Mortality and subsequent healthcare use among older patients discharged to a municipality with excess demand for elderly care

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Abstract: There is limited knowledge on how excess demand for elderly care influences patient outcomes. We used a natural experiment to estimate the causal effect of discharging elderly patients from hospital to municipalities with excess demand. In Norway, hospital in-patients are defined as ready-for-discharge when hospital treatment is completed, but the patient needs further care from municipal services. After this, the municipality of residence is obliged to either provide care for the patient or to pay the hospital a fixed fee per day that the patient spends in hospital. Municipal fee-days may thus indicate excess municipal demand. In the current paper, we studied how excess municipal demand, indicated by the number of fee-days accumulated in the municipality 30 days before an acute admission, influenced patient outcomes. To minimize confounding, we compared patients living within the same municipality, admitted during the same type of day, in the same year, but with varying excess demand. Our outcomes were mortality, resource use and healthcare costs at the primary and secondary care level, within 30 days. Between 2012 and 2016, 354,834 individuals (age≥70 years) had a total of 895,892 acute admissions. There was a 2% increased 30-day mortality per standard deviation change in accumulate fee-days (Hazard ratio (HR) of 1.02, 95% confidence interval (CI) 1.01-1.03). Individuals living in small municipalities (population<10,000) had HR of 1.04, (95% CI 1.02-1.07), while individuals living in larger municipalities (population>10,000) had HR of 1.01 (95% CI 1.00-1.03). We found no substantial effect on subsequent healthcare use or costs. Relevance tests supported that fee-days was a good indication of excess demand, and balance tests supported that patients were comparable between periods with different excess demand. In conclusion, our results imply that older patients who are discharged to a municipality with excess demand have slightly elevated mortality, particularly in small municipalities.

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1 Introduction

Healthcare costs have increased during the last decades in Norway, as in many other European countries. In near future, demand for healthcare services, and consequently, the healthcare costs are expected to increase further, primarily because of demographic changes and in particular due to the ageing population (OECD, 2006). This has led to increasing efforts to keep resource use and healthcare costs as low as possible, while simultaneously maintaining quality of care.

The cost of care at the primary care level is believed to be lower than the cost of care at the secondary care level since care at the primary care level requires less specialized and intensive treatment (Meld St. 47, 2009). A common approach to reducing healthcare costs has therefore been to shift certain tasks from the secondary care level to the primary care level (Schut, Sorbe et al, 2013; Scottish government, 2018).

The Norwegian Coordination Reform was implemented in 2012 (Meld St. 47, 2009). The reform had several aspects, including implementation of a) two new acts defining and clarifying the municipalities' responsibilities for preventive, curative, and care services b) economic incentives to reduce the demand for hospital services, and c) municipal acute wards, with a similar aim (Swanson and Hagen, 2016). An important goal of the reform was to shorten patients' length of stay in hospital by expediting their return to the primary care level after the necessary treatments have been provided in the hospital.

To incentivise both secondary and primary care providers to return patients to the primary care level as soon as possible, a system of *fee-days* was implemented. Following this reform, when a hospital considers a patient's treatment as completed, the patient is defined as ready-for-discharge. After this, the municipality where the patient resides is obliged to take over the responsibility for the patient's treatment and care. If the patient is not returned to the primary care level, the patient remains at the hospital, but for each additional day the patient spends there, the municipality must pay a daily fee (Norwegian Ministry of Health, 2011). In 2020, the daily fee was set at about €490 (The Norwegian Directorate of Health, 2022). Additional days in the hospital after a patient has been defined as ready-for-discharge are herein referred to as fee-days.

When a patient is discharged from the hospital, the municipality has to decide on the allocation of healthcare services to the patient. A municipality may be more likely to leave a patient waiting in the hospital after being defined as ready-for-discharge if the capacity to provide sufficient care is limited in the municipality. Therefore, fee-days may indicate excess demand for primary care services in a municipality; there is a higher demand for primary care in the municipality than the municipality is able to provide. For example, a patient with hip fracture is always treated in the hospital. Hip fractures often occur in old individuals, and the trauma and treatment may increase a patient's need for care in a short- or long-term nursing home. If there is an available place in a nursing home when the patient is defined as ready-for-discharge, the patient can be transferred to the nursing home immediately. In this case, no fee-days would accumulate. However, if there are no available resources in the municipality, the patient may stay in the hospital until adequate care is available, accumulating a number of fee-days.

In the current paper, we evaluated situations of excess demand of primary care services in a municipality by studying the effect of discharging patients aged≥70 years to a municipality with excess demand, as measured by accumulated fee-days. Comparing outcomes between municipalities is problematic, since differences might be caused both by municipality characteristics, like demography and patient case-mix, primary care capacity, as well as its financial situation and willingness to pay fees. Therefore, to minimize confounding, we used a fixed effects design where we compared individuals experiencing variations in excess demand within the same municipality admitted in the same year and on similar days (weekday or holiday/weekend). Using this design, we estimated mortality, subsequent healthcare use and healthcare costs among patients discharged to a municipality with varying excess demand in their elderly care, as measured by accumulated fee-days.

2 Material and Methods

2.1 The Norwegian Healthcare System

In Norway, the majority (85%) of healthcare services are universally covered and publicly funded through taxes. Opting out of the public system is not an option. Healthcare services are delivered at two levels that are financed differently: the secondary care level, which primarily includes hospitals, is state owned. They are organized within, and financed through, four Regional Health Authorities that report directly to the Ministry of Health. In the secondary care level, treatment is provided to patients with acute and severe conditions that require specialist treatment for a limited time-period. The primary care level includes a wider range of treatments and services such as general practitioners (GPs), home nursing, and nursing homes. Primary care services are administered by the country's 424 (in 2016) municipalities, and financed through municipal block grants, government-sponsored fee-for-service, and from user charges—the level of each differ by type of service. For GPs, each amount to approximately 30%. At the primary care level, treatment is typically provided to patients with less acute and severe conditions that require less specialized treatment. Treatment and care provided at the primary care level is often continuous over longer time-periods, and often provided both before and after treatment is provided at the secondary care level (Lindahl, 2017; Saunes, Karanikolos et al., 2020).

2.2 Data

All Norwegian residents have a unique identification number which makes it possible to link information from a range of registries. We linked individual level data using data from four national registers: the Norwegian Patient Registry, the Norwegian Cause of Death Registry, the Control and Payment of Health Reimbursement Registry, and Statistics Norway.

All Norwegian hospitals are required to submit information about their clinical activity to the Norwegian Patient Registry (Bakken, Ariansen et al., 2019). The registry, which covers close to 100% of all hospital treatments in Norway, includes information such as date and time of when patients are admitted to hospital, when patients are transferred between wards and/or hospitals, when those responsible for the treatment in a hospital defines that treatment is completed (and that a patient is ready-for-discharge), and when a patient is actually discharged. The Norwegian Patient Registry also includes primary and secondary diagnoses (coded as ICD-10 codes) and procedures (coded as NCDS-codes). We had access to data including individual patient's number of fee-days from 2012 to 2016. Data on fee-days was available only from 2012, after the implementation of the Coordination reform.

The entire Norwegian population is covered by the Cause of Death registry, providing us access to information on all-cause mortality, not limited to in-hospital deaths

(The Norwegian Institute of Public Health, 2022). We obtained information on the use of general practitioners (GPs) and out-of-hours services both before and after a hospital visit using the Control and Payment of Health Reimbursement Registry. The Control and Payment of Health Reimbursement Registry contains information on the diagnosis of the patient and on the procedures provided to the patient (The Norwegian Directorate of Health, 2022). Demographic information was collected from Statistics Norway (Statistics Norway, 2022). Demographic information includes age, sex, level of education and municipality of residence.

2.3 Study design

To estimate the effect of excess demand on patient outcomes we used a natural experiment exploiting information on fee-days; fee-days was used as an indication of excess municipal demand.

We performed the study in five steps: first, we defined the starting point of our analyses and decided what patients to use as our units of analysis. Second, we analysed whether our assumed exogenous variable (accumulated fee-days) was a relevant measure, meaning, whether it actually measured excess demand in municipal healthcare services. Third, to assess balance of confounding variables, we investigated possible associations from observed possible confounding variables during times of low or high excess municipal demand. Fourth, we examined how excess demand influenced patient outcomes. Last, we performed the analyses on subsamples to investigate whether results differed according to municipality size or for patients with distinct diagnoses. We also ran sensitivity analyses to test the robustness of our results.

Below, we describe each of these steps.

2.3.1 Defining starting point and units of analysis

We used date of admission to hospital as the starting point of our analyses since discharge date could easily be related to the municipalities' resource situation. Since municipalities might have a lower threshold to admit patients to hospital in times of excess demand, we used only acute admissions assuming that these were not likely to be influenced by excess municipal demand. Also, since older individuals are more likely to need municipal healthcare after an acute hospital admission, we choose to only include patients aged 70 years or above. Consequently, we analysed all persons aged 70 years or older who were acutely admitted to hospital in the period 2012 to 2016. In our model, one individual could have several admissions—each admission was used as one unit of analysis in the model.

2.3.2 Relevance: fee-days as measure of excess demand of municipal healthcare services.

We used the number of accumulated fee-days as an indicator of excess demand in a municipality's healthcare services. To count fee-days, we used information on all somatic contacts that the Norwegian population (5.2 million in 2016) had with hospitals in the period 2012 to 2016. First, for each day in the entire period (2012-2016) and for each municipality, we calculated the number of fee-days by adding the number of patients waiting to be discharged. For example, if no patients in a given municipality were waiting to be discharged (after having been defined as ready for discharge) on April 29th, 2014, the number of fee-days was zero for this municipality on April 29th, 2014. However, if three patients were waiting to be discharged, the number of fee-days April 29th, 2014, would be three. A patient that was discharged on the same day as they became ready-for-discharge accumulated zero fee-days.

For each admission of an index patient (i.e., unit of analysis), we calculated accumulated fee-days as the sum of fee-days of all patients from the municipality during the 30 days prior to the index patient's admission. By measuring fee-days in a municipality before the acute admission of a patient, we limited the possibility that the acutely admitted patient could influence the indicator of excess demand, thus, reducing the chance of bias. The variable *accumulated fee-days* was standardized per 10,000 inhabitants above the age of 70 in the municipality of residency and calculated on a per-day basis (i.e., divided by 30).

We tested whether accumulated fee-days measured in the 30-day-period prior to index-patients' admission was a relevant measure of excess municipal demand by estimating whether an increase in accumulated fee-days 1) increased the probability that index-patients acutely admitted to hospital also accumulated fee-days (yes/no), and 2) increased the number of fee-days that index-patients acutely admitted to hospital accumulated. An increase in the probability of becoming a waiting patient and/ or an increase in the number of fee-days in our patients under analysis, would indicate that the municipality did not have resources to take care of the patient and hence, that accumulated fee-days is a relevant measure of excess demand for municipality healthcare services.

2.3.3 Balance – are patients comparable in times of no or high excess demand?

If we compare patients from different municipalities, differences in outcomes may be confounded by municipality characteristics like demography and patient case-mix, primary care capacity, or a municipality's financial situation and willingness to pay fees. Therefore, we only compared patients residing in the same municipality. Within the time-period of our analyses (2012 – 2016) factors related to the municipalities and the patients might change. To limit bias from time trends, we compared patients being treated during the same calendar year. Similarly, patients that were admitted during week-days and weekends/holidays may differ. For example, fewer people working in the home-based care services during weekends and holidays may lead to delayed detection of severe diseases among home-dwelling persons during weekends and holidays. Thus, we only compared patients who were admitted on a weekday (Monday thru Friday) to other patients admitted on a weekday, and patients admitted on a weekend (Saturdays, Sundays, or public holidays) to other patients admitted on a weekend. Last, seasonal variation might influence the demand for municipal healthcare services and be associated with patient characteristics. For example, the seasonal flu might increase the need for hospital admissions and municipal nursing homes, and care needs for patients admitted during the seasonal flu, who might be older and more frail, may be different from other patients. Thus, comparing patients admitted during different seasons might bias the results. To adjust for seasonal differences, we included dummy variables for month of admission and region. Since Norway is long-stretched geographically (covering 13 degrees of latitude), seasonal variation occurs differently in different geographic locations. For example, the seasonal flu might occur earlier in the Northern parts than in the Southern parts. Therefore, we chose to adjust for season (month) by Regional Health Authority (i.e., Regional Health Authority months). Altogether, 48 (12*4) Regional Health Authority month dummy variables were included. To improve precision, we also adjusted the model for the patient characteristics sex, age and age squared. Last, since we included the same individuals in the model several times (i.e., per acute admissions), we clustered the standard errors by individual and municipality.

To assess any violations of our balance assumptions, we estimated associations between observed possible confounding variables in periods with different excess demand, as measured by accumulated fee-days. This was done by estimating the association between the accumulated fee-days and the following variables: number of prior admissions 1 and 6 months before the acute admission, sex, education (whether individual had secondary education or not) and (whether individual had tertiary education or not), whether the acute admission was due to one of seven high volume causes, femoral fracture (ICD-10 S72), pneumonia (ICD-10 J15 or J18), myocardial infarction (ICD-10 I21), heart failure (ICD-10 I50), chronic obstructive pulmonary disease (COPD) (ICD-10 J44), dementia (ICD-10 F00–F04), or influenza (ICD-10 J09-J11), a person's immigration background (born outside of Norway or not), age, and individuals comorbidities in the year preceding the acute admission. Comorbidity was estimated as Charlson comorbidity index on a continuous scale (from 0 to 17) and based on information from all previous hospital admissions in the year preceding the acute admission (Charlson, Pompei et al., 1987; Nilssen, Strand et al., 2014).

2.3.4 Does excess municipal demand have an effect on patient outcomes?

Our primary outcome was all-cause mortality 30-days after an acute admission. Healthcare utilization was measured as the number of readmissions to hospital and the number of GP-contacts that patients had 30 days from their acute admission. For the number of GP-contacts, we differentiated between contacts occurring within office hours and out-of-hours contacts; the latter are assumed to be more acute. To estimate whether there were any long-term consequences of excess demand on patients' health, we also estimated accumulated healthcare costs within 60 days from admission. We estimated specialised care costs based on Diagnosis Related Groups (DRGs) (Fetter, 1980). Costs were estimated as Euro 2016, where one DRG-point was valued at €5,075, based on 2016-unit prices, and when using the average Euro exchange rate between 2008-2016 (The Norwegian Directorate of Health, 2022; The Central Bank of Norway, 2022).

We performed separate analyses of mortality and healthcare utilization by whether patients lived in a smaller (population<10,000) or larger (population>10,000) municipality.

2.3.5 Sensitivity analyses (robustness)

Additional analyses were performed to substantiate the assumptions that the analyses rested on.

First, we performed analyses with more restrictive grouping of admissions; in addition to comparing patients living within the same municipality, treated in the same calendar year, and admitted on the same type of day, we also compared people within the same: 1) Sex, 2) age groups (70-79 years, 80-89 years, or 90 years or above), 3) type of treatment (differentiating between medical or surgical treatments), and 4) education level (differentiating between patients with primary (primary and lower secondary school), secondary (upper secondary and post-secondary school) and tertiary (first and second stage of tertiary education) education). Second, we ran analyses comparing patients admitted on the same weekday (i.e., Monday compared to Monday), but on days that were at least 28 days apart. Third, we estimated all-cause mortality 30 days after the acute admission but restricting patients to enter the analyses until 5 days after admission. Five days was chosen since the mean length of hospital stay was 5 days, consequently, excess mortality occurring between 5 and 30 days is more likely to be caused by compromised care in the municipality than mortality during the first days after admission. Fourth, we estimated survival within the five most common diagnoses in the patient population, namely patients with 1. pneumonia (J15 or J18), 2. myocardial infraction (I21 and I22), 3. femoral fractures (S72), 4. heart failure (150), or 5. COPD (J44). Fifth, we performed separate analyses by year to evaluate whether results were driven by a special incidence in one year. Sixth, we performed analyses where we adjusted for pressure in the hospital where the index-patient was admitted. Hospital pressure was measured in the 30-day period before index-patients admission, and estimated as the total number of patients waiting in the hospital divided by the total number inpatients. When the variable was constructed, we excluded patients from the index-patients municipality. Last, we tested whether using a longer time span for our outcome variables (i.e, 60-day mortality instead of 30-day mortality) influenced our results.

We also performed analyses when summarizing fee-days (our exogenous variable) in the five-day-period prior to an admission (instead of 30 days), results did not change and analyses were not shown.

2.4 Statistics

For tests of the relevance and balance, when using accumulated fee-days as proxy for municipal excess demand, fixed effects logistic regression was used for binary outcomes and fixed effects ordinary linear regression was used for continuous outcomes. There are no distinct cutoffs for a relevance test. Previously, a F-statistics >10 has been suggested (Staiger and Stock, 1997), although recent studies have suggested F>100 (Lee, McCrary et al., 2019).

The association between *accumulated fee-days* and mortality was estimated using stratified Cox regression, using the grouping of patients by municipality, year and weekend/weekday as strata; hence only variation within patient strata was used to identify causal effects. For our sensitivity analyses (2.3.5) the strata's were further differentiated by respectively age, sex, type of treatment and education level. Time of admission was used as the time axis in all analyses. Patients were followed to time of death, 30 days (5-30 days with postponed entry) or end of 2016, which ever occurred first. When estimating the association between accumulated fee-days on the number of readmissions, number of GP-visits and costs (secondary outcomes), we used fixed-effects Poisson regression reporting the outcomes as incidence rate ratios (IRR). In the Poisson analysis, we used each patient's available exposure time restricted to the time where patients were alive after their acute admission or end of follow up.

All analyses were performed as specified in the chapter above, in summary: our units of analysis were acute hospital admissions from patients aged 70 years or above in the period 2012-2016. In all analyses, we grouped patients according to a combination of their municipality of residence, the calendar year and type of day they were admitted on (weekday/ weekend). We adjusted for regional season with dummies for Regional Health Authority months, sex, age and age squared. In analyses of repeated outcomes, standard errors were clustered by individual and municipality. In the cox regression, standard errors were clustered by municipality of residence. Excess demand was in all analyses indicated using accumulated fee-days estimated in the 30-day period before an acute admission. Accumulated fee-days was measured on a per-day basis and standardized per 10,000 person aged 70 years or above in a municipality. In the results, we refer to increase in excess demand, which was quantified as a change in one standard deviation (SD) in accumulated fee-days.

All analyses were performed using Stata version 15.1.

3 Results

3.1 Descriptive statistics

Between 2012 and 2016, 354,834 individuals (55% women, mean age of 80 years) in the population aged 70 years or above in Norway had a total of 895,892 acute admissions. On average, these individuals had 2.5 admissions and the average length of stay was 5.57 days. Among the admissions, 5% accumulated fee-days. The mean waiting time from being defined as ready for discharge to being discharged from hospital was 4.11 days. Among the admissions, 17% of patients had an admission during the 30 days prior to their index admission, and 39% during the 60 days prior to their index admission. Within 30 and 60 days after admission, 9% and 13% of patients died, respectively. Patients were most commonly admitted for pneumonia (7%), femoral fractures (5%), heart failure (4%), myocardial infarction (3%) and COPD (3%), Table 1.

Table 1: Descriptive statistics of the patients, and acute admissions, included in the analyses: Numbers given for the total sample and when dividing the population into patients from smaller (population<10,000) or larger (population>10,000) municipalities. Numbers are provided as number of patients, shares or standard deviation (SD), as appropriate.

	Total sample		Larger municipalities		Smaller municipalities	
Number of individuals	354,834	(1.00)	256,650	(1.00)	98,184	(1.00)
Women	196,133	(0.55)	143,671	(0.22)	52,462	(0.22)
Age (SD)	80.46	(7.27)	80.44	(7.27)	80.53	(7.28)
Number of admissions (mean) (SD)	2.52	(2.41)	2.57	(2.48)	2.41	(2.21)
Number of admissions per year:						
2012	174,928	(0.20)	128,195	(0.19)	46,733	(0.20)
2013	174,060	(0.19)	128,793	(0.19)	45,267	(0.19)
2014	178,075	(0.20)	131,973	(0.20)	46,102	(0.20)
2015	181,994	(0.20)	135,095	(0.20)	46,899	(0.20)
2016	186,835	(0.21)	137,645	(0.21)	49,190	(0.21)
Total number of admissions						
Type of admission (diagnosis)						
Pneumonia (J15 or J18)	67,067	(0.07)	49,818	(0.08)	17,249	(0.07)
Femoral fractures (S72)	40,946	(0.05)	29,700	(0.04)	11,246	(0.05)
Heart failure (I50)	31,910	(0.04)	23,866	(0.04)	8,044	(0.03)
Myocardial infarction (I21 or I22)	29,916	(0.03)	21,059	(0.03)	8,857	(0.04)
COPD (J44)	29,150	(0.03)	21,831	(0.03)	7,319	(0.03)
No. patients waiting	47,874	(0.05)	40,257	(0.06)	7,617	(0.03)
Fee-days (SD) all patients	0.22	(1.57)	0.25	(1.69)	0.12	(1.16)
Fee-days (SD) for waiting patients	4.11	(5.48)	4.17	(5.52)	3.80	(5.22)
Length (days) of hospital stay (SD)	5.57	(6.46)	5.61	(6.51)	5.44	(6.33)
Pre-admission (last month), no. (SD)	147,980	(0.17)	111,854	(0.17)	36,126	(0.15)
Pre-admission last 6 months, no. (SD)	350,617	(0.39)	264,396	(0.40)	86,221	(0.37)
Death (within 30 days), no.	77,554	(0.09)	57,203	(0.09)	20,351	(0.09)
Death (within 60 days), no.	112,843	(0.13)	83,580	(0.13)	29,263	(0.12)
Accumulated fee-days (SD)	3,00	(4,58)	3,51	(4,69)	1,57	(3,89)

COPD = Chronic obstructive pulmonary disease

Patients from smaller municipalities (population<10,000) accumulated fewer fee-days (0.12 versus 0.25) when compared to patients from larger municipalities (population>10,000).

This was both because fewer patients from small municipalities became waiting patients (3% versus 6%) and because patients from smaller municipalities who actually waited, accumulated fewer fee-days (3.80 versus 4.17).

3.2 Relevance

The mean number of *accumulated fee-days* in the municipalities 30 days prior to an acute admission was 2.99 (SD 4.58) per day per 10,000 inhabitants 70 years and older. The 25th, 50th (median) and 75th percentile were 0.30, 1.40 and 3.62, respectively.

There was a strong association between accumulated fee-days and the patient's risk of becoming a waiting patient, hence supporting the relevance assumption: when excess demand, as measured by accumulated fee-days, increased by 1 SD, there was a 1% higher probability (95% confidence interval (CI) 0.8 to 1.3%, F=95) that the index patient became a waiting patient themselves. Also the length of hospital stay for index-patients increased by 0.10 days (95% CI 0.08 to 0.12, F=112), when excess demand increased.

3.3 Balance

The balance tests of the associations between excess demand and observed confounding variables supported our independence assumption, where these associations were compatible with no associations.

Table 2: Balance tests of the associations between accumulated fee-days (i.e., excess demand) and observed confounding variables. For dichotomous variables we used fixed effects logistic regressions (indicated by [1]) and for continuous outcomes we used fixed effects ordinary linear regression (indicated by [2]).

	Coefficient	95% CI	
Preadmission (1 months)[1]	0.000	-0.001	0.001
Preadmission (6 months)[1]	-0.003	-0.006	0.000
Women[1]	0.001	-0.000	0.003
Hip fracture[1]	0.000	-0.001	0.001
Secondary education[1]	-0.001	-0.003	0.000
Tertiary education[1]	0.000	-0.002	0.001
Pneumonia[1]	0.000	-0.001	0.001
Myocardial infarction[1]	0.000	-0.001	0.001
Heart failure[1]	0.000	-0.001	0.001
COPD[1]	0.000	-0.001	0.000
Dementia[1]	0.000	-0.000	0.000
Influensa[1]	0.000	-0.000	0.001
Immigration background[1]*	0.000	-0.001	0.000
Age[2]	0.018	-0.004	0.040
Complex treatment[2]	0.000	-0.005	0.004
Comorbidities[2]	0.001	-0.007	0.010

The units of analysis were acute hospital admissions from patients aged≥70 years. In the model, we grouped patients according to a combination of their municipality of residence, the calendar year and type of day they were admitted on (weekday/ weekend). We adjusted for regional season with dummies for Regional Health Authority months, sex, age, and age squared. Standard errors were clustered by individual and municipality. In the results, we refer to increase in excess demand, which was quantified as a change in one standard deviation in accumulated fee-days. [1] Variables measured on a dichotomous scale. [2] Variables measured on a continuous scale. * Immigration background (yes) defined as those born outside of Norway from non-Norwegian parents (n=33,647).

3.4 Excess demand and patient mortality

Overall, 30-day mortality increased by a hazard ratio (HR) of 1.02, 95% confidence interval (CI) 1.01 to 1.03, when excess demand, as measured by accumulated fee-days, increased. Patients living in smaller municipalities (population<10,000) had a higher 30-day mortality (HR 1.04, 95% CI 1.02 to 1.07) when excess demand increased, compared to patients living in larger municipalities (population<10,000) (HR 1.01, 95% CI 1.00 to 1.03). For details, see Appendix 1.

3.5 Excess demand and healthcare utilization and healthcare costs

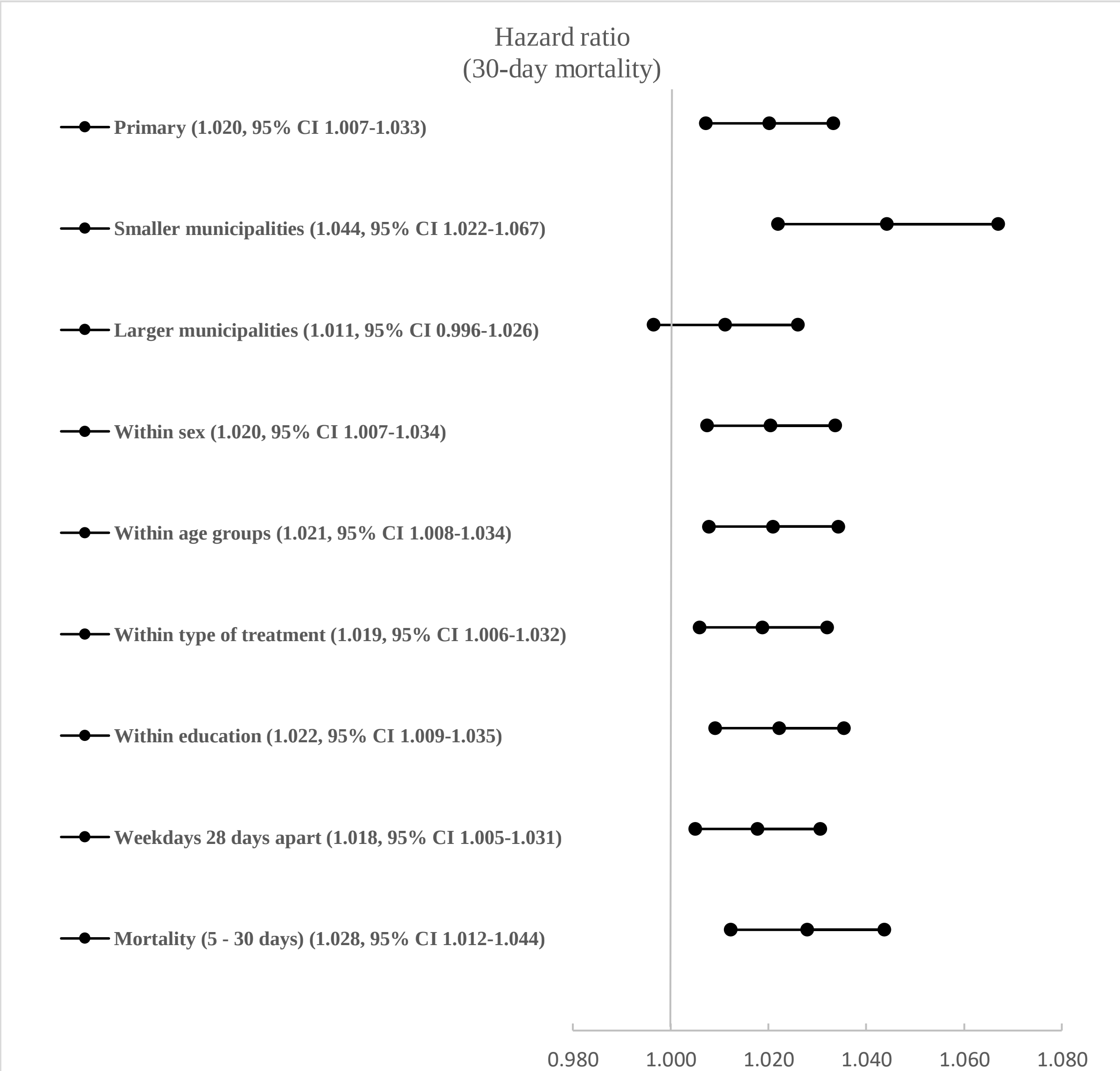
There was no association between excess demand, as measured by accumulated fee-days, and subsequent healthcare utilization or healthcare costs for the whole population, or for patients living in smaller (population<10,000) or larger (population>10,000) municipalities. For details, see Appendix 2.

3.6 Additional analyses

Results were stable when analyses were performed with more restrictive groups of patients, Figure 1. For example, the 30-day mortality of increased excess demand, as measured by accumulated fee-days, was similar when we, in addition to comparing patients living within the same municipality, treated in the same calendar year, and admitted on the same type of day, also compared people within the same: sex, age groups, type of treatment, and education level. Also, restricting analyses to compare only patients admitted on the same type of day, but admitted at least 28 days apart, and, when restricting analyses to the 5–30-day period after an acute admission, did not alter the results.

Mortality differed between patients depending on the patient's diagnosis; while patients admitted for pneumonia had 30-day mortality HR of 1.02 (95% CI 0.99 to 1.06), excess demand, as measured by accumulated fee-days, increased 30-day mortality for patients admitted for femoral fractures by a HR of 1.05 (95% CI 0.98 to 1.11), heart failure by a HR of 1.01 (95% CI 0.96 to 1.07), myocardial infarction by a HR of 1.00 (95% CI 0.94 to 1.08), and COPD by a HR of 1.03 (95% CI 0.93 to 1.13), see Appendix 3. Results were similar in separate analyses by years (Appendix 4). When mortality was measured during 60-days after admission, the association with excess demand, as measured by accumulated fee-days, was reduced for the total population (HR 1.01, 95% CI 1.00-1.02) and for patients in larger municipalities (HR 1.00, 95% CI 0.99 to 1.02), but still indicated higher mortality in patients from smaller municipalities (HR 1.03, 95% CI 1.01 to 1.05). Healthcare utilization and costs were not substantially associated with excess demand, as measured by accumulated fee-days, when analyses were performed in a 60-day perspective. For details, see Appendix 5. Analyses were stable when adjusting for hospital pressure, both for the entire sample (1.020, 95% CI 1.007- 1.033), in smaller municipalities (1.044, 95% CI 1.021-1.067) and in larger municipalities (1.011, 95% CI 0.996 – 1.026).

Figure 1: Hazard ratios for mortality within 30 days from acute admission, as accumulated fee-days (i.e., excess demand) increases by one standard deviation. The units of analysis were acute hospital admissions from patients aged≥70 years.



Analyses include the primary analysis (top). In the primary model, we grouped patients according to a combination of their municipality of residence, the calendar year and type of day they were admitted on (weekday/ weekend). We adjusted for regional season with dummies for Regional Health Authority months, sex, age, and age squared. Standard errors were clustered by municipality. Below the primary analysis, we show a range of stratified and sensitivity analyses: stratified analyses by smaller (population<10,000) or larger (population>10,000); analyses performed within the same 1) sex, 2) age groups (70-79, 80-89, 90+), 3) type of treatment (differentiating between medical or surgical treatments), and 4) education level (differentiating between patients with primary, secondary, or tertiary education); analyses comparing patients admitted on the same weekday (i.e., Monday compared to Monday), but on days that were at least 28 days apart; and analyses restricting patients to enter the analysis on day 5 from the acute admission.

4 Discussion

In the current paper, we used a natural experiment to study the effect of discharging patients aged≥70 years to a municipality with excess demand, as measured by accumulated fee-days. Findings indicated that excess demand was associated with mortality, and that these findings were driven by patients residing in municipalities with less than 10,000 inhabitants. Neither healthcare utilization nor healthcare costs were influenced by excess municipal demand.

In the paper, we found support for that accumulated fee-days implied excess municipal demand. We further found that an increasing number of fee-days lead to a slight increase in mortality. It might therefore seem possible to reduce mortality by reducing the number of accumulated fee-days. However, accumulated fee-days is only an indication of excess demand. If reducing the number of fee days by accepting patients earlier, without expanding the supply of care services, the registered accumulated fee days would indeed be reduced. But by accepting more patients, demand would not reduce but rather increase, and so would the gap between demand and supply (i.e., excess demand). Therefore, even though registered accumulated fee days would decrease, excess demand would increase. Since the supply of care services is less flexible in a short time perspective, a reduction in accumulated fee days in a short time perspective might therefore lead to increase mortality. In a long-time perspective, a municipality can influence their supply of care, and thus, decrease the number of fee-days that the patients use without hampering patient safety.

If municipalities have flexible care services or reserve capacity, they are more likely to be able to meet their inhabitants varying demand. Several factors influence the municipalities' ability to increase supply of their care services, including level of care, time-perspectives, and size of the municipality. Patients discharged from hospital with need for care can receive care at different levels, both at home (with home-based care) and in institutions (such as nursing homes). Home-based care is more flexible with regards to prioritizing the more care-demanding patients. In addition, in a short time-perspective, a municipality can theoretically expand their capacity with regards to home-based care by hiring more people to deliver home-based care services. This is only possible if there are people available in the municipality with the correct competence. It is more likely that large municipalities have access to individuals with the correct competence, and thus, the possibility to expand the supply of home-based care might be higher in larger municipalities. Patients with severe and complex conditions may need care in institutions such as nursing homes. There is less flexibility with regards to expanding supply of institutionalized care as this requires long-time investments with high costs (Hagen and Tingvold, 2018; Iversen et al., 2021). Thus, in a short time-perspective the supply of care is less flexible for patients with a higher level of need.

In this study, a design similar to instrumental variable analysis was used. In our analysis, however, we do not perform a two-stage instrumental variable analysis, but rather use the instrument (accumulated fee-days) directly as an exposure variable since excess demand is non-measurable. Despite this, our analyses rest on the same assumptions as instrumental variable analysis: 1) the *relevance assumption*, that is, that the exogenous variable (accumulated fee-days) has to be associated with the exposure (excess demand), 2) the *independence assumption*, that is, that there are no confounders that influence the relationship between the exogenous variable, the exposure and the outcomes, and 3) *exclusion restriction*, that is, that the exogenous variable affects the outcome only through the exposure variable. As a general rule, the relevance assumption is the only assumption which can be tested using statistical analyses, while the exclusion restriction and independence rests partly on statistical tests, and partly on the theory and logic underlying the model. First, our analyses show that our exogenous variable (accumulated fee-days) was relevant as it increased the likelihood of index-patients becoming a waiting patient, and the number of fee-days that index-patients accumulated. Also in the literature we find support of the relevance assumption, as in Kjekshus et al. (2005), who concluded that the variation in length of *additional* stay (defined as excessive days in hospital beyond an outlier limit)[1] was primarily explained by the capacity of primary healthcare providers (i.e., the share of elderly people in a municipality and the municipality's total healthcare expenditures per elderly) (Kjekshus, 2005). Relevance is also supported by a study by Gautun and Syse, (Gautun and Syse, 2017), where they surveyed 1,938 nurses from 80% of Norway's municipalities, employed at the same municipal institution before and after the Coordination reform, to investigate the extent to which nurses in nursing homes and home care services felt equipped to provide adequate care for patients discharged from hospitals after the Coordination reform. They conclude that the ability to fulfil the Coordination Reform's intentions of providing safe care to patients in their own homes, as an alternative to prolonged hospital stays, might have been hampered because of insufficient transfer of resources to the home services. Other studies have also shown that post-discharge interventions carried out at the primary care level can reduce mortality (Garåsen H., Windspoll, 2008). Second, we attempted to ensure independence by comparing patients living within the same municipality, treated in the same calendar year, admitted on the same type of day (weekday/ weekend) in the same regional-season. Our analyses supported the independence assumption, as patient characteristics were not associated with excess demand. However, unobserved differences between patients might still influence our results. Last, we also assumed that accumulated fee-days did not affect our outcomes via other mechanisms than excess demand (exclusion restriction). However, we cannot be sure whether excess demand in municipal care services is the *only* driver of our results. Importantly, accumulated fee-days might also increase because of excess hospital demand, i.e., when a hospital is busy, the hospital might have a lower threshold to define patients as ready for discharge. However, a recent Norwegian study did not find that overall busyness in hospitals influenced whether patients were listed as waiting patients (Nilsen, Asheim et al., 2022). A further question is whether excess mortality might have been influenced by compromised hospital care or/ as well as compromised municipal care. Comparisons of our analyses of 0-30- and 5-30-day mortality indicated that patient mortality was mostly influenced in the period after discharge (5-30 days mortality). However, we do not have a perfect way to differentiate between compromised care at the hospital or municipal level. Previous analyses have shown that a general high pressure in hospitals does not increase patient mortality (Nilsen, Asheim et al., 2022).

Earlier, it has been implied that smaller municipalities have handled the Coordination reform better than larger municipalities, since they accumulated fewer fee-days compared to larger municipalities *(*Otterstad, 2015). We also found that fewer patients from smaller municipalities ended up as waiting patients (3%) compared to patients from larger municipalities (6%) (Table 1), and, that the patients who accumulated fee-days from smaller municipalities waited shorter (3.80 days) compared to patients from larger municipalities (4.17 days) (Table 1). However, our analyses also showed that the interpretation that smaller municipalities handed the reform better than larger municipalities, should be nuanced, since patients from smaller municipalities were more vulnerable to variation in excess demand. This aligns with findings from Gautun and Syse, 2017, where nurses working in smaller municipalities (population<10,000) reported a

[1] The outlier limit was defined based on observed inpatient days for a particular diagnosis, where 95% of all stays were defined as expected or regular while the remaining 5% of stays were over this cut off and defined as irregular, long, or outliers (Kjekshus, 2005).

higher increase in the number of patients discharged to the municipality following the reform, compared to nurses working in larger municipalities (Gautun and Syse, 2017).

We believe that the present study's novel design may ensure comparability between patients exposed to different levels of municipality excess demand (Nilsen, Asheim et al., 2022; Svedahl, Pape et al., 2021). To the best of our knowledge, no similar analyses have been performed to answer the research question we have tried to answer. Previous researchers have, however, estimated the effect of the Coordination reform, on patient outcomes. Findings indicate that the reform, as intended, led to shorter hospital stays (Melberg and Hagen, 2016; The Office of the Auditor General, 2016), and, that there was an equal or a small increase in the number of re-admissions after the implementation of the Coordination reform (Melberg and Hagen, 2016; Ambugo and Hagen, 2019; The Directorate of Health, 2015). Studies have also found indications of increased demand of municipal healthcare services, reported from both general practitioners (GPs) and nurses working in the municipalities, after the implementation of the Coordination reform. They report an increase in the number of poorly functioning patients discharged to municipal services *(Gautun, 2020; Svedahl, Pape et al., 2019; Gautun and Syse, 2017)*. In the current study we do not evaluate the Coordination reform per se, but evaluate the effect of excess demand which was made possible through specifications in the Coordination reform, that incentivized municipalities to care for their inhabitants earlier by making hospitals indicate when patients were ready-for-discharge and giving municipalities the obligation of pay the appropriate amount of fees to hospitals if care could not be provided in the municipality.

Previous research has primarily focused on how treatments at the hospital level influence patient outcomes (Rennke, Nguyen et al., 2013; Hesselink, Schoonhoven et al., 2011). With the introduction of fee-days, after the coordination reform, we were able to find a novel approach to also study how municipal factors influence patient outcomes. Even though this provides us with the ability to study factors related to the municipal care services in Norway, our findings are not necessarily generalizable to other countries with different mechanisms in their healthcare sector. However, similar study designs might be applicable in other settings.

Our analyses were compatible with no association between excess demand and subsequent healthcare use (re-admissions and GP). Ideally, we should also have used information on where patients were discharged to (nursing home or home), and the level and cost of care that they received. Many of the patients were likely discharged to a nursing home where more complex treatment and follow up from nursing-home general practitioners could be provided. Or, for those discharged to their home, formal or informal care could be provided. Also, other outcomes, such as health related quality of life, are likely influenced by compromised municipal care, but such information was not available in our data. Further analyses should investigate in more detail how patient treatments, as well as health related quality of life, are influenced by suboptimal municipal care.

There may be a trade-offs between bias and precision in studies like this, where only variation within groups are analyzed. Since this study was based on a data covering the entire Norwegian population, in a 5-year period, it provided us with statistical power to detect even small differences in patient outcomes in times with low or high excess demand. However, our subgroup analyses, where patients were stratified based on their diagnosis, probably suffer from a lack of power. We tested whether we could allow for less restrictive groups (i.e., when not controlling for seasonal variation by regional health authority). This compromised our independence assumption.

The municipality fee can be seen as an incitement to accept patients from the hospital as early as possible. Dependent on a municipalities economic situation, the municipality fee could be an incitement for some municipalities to accept the patient even in situations where they are not prepared to provide sufficient care of the patient. Implications from our study indicate that such situation could be particularly relevant for small municipalities, who may be vulnerable because they have fewer structural, financial and human resources to allocate.

5 Conclusion

In this study, we used a natural experiment to study the effect of excess demand on patient outcomes. We find that patients aged≥70 years who are discharged to a municipality with excess demand, have slightly higher 30-day mortality, compared to similar patients discharged to a municipality with lower demand. This excess mortality seems to be caused by compromised municipal care and primarily driven by patients living in municipalities with a population below 10,000 inhabitants. The present study’s results thus indicate that excess municipal demand could hamper patient safety, particularly in small municipalities.

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Ethics

The study was approved by the Regional Committee of Ethics in Medical Research (2016/2159). Participant consent was not required.

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