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Draft Version 3.0

Title: The effect of hospital ownership type on quality of care in elective and emergency orthopaedic surgery

An instrumental variable approach using German hospital claims data

Authors:

Stefan Rabbe, Hamburg Center for Health Economics, Hamburg, Germany, stefan.rabbe@uni-hamburg.de, https://orcid.org/ 0000-0002-8657-5694

Ricarda Milstein, Hamburg Center for Health Economics, Hamburg, Germany, https://orcid.org/0000-0001-7074-1734

Jonas Schreyögg, Hamburg Center for Health Economics, Hamburg, Germany, https://orcid.org/0000-0001-8030-2161

Abstract (250/250 words)

Evidence on the effect of hospital ownership type on quality of care is inconclusive. Theory suggests that for-profit (FP) hospitals may have stronger incentives to provide lower quality and exploit information asymmetries compared to hospitals of other ownership types, especially when quality is unobservable to the patient a priori. In this paper, we contribute to the literature by examining differences in quality outcomes among hospitals of different ownership type while accounting for patient self-selection via instrumental variables. Specifically, we looked at hip replacement surgery in (i) emergency care for patients with a femur fracture (for which quality is potentially harder to observe) and (ii) elective care for patients with hip arthrosis (for which quality is potentially easier to observe). To do so, we drew upon claims data from all hospitals in Germany at the patient level, which we merged with data at the hospital and regional levels for the years 2012-2016. To tackle potential endogeneity in hospital choice, we instrumented ownership choice and used entropy balancing. We analysed quality outcomes for surgery-related and post-surgery-related adverse events, as well as inhospital mortality and length of stay. We included 210,477 patients with femur fracture and 465,607 patients with hip arthrosis. For the emergency care cases, we found only minor differences and mixed results. For the elective cases, the results of our instrumental variable approach suggest that there were fewer adverse events after surgery (e.g., thrombosis/embolism) and a shorter length of stay in FP hospitals compared to public hospitals.

Introduction

Evidence on ownership type and how it affects the quality of care a hospital provides is inconclusive [1, 2]. Most theories postulate that firms with different ownership types, i.e., for-profit (FP), not-for-profit (NFP), and public, seek to maximise different things and therefore perform differently in dimensions such as quality, efficiency and scope of services [3–6]. The hospital sector is no exception in this regard: FP hospitals are understood to seek the maximisation of profits by increasing efficiency [7], cream-skimming profitable patients [8], avoiding the provision of non-lucrative interventions [9], or reducing costs by lowering the (non-contractible) quality of care they provide [10]. In turn, NFP hospitals are thought to maximise aspects other than profit, although whether they do so because they cannot distribute profits to shareholders (known as the non-distribution constraint) or because they are altruistic is unclear. In the latter case, they may signal their altruistic motives by self-restraining the allocation of their profit and instead investing more in quality of their product [4, 11]. In other words, estimating a causal relationship between hospital ownership status and hospital outcomes is difficult because patients who receive care from hospitals with different ownership types and the hospitals themselves may differ from each other in multiple ways, some of which are unobservable [16].To date, the empirical literature on the subject has failed to identify a clear relationship between different ownership types and quality outcomes. It is not clear whether this is due to inaccurate predictions based on theory or limitations in existing studies. Research gaps exist for outcomes other than overall hospital mortality and geographic regions outside the United States (US) [1], as well as for the use of causal methods. Two streams of literature address these issues: The first investigates conversions in hospital ownership status using methods that help account for many unobservable effects [17–22], whereas the second aims to correct for patient selection, usually by means of an instrumental variable [22–27] or matching approach [8]. However, most of these studies have substantial limitations, such as small sample sizes resulting from too few examples of hospital ownership conversions or data sets comprising only a subsample of patients. Furthermore, they often fail to account sufficiently for differences in hospital variables, especially when applying instrumental variable methods [16]

In our study, we attempted to address these limitations and contribute to the literature in five ways. First, we investigated whether hospitals behave differently for emergency versus elective care by contrasting an emergency case (hip fracture), for which the quality of care is probably non-contractible, with an elective case (hip arthrosis), for which the quality of care is largely contractible. Both are treated with hip replacement, which is an effective but costly major surgical treatment [28]. This approach can facilitate an understanding of whether hospitals with different ownership types provide care differently in different health care settings. Second, we went beyond the common focus on mortality as a quality indicator and used surgical adverse events (e.g., rupture of the surgery wound), post-surgical adverse events (e.g., deep vein thrombosis or pulmonary embolism) and length of stay to capture differences in the quality of care at a more granular level. These outcomes can be attributed directly to individual hospitals and their provision of care, in contrast, for example, to readmission or one-year mortality. Third, we used a comprehensive nationwide dataset comprising all inpatient cases in Germany and combined it with information from the hospital and regional levels for the years 2012 to 2016. To our knowledge, we are the first to be able to draw upon such a large and unbiased sample of hospital cases in Germany to address this research question. Fourth, we used ordinary least squares (OLS) regression and an instrumental variable approach to correct for observable patient characteristics. Because the latter may not properly account for the heterogeneity of hospital characteristics [16], we additionally used an entropy balancing approach to account for differences in hospital characteristics in order to simulate that hospitals of different ownership types are comparable in their observable characteristics. Fifth, we chose to investigate the research question in Germany, which represents an ideal environment to study differences in hospital quality thanks to the presence of many hospitals with different ownership types, fixed prices for comparable treatments, and free choice of hospitals for patients.

