascertain whether increased rates of home deaths contribute to fiscal sustainability or posing unforeseen financial burdens at the municipal level. Therefore, this study aims to comprehensively investigate the longitudinal association between home-based death rates and per capita healthcare expenditure across Japanese municipalities, with a particular focus on understanding the moderating role of demographic ageing. By utilising extensive municipality-level panel data, this research provides a robust ecological perspective on the complex economic implications of evolving end-of-life care patterns, offering vital insights for policymakers in Japan and other ageing nations.

II. Methods

1. Study Design and Data Sources

We carried out a longitudinal ecological study based on municipality-level panel data covering all 1,741 Japanese municipalities for fiscal years 2015 to 2022. The dataset was compiled from publicly available government sources, including statistics from the Ministry of Health, Labour and Welfare (MHLW) and the Ministry of Internal Affairs and Communications (MIC), and includes information on home-based deaths, health-care and long-term-care resources, expenditure under the National Health Insurance and the Medical Care System for the Latter-Stage Elderly, and long-term care insurance (LTCI) benefits. All data were cleaned, standardised, and assembled into a publicly available research dataset, which also documents variable definitions and original sources [16].

2. Outcome Variables

We analysed three expenditure outcomes, each natural-log-transformed to reduce right skewness and to allow regression coefficients to be interpreted as approximate percentage changes: (1) total health-care expenditure per resident, (2) inpatient health-care expenditure per resident, and (3) LTCI benefits per certified individual. LTCI benefits represents public benefits paid under Japan's universal long-term care insurance system, introduced in 2000 and financed by premiums and tax revenues [17]. The scheme reimburses institutional care, home-based day and visit services, and community-based integrated programmes for older adults who have been officially certified as needing support or care; it is administered separately from the medical insurance system.

3. Explanatory Variables

The principal explanatory variable was the municipality-level proportion of home deaths in the preceding fiscal year, expressed as a percentage of all registered deaths in the municipality during that year. To assess demographic heterogeneity, we later introduced an interaction between this lagged home-based death rate and the municipal ageing rate. Control variables were chosen a priori on theoretical grounds. To reduce the risk of reverse causation, all explanatory variables including the ageing rate, population density, income level, and healthcare and long-term-care resources were lagged by one fiscal year. This temporal separation ensures that the covariates precede the outcome, reinforcing the temporal ordering required for causal interpretation. Demographic and socio-economic characteristics included the share of residents aged 65 years or older (ageing rate), population density (log-transformed persons per km^2) and average income-tax revenue per capita (log-transformed yen). The income-tax revenue per capita was calculated as the municipal average of the income-based component of individual resident tax, among working residents. This variable is considered an appropriate proxy for regional income levels, as it captures the taxable income of employed individuals while avoiding distortions caused by non-working populations such as older adults or children. Health-care resources were captured by the absolute numbers of home-visit nursing agencies, home-care support clinics and hospital beds in each municipality , regardless of medical department or whether they serve acute or chronic care. Long-term-care resources comprised the numbers of beds in long-term-care medical facilities, residential care homes (welfare facilities) and nursing homes (health facilities) as well as the counts of small-scale multifunctional in-home-care facilities and nurse-led multifunctional home-care services. Because long-term-care need scales with the older population, these latter indicators were standardised per 10,000 residents aged 65 years or older; all other resource variables were analysed as municipal totals. Descriptive statistics confirmed that no variable showed extreme leverage after transformation.

Among the 13,858 municipality-year observations from 2015 to 2022, 12,117 were included in the regression analyses. Observations were excluded if the lagged value of the home-based death rate was missing. This missingness primarily occurred in municipalities where the number of deaths in the preceding year was zero or not recorded, making the calculation of the home-based death rate infeasible. No other variables had missing values.

4. **Statistical Analysis**

The panel data consisted of 12,117 municipality-year observations. We estimated fixed-effects regression models to control for unobserved, time-invariant municipal characteristics and nationwide temporal shocks. Heteroskedasticity- and autocorrelation-consistent standard errors were clustered at the municipality level to take account of serial correlation within municipalities. Primary models included the lagged home-based death rate and all covariates; extended models added the interaction term with the ageing rate. To aid interpretation and reduce multicollinearity, the lagged home-based death rate and ageing rate were mean-centred before constructing the interaction term. Prior to model estimation, multicollinearity was assessed using variance inflation factors (VIFs). All values were below 2, suggesting that multicollinearity was not a concern. Goodness of fit was evaluated with within-R^2 and F statistics, and a poolability test confirmed the necessity of fixed effects. All continuous variables including the home-based death rate were entered as percentage values (range 0–100). Thus, coefficients represent the relative change in the outcome per one-percentage-point (pp) increase in the explanatory variable. All analyses were conducted in Python (version 3.11) using pandas for data management and the *linearmodels* package for estimation. Descriptive summaries (means, standard deviations and ranges) were produced for every variable to characterise inter-municipal and temporal variation. Because the analysis used a complete national dataset, no priori sample size calculation was conducted. The significance level was set at 0.05. To visualise significant interaction effects, we generated predictive plots for models in which the interaction term reached statistical significance. These plots depict the predicted outcomes across the observed range of home-based death rates, stratified by low and high ageing rates (defined as the 10th and 90th percentiles, respectively). Predicted values were computed based on model coefficients, assuming the mean values for all other covariates. All monetary variables were analysed in Japanese yen. For ease of interpretation, results and figures are presented in US dollars, converted using the average exchange rate for 2022 (¥131.56 per USD).

5. Ethical Considerations

This study used only publicly available, aggregated municipal-level data that contained no personally identifiable information. As such, it does not require ethical approval in accordance with local and international research ethics guidelines.

Table 1. Descriptive statistics of variables used in the analysis (2015–2022)

Variable	Mean	SD	Min	Max
Home-based death rate (%)	12.34	5.72	0.00	100.00
Total healthcare expenditure per capita (yen)	589,553.56	91,435.07	224645.44	1,034,904.88
Inpatient healthcare expenditure per capita (yen)	286,113.46	72,994.16	28336.43	2,082,604.04
Long-term care insurance benefits per certified individual (yen)	1,468,389.61	188,663.03	5757.94	4,350,399.67
Ageing rate (%)	33.24	7.36	13.85	66.71
Population density (persons per km²)	1,293.03	4,300.56	1.01	58,520.74
Average income tax per capita (yen)	98,317.68	28,345.72	45521.79	6,295,050.98
Number of home-visit nursing agencies	6.59	21.26	0	576
Number of home care support clinics	8.32	28.59	0	781
Number of hospital beds	890.75	2,359.08	0	41,616
Number of beds in long-term care medical facilities	21.24	81.56	0	2,642
Number of beds in residential care homes (long-term care welfare facilities)	213.59	498.48	0	10,366
Number of beds in nursing homes (long-term care health facilities)	321.25	731.45	0	16,998
Number of small-scale multifunctional in-home care facilities	0.32	1.29	0	41
Number of nurse-led multifunctional home care services	3.10	8.33	0	164

Values represent pooled data across all municipalities and years from 2015 to 2022. All monetary units are in Japanese yen. Percentages are shown without transformation. Healthcare and long-term care resources are reported as raw counts per municipality.

III. Results

Table 1 summarises 13,928 municipality–year observations. The mean home-based death rate was 12.3% (SD = 5.72). On average, municipalities spent approximately $4,481.19 per resident on total healthcare and $2,175.14 on inpatient care. LTCI benefits averaged around $11,161.47 per certified individual. The mean ageing rate was 33.2%, and population density showed considerable dispersion. Service capacity indicators also exhibited wide variability; for instance, the number of home-visit nursing agencies ranged from zero to 576 within a single municipality–year. Table 2 presents the results of the fixed-effects regression models without interaction terms. A one-percentage-point increase in the home-based death rate in the preceding year was significantly associated with a 0.062 log-point increase in the log of total healthcare expenditure (95 % CI: 0.010 to 0.113) and a 0.091 log-point increase in log inpatient expenditure (95 % CI: 0.001 to 0.182). In contrast, no significant association was found between home-based death rate and LTCI benefits ($b = -0.031$, 95% CI: -0.122 to 0.061). Among covariates, higher population density and lower income were positively associated with total and inpatient expenditure. Greater availability of home-visit nursing agencies was also associated with higher total expenditure.

Table 2. Association between home-based death rate and healthcare expenditure: fixed-effects regression results

	Total healthcare expenditure (per capita, log)				Inpatient healthcare expenditure (per capita, log)				Long-term care insurance benefits (per certified individual, log)			
Variable	Coefficient	SE	p-value	95% CI [lower, upper]	Coefficient	SE	p-value	95% CI [lower, upper]	Coefficient	SE	p-value	95% CI [lower, upper]
Constant	13.63	0.233	0.000	13.17, 14.08	12.92	0.308	0.000	12.32, 13.53	13.62	0.345	0.000	12.94, 14.30
Home-based death rate (lagged, %)	0.07	0.026	0.011	0.02, 0.12	0.10	0.047	0.036	0.01, 0.19	-0.03	0.045	0.506	-0.12, 0.06
Ageing rate (%)	0.13	0.149	0.389	-0.17, 0.42	0.25	0.214	0.234	-0.16, 0.67	0.45	0.302	0.139	-0.14, 1.04
Population density (log)	0.07	0.028	0.020	0.01, 0.12	0.05	0.032	0.087	-0.01, 0.12	-0.03	0.041	0.434	-0.11, 0.05
Average income tax (log)	-0.07	0.013	0.000	-0.09, -0.04	-0.07	0.022	0.002	-0.11, -0.03	0.05	0.032	0.144	-0.02, 0.11
Number of home-visit nursing agencies (per 10,000 population)	0.00	0.002	0.022	0.00, 0.01	0.01	0.003	0.111	0.00, 0.01	0.00	0.003	0.915	-0.01, 0.01
Number of home care support clinics (per 10,000 population)	0.00	0.003	0.106	0.00, 0.01	0.01	0.004	0.151	0.00, 0.01	0.00	0.002	0.916	0.00, 0.00
Number of hospital beds (per 10,000 population)	0.00	0.000	0.000	0.00, 0.00	0.00	0.000	0.000	0.00, 0.00	0.00	0.000	0.000	0.00, 0.00
Number of beds in long-term care medical facilities (per 10,000 older people)	0.00	0.000	0.997	0.00, 0.00	0.00	0.000	0.875	0.00, 0.00	0.00	0.000	0.569	0.00, 0.00
Capacity of long-term care welfare facilities (per 10,000 older people)	0.00	0.000	0.937	0.00, 0.00	0.00	0.000	0.515	0.00, 0.00	0.00	0.000	0.063	0.00, 0.00
Capacity of long-term care health facilities (per 10,000 older people)	0.00	0.000	0.155	0.00, 0.00	0.00	0.000	0.215	0.00, 0.00	0.00	0.000	0.430	0.00, 0.00
Number of small-scale multifunctional in-home care facilities (per 10,000 older people)	0.00	0.002	0.692	0.00, 0.01	0.00	0.004	0.566	0.00, 0.01	0.00	0.002	0.053	0.00, 0.01
Number of combined services (nurse-led multifunctional home care) (per 10,000 older people	0.00	0.001	0.693	0.00, 0.00	0.00	0.002	0.801	0.00, 0.00	0.01	0.003	0.011	0.00, 0.01

All models include municipality and year fixed effects. Standard errors are clustered at the municipality level.

For the model predicting total healthcare expenditure (per capita, log-transformed): R^2 (within) = 0.0049; F-statistic (robust) = 26.98; $p < 0.001$; Observations = 12,117; Municipalities = 1,741.

For the model predicting inpatient healthcare expenditure (per capita, log-transformed): R^2 (within) = 0.0357; F-statistic (robust) = 9.54; $p < 0.001$; Observations = 12,117; Municipalities = 1,741.

Table 3. Fixed-effects regression including interaction terms between home-based death rate and contextual variables

Variable	Total healthcare expenditure (per capita, log)				Inpatient healthcare expenditure (per capita, log)				Long-term care insurance benefits (per certified individual, log)			
	Coefficient	SE	p-value	95% CI [lower, upper]	Coefficient	SE	p-value	95% CI [lower, upper]	Coefficient	SE	p-value	95% CI [lower, upper]
Constant	13.59	0.228	0.000	13.14, 14.03	12.86	0.304	0.000	12.27, 13.46	13.61	0.345	0.000	12.93, 14.29
Home-based death rate (lagged, %)	0.38	0.104	0.000	0.18, 0.59	0.59	0.201	0.003	0.20, 0.99	0.06	0.165	0.715	-0.26, 0.38
Ageing rate (%)	0.28	0.154	0.068	-0.02, 0.58	0.49	0.234	0.036	0.03, 0.95	0.49	0.326	0.133	--0.15, 1.13
Home-based death rate × Ageing rate	-0.966	0.272	0.0004	-1.50, -0.43	-1.50	0.526	0.004	-2.5, -0.47	-0.27	0.503	0.585	-1.26, 0.71
Population density (log)	0.07	0.027	0.014	0.01, 0.12	0.06	0.030	0.065	0.00, 0.11	-0.03	0.041	0.439	--0.11, 0.05
Average income tax (log)	-0.07	0.014	0.000	-0.09, -0.04	-0.07	0.022	0.002	-0.11, -0.03	0.05	0.032	0.149	-0.02, 0.11
Number of home-visit nursing agencies (per 10,000 population)	0.00	0.002	0.026	0.00, 0.01	0.01	0.004	0.126	0.00, 0.01	0.00	0.003	0.902	-0.01, 0.01
Number of home care support clinics (per 10,000 population)	0.00	0.003	0.091	0.00, 0.01	0.01	0.000	0.129	0.00, 0.01	0.00	0.002	0.912	0.00, 0.00
Number of hospital beds (per 10,000 population)	0.00	0.000	0.000	0.00, 0.00	0.00	0.010	0.000	0.00, 0.00	0.00	0.000	0.000	0.00, 0.00
Number of beds in long-term care medical facilities (per 10,000 older people)	0.00	0.000	0.990	0.00, 0.00	0.00	0.000	0.880	0.00, 0.00	0.00	0.000	0.569	0.00, 0.00
Capacity of long-term care welfare facilities (per 10,000 older people)	0.00	0.000	0.967	0.00, 0.00	0.00	0.000	0.529	0.00, 0.00	0.00	0.000	0.064	0.00, 0.00
Capacity of long-term care health facilities (per 10,000 older people)	0.00	0.000	0.128	0.00, 0.00	0.00	0.000	0.183	0.00, 0.00	0.00	0.000	0.430	0.00, 0.00
Number of small-scale multifunctional in-home care facilities (per 10,000 older people)	0.00	0.002	0.669	0.00, 0.01	0.00	0.004	0.548	0.00, 0.01	0.00	0.002	0.052	0.00, 0.01
Number of combined services (nurse-led multifunctional home care) (per 10,000 older people)	0.00	0.001	0.836	0.00, 0.00	0.00	0.002	0.936	0.00, 0.00	0.01	0.003	0.010	0.00, 0.01

All models include municipality and year fixed effects. Standard errors are clustered at the municipality level.
For the model predicting total healthcare expenditure (per capita, log-transformed): R^2 (within) = 0.0268; F-statistic (robust) = 32.44; $p < 0.001$; Observations = 12,117; Municipalities = 1,741.
For the model predicting inpatient healthcare expenditure (per capita, log-transformed): R^2 (within) = 0.0533; F-statistic (robust) = 13.66; $p < 0.001$; Observations = 12,117; Municipalities = 1,741.
For the model predicting Long-term care insurance benefits (per capita, log-transformed): R^2 (within) = 0.0333; F-statistic (robust) = 5.86; $p < 0.001$; Observations = 12,117; Municipalities = 1,741.

Table 3 introduces interaction terms to explore the contextual influence of the ageing rate. The main effect of the home-based death rate remained positive and significant for both healthcare expenditure outcomes. However, the interaction term between home-based death rate and ageing rate was significantly negative ($p < 0.01$ for both models), indicating that in more aged municipalities, the association between home-based deaths and healthcare expenditure was attenuated or reversed. The inflection point of this relationship was estimated to be approximately 39.5% for both total and inpatient healthcare expenditure, calculated by dividing the coefficient of the main effect of the home-based death rate by that of the interaction term and then re-centring based on the average ageing rate (33.2%). No significant interaction was observed for LTCI benefits, suggesting that the modifying effect of population ageing was more relevant to healthcare spending.

The explanatory power of the models, though modest, improved with the inclusion of interaction terms. Within R^2 for total healthcare expenditure increased from 0.0036 to 0.0263, and for inpatient expenditure from 0.0190 to 0.0364, indicating that demographic context contributed to explaining variance in spending.

To aid interpretation, we visualised the marginal effect of the home-based death rate on predicted healthcare expenditure at two ageing levels (1 SD below and above the mean; approximately 24.1% and 42.5%). Figure 1 and Figure 2 were generated for models with statistically significant interaction terms. The plots demonstrate the divergent associations between home-based deaths and expenditure depending on the level of population ageing, while holding other covariates constant.

IV. Discussion

This study examined the relationship between home-based death rates and municipal-level healthcare and long-term care expenditures in Japan. Using fixed-effects models with data from 2015 to 2022, we found that while higher home-based death rates were generally associated with increased total and inpatient healthcare expenditures, this association was moderated by demographic ageing. Specifically, in municipalities with higher proportions of older adults (specifically above an estimated 40% ageing rate), increased home-based death rates were linked to reduced healthcare costs, suggesting a more efficient system emerges in highly aged contexts. In contrast, no significant association was observed between home-based death rates and LTCI benefits, indicating that shifts in end-of-life care location may have limited influence on formal long-term care costs.

1. Interpretation of the home-based death rate and public expenditure

The primary regression model indicated a positive association between the lagged home-based death rate and both total and inpatient healthcare expenditures. This finding appears to contrast with several prior studies, which have reported that home-based end-of-life care is generally associated with lower healthcare utilisation and reduced expenditures, particularly in older populations [11,12]. For example, Kato & Fukuda found that patients who died at home had significantly lower total medical costs compared to those who died in hospitals [11]. However, the present analysis differs from those studies in key respects. First, our outcome measures were aggregated at the municipality level and captured all insured healthcare spending, not limited to terminal care or the last month of life. Second, our model accounted for annual and municipal fixed effects, offering a conservative estimate of the longitudinal association. It is possible that municipalities with higher home-based death rates may also exhibit greater healthcare engagement overall, such as increased use of home medical care or emergency services prior to death. Moreover, in areas with underdeveloped home care infrastructure, initial implementation of home-based end-of-life care might require additional resource investment, contributing to short-term increases in expenditure. This is particularly relevant if the expanded home-based services primarily complement existing acute care rather than directly substituting it, leading to a net increase in overall service utilisation during the early phases of development [1]. These explanations are consistent with observations that home-based end-of-life care can reduce costs primarily in systems where integration, continuity, and care coordination are already established [18,19]. Further supporting this interpretation, Kinjo et al. conducted a comparative analysis of physician-led home visit care (Zaitaku care) and hospital care in a rural Japanese setting, finding that while home care was more costly when initiated late, it was significantly less expensive when implemented earlier and sustained over time [20]. Specifically, average daily medical costs in the final month were lower for long-term home care users compared to those receiving hospital-based care. This suggests that the economic efficiency of home-based care is contingent on both timing and duration of implementation, which may partially explain why some municipalities exhibit higher short-term costs despite promoting home-based deaths.

The interaction models revealed that the cost-reducing effect of home-based deaths became more pronounced in municipalities with higher ageing rates. This suggests that home-based end-of-life care may be particularly effective in mitigating healthcare expenditures in ageing communities, where the demand for costly institutional services tends to be higher. Supporting this interpretation, Lustbader et al. (2017) demonstrated that a home-based palliative care programme reduced healthcare costs by approximately USD 12,000 during the final three months of life among older patients, mainly by avoiding hospitalisations and intensive treatments. Their findings imply that, in older populations, home-based care can help align treatment intensity with patients' preferences, resulting in both improved care quality and reduced costs. Additional evidence from Riley and Lubitz (2010) showed that Medicare expenditures in the final year of life were lower among older decedents, possibly reflecting reduced use of aggressive interventions. Although their analysis did not examine the place of death, it highlighted the influence of age on service utilisation patterns [21]. In the Japanese context, Seo and Takikawa (2022) reported that suburban areas with a higher proportion of older adults had increased inpatient and total expenditures, underscoring the financial burden of population ageing and the potential value of community-based alternatives such as home-based care [22]. However, in municipalities with lower ageing rates, expansion of home-based services may lead to higher short-term expenditures. This may be due to premature deployment or misalignment with local demographic needs. A recent study reported that the number of home-visit nursing agencies increased more rapidly in municipalities with lower ageing rates, suggesting that service expansion may have preceded actual demand [23]. Furthermore, a systematic review by Curioni et al. (2023) emphasised the cost-effectiveness of home-based care, particularly for older adults with frailty, reinforcing the notion that demographic ageing can enhance the efficiency of such care models [24]. The identified threshold of approximately 40% in the ageing rate—above which home-based death is associated with reduced healthcare expenditure—may thus represent a tipping point at which the demographic structure enables more effective use of end-of-life care services.

With respect to LTCI benefits, our fixed-effects models detected no significant association with the lagged home-based death rate. Two institutional characteristics of Japan's LTCI system help to explain this neutrality. First, the scheme reimburses services only up to a monthly cap that is fixed by care-need level; once that ceiling is reached, any additional care is either self-funded or forgone [2]. Consequently, even when functional decline accelerates near death, public outlays may plateau. Second, facility-based services carry markedly higher per-diem fees than home-visit services. Micro-level analysis by Olivares-Tirado et al. (2011) showed that institutional care, particularly for individuals with high care-need levels, is a major driver of the highest LTCI benefits [25]. If people who die at home avoid or exit such facilities, the potential increase in spending triggered by functional decline can be offset by the reduction in high-cost institutional fees. Taken together, these features suggest that shifts toward home-based dying primarily influence the medical sector, whereas LTCI costs remain stable because of benefit caps and substitution away from expensive facility care.

2. Influence of healthcare and long-term care resources

The inclusion of healthcare and long-term care infrastructure indicators in the models yielded mixed results. None of the variables reflecting long-term care facility capacity, including medical care beds and various residential or semi-residential care settings, demonstrated statistically significant associations with healthcare expenditures. This finding aligns with the view that facility availability alone does not necessarily influence cost outcomes unless integrated with patient care pathways [26]. These results are also consistent with domestic research in Japan suggesting that the distribution of long-term care infrastructure does not automatically reduce hospital use or costs unless accompanied by adequate care coordination mechanisms [1,17]. This study also found that certain long-term care service indicators, such as the number of hospital beds or capacity of small-scale multifunctional home care facilities, showed statistically significant but negligible associations with LTCI benefits. Given the minimal effect sizes, these findings suggest limited practical influence on overall long-term care costs, and highlight the need to examine broader structural factors such as care need levels and service mix.

Among healthcare resource indicators, the number of home-care support clinics per 10,000 population exhibited a statistically significant negative association with both total and inpatient healthcare expenditures in models including interaction terms. This suggests that expanding infrastructure for primary-care–based home visits may help moderate municipal-level healthcare costs, particularly in more aged communities. A recent study reported that enhanced home-care support clinics were associated with significantly fewer hospitalisations and emergency outpatient visits compared with conventional clinics, indicating that such services may reduce acute care utilisation [27]. Given these findings, it is plausible that the broader availability of home-care support clinics contributes to reducing healthcare expenditure, although further research is needed to quantify these fiscal effects.

Although international studies such as Lustbader et al. (2017) have demonstrated cost savings through home-based palliative care via reduced hospitalizations, these effects appear context-dependent, influenced by healthcare system structure and service maturity [12]. Evidence from Japan remains relatively limited, but our findings contribute to understanding how community-based primary care infrastructure may promote fiscal sustainability in super-aged settings.

3. Limitations and considerations

Several limitations should be acknowledged. Firstly, this study primarily focused on healthcare expenditures covered by public insurance schemes in Japan, namely the National Health Insurance and the Medical Care System for the Latter-Stage Elderly, and public benefits under the LTCI system. While these public schemes accounted for approximately 55% of Japan’s total healthcare expenditure in 2020 [28], our analysis did not include expenditures for working-age individuals covered by employment-based health insurance, nor did it capture out-of-pocket costs and privately funded services under LTCI. Consequently, the potential for cost-shifting between different healthcare sectors (e.g., medical vs. long-term care) or across various insurance schemes could not be fully accounted for, which limits the overall comprehensiveness of our economic interpretation. Despite these limitations, the coverage of older and non-working populations allows for meaningful interpretation of healthcare spending patterns in the most demographically relevant segments.

Secondly, the home-based death rate, while a crucial outcome metric, reflects only the place of death and does not capture critical quality-related dimensions such as symptom management, caregiver satisfaction, or the continuum of care coordination [12,29]. Thus, the metric should not be interpreted as a definitive indicator of quality or appropriateness of care. Future research should integrate quality-of-life and patient experience metrics to provide a more holistic evaluation.

Thirdly, while our use of year fixed effects robustly adjusted for national time trends and unobserved time-invariant municipal characteristics, potential interactions between these trends and our primary variables (e.g., how the impact of home-based deaths evolves with specific policy changes or medical advancements) were not explicitly modeled. Although within R^2 values were small, this is a known characteristic of fixed-effects models when within-unit variation in key predictors is limited. The model nonetheless captures meaningful policy-relevant associations.

Fourthly, residual confounding from unmeasured or unobservable time-varying factors, such as granular changes in population health status, the severity of illness, evolving regional care practices, or specific local policy implementations that vary across municipalities, may persist. Incorporating more granular data on these time-varying confounders, where available, would further strengthen future analyses. In addition, the absence of individual-level data, such as patient clinical status or care preferences, limits the ability to adjust for important confounders.

Fifthly, as an ecological study utilizing aggregate municipal-level data, the absence of individual-level data, such as patient clinical status, specific diagnoses, or care preferences, inherently limits our ability to adjust for important individual-level confounders. While this design is robust for understanding macro-level population dynamics and policy impacts, it precludes direct causal inference. However, our application of fixed-effects models and inclusion of relevant time-varying municipal-level covariates enhances the robustness of our findings by controlling for observable confounders and unobserved time-invariant characteristics. This study thus provides crucial insights into population-level associations that complement patient-level analyses by revealing broader municipal-level patterns relevant for health policy.

Finally, while the generalisability of our findings may be primarily relevant to countries with universal healthcare and long-term care insurance structures, and particularly advanced demographic ageing, direct transferability should consider differences in specific care delivery models, insurance coverage, and population health. Nonetheless, Japan's unparalleled status as a super-aged society provides a unique and invaluable natural laboratory for understanding the complex interplay between demographic shifts, end-of-life care patterns, and healthcare expenditure. Therefore, the policy-relevant implications derived from this study, particularly concerning the strategic balancing of healthcare expenditure with end-of-life care strategies in an ageing context, offer crucial insights and foresight for other nations confronting similar demographic transitions. Indeed, countries such as South Korea, Germany, and China are rapidly approaching comparable levels of population ageing and associated healthcare cost burdens. As noted by Suzman and Beard (2015), the demographic trajectory of these nations closely mirrors Japan's experience, suggesting that the insights from Japan may serve as an early reference point for developing cost-effective and culturally appropriate care strategies in super-ageing societies [30].

V. Conclusion

This study provides evidence that the fiscal implications of home-based end-of-life care vary according to demographic context. While higher home-based death rates were not universally associated with cost reductions, municipalities with more advanced ageing showed potential for meaningful savings. These findings underscore the need for tailored policy strategies that align with local demographic conditions and healthcare infrastructure, particularly when promoting home-based care models in ageing societies. Although the analysis primarily focused on healthcare expenditures, additional consideration of long-term care costs will be essential for fully understanding the economic impact of end-of-life care delivery.

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Tables

Table 1. Descriptive statistics of variables used in the analysis (2015–2022)

Table 2. Association between home-based death rate and healthcare expenditure: fixed-effects regression results

Table 3. Fixed-effects regression including interaction terms between home-based death rate and contextual variables

Figure legends

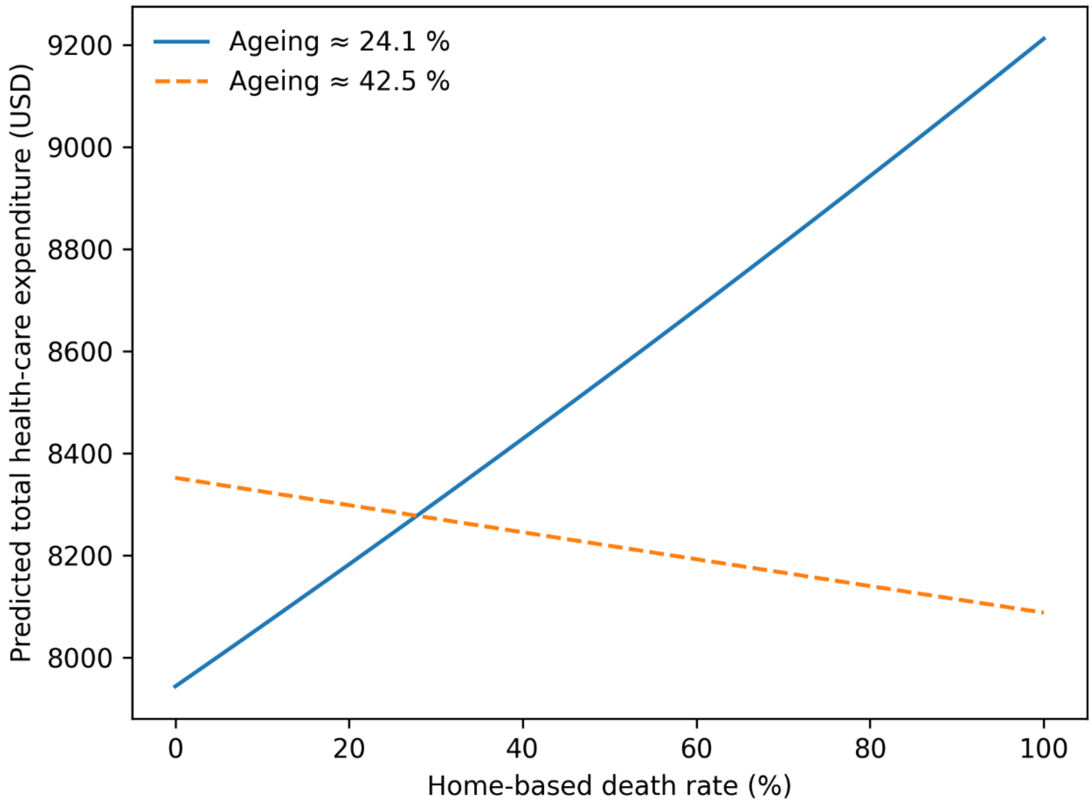

Figure 1: Predicted inpatient healthcare expenditure (USD) by home-based death rate at two levels of population ageing

Solid blue line: Ageing ≈ 24.1% (−1 SD from the mean)

Dashed orange line: Ageing ≈ 42.5% (+1 SD from the mean)

Predictions are based on a fixed-effects regression model including an interaction term between the lagged home-based death rate and the ageing rate. All other covariates were held constant at their mean values. Expenditure estimates were converted from Japanese yen to US dollars using the 2022 average exchange rate (1 USD = 131.56 JPY).

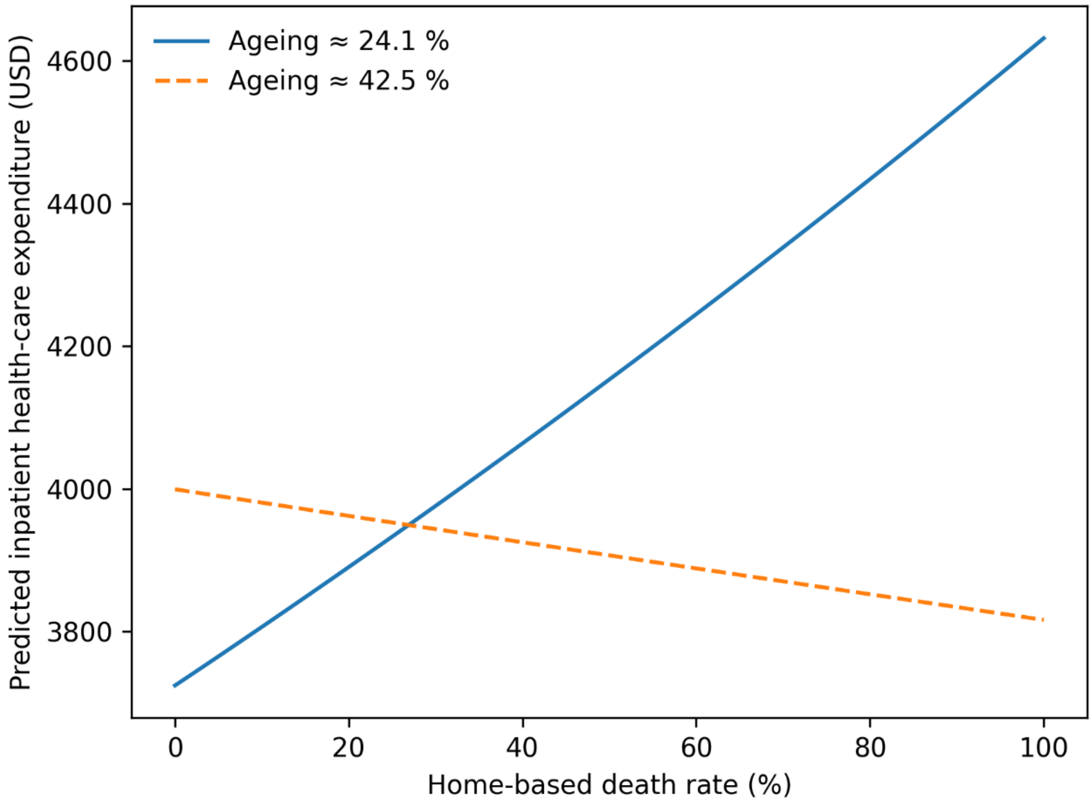

Figure 2: Predicted total healthcare expenditure (USD) by home-based death rate at two levels of population ageing

Solid blue line: Ageing ≈ 24.1% (−1 SD from the mean)

Dashed orange line: Ageing ≈ 42.5% (+1 SD from the mean)

Estimates were derived from a fixed-effects model with an interaction term between the lagged home-based death rate and the ageing rate. Predictions are shown on the original expenditure scale, converted from yen to US dollars using the 2022 average exchange rate (1 USD = 131.56 JPY), with other variables held at their mean values.