Previous research

The empirical literature on the effect of hospital ownership type on quality of care is extensive, but derives mainly from evidence in the US [1]. Although most of these studies found little or no conclusive effect of different ownership types on quality outcomes, only a few of them analysed outcomes other than mortality and compared all three types of ownership. Furthermore, the underlying data varied in terms of data sources, geographical area, time and outcomes, and only a few of the studies used empirical approaches that were appropriate for establishing causality [1].

Some of the more recent studies have used causal methods to investigate hospital markets outside the US. These can be categorised into two streams. The first investigates conversions in ownership status. Farsi [20] used a fixed-effects model to analyse such conversions in hospitals in California and their effect on the care received by patients with acute myocardial infarction (AMI) and congestive heart failure. He found adverse consequences both for conversions from FP to NFP status, and from NFP to FP status, but noted that certain changes appeared before the conversion had taken place. Wübker and Wuckel [22] used fixed effects to analyse ownership changes in the German hospital market using data from a statutory health insurer from 2006 to 2015 for patients with AMI and pneumonia. They found lower one-year mortality for patients with pneumonia, but no changes for AMI patients after conversion to FP ownership. Their results suggest that the effect of ownership conversion may differ by indication. Overall, however, many of the studies in this stream of the literature are limited by the small number of hospitals in their samples, or geographic or other restrictions (e.g., hospitals from only one state or patient data from only one insurer), and bias may arise if the hospitals in question differ from one another in important ways before the change in ownership status.

The second stream uses instrumental variable methods to account for patient self-selection. In most cases, this has entailed using differential distances between a patient's place of residence and the nearest hospital locations as an instrument for hospital choice. The findings of the studies in this stream of the literature are mixed. Gowrisankaran and Town [23] were among the first to use this approach to estimate the effects of hospital ownership on quality. They found a negative association between FP ownership and inpatient mortality compared to NFP hospitals, but no clear effect when comparing FP to public hospitals. Lien et al. [29] used an instrumental variable approach based on differential distances for two emergency indications in Taiwanese hospitals. NFP hospitals performed better in terms of one-month and 12-month mortality, but did not differ with regard to expenditure. More recently, Moscelli et al. [24] analysed the effect of private hospital ownership on quality of care for 133 non-emergency indications in the English NHS. The authors did not identify any differences between private and public hospitals in this regard, nor between hospitals specialising in non-emergency treatments and other hospitals after applying an instrumental variable approach on differential distances between hospital types. However, they were not able to correct for differences in hospital characteristics. Wübker and Wuckel [22] analysed patients with heart attack or pneumonia using claims data from a statutory health insurer in Germany. They found no difference in 30-day or one-year mortality for heart attack, but slightly higher 30-day mortality for pneumonia patients in FP hospitals. Moscone et al. [27] were the first to compare different elective and emergency treatments in this area of enquiry. They found no differences in quality between FP and public hospitals in Lombardy, Italy, for readmission or mortality rates, except for AMI treatment, for which FP hospitals had a lower mortality rate, and for hip replacement, for which FP hospitals had higher readmission rates. We are not aware of any study that has taken an instrumental variable approach while drawing upon a full country sample comprising both emergency and elective cases.

Background and Data

Health Care Setting

We compared the quality of care for two common conditions with a different underlying diagnosis (emergency vs. elective, i.e. non-contractible vs. contractible) but comparable surgical treatment (total or partial replacement of the hip joint).

We defined emergency cases as having the diagnosis of femoral neck fracture, also known as hip fracture, followed by total or partial hip replacement surgery. Hip fractures occur frequently among the elderly [30] and are often treated by a total or partial replacement of the hip joint. A hip fracture requires immediate medical attention and surgery within the first 24 to 48 hours to reduce mortality and post-surgery complications [31, 32]. Hip fracture is a severe diagnosis, and hip replacement surgery is not without risks. Hip fracture is associated with an inpatient mortality rate of up to 5%, a 30-day mortality rate of up to 10%, and a one-year mortality rate of up to 30%, but mortality rates have declined in recent years [33]. Inpatient mortality after hip replacement due to hip fracture is 3.4% [34]. Patients undergoing hip replacement for hip fractures are frequently of older age and have an increased danger of thromboembolism due to immobility after surgery [35].

We defined elective cases as having the diagnosis of hip arthrosis (osteoarthritis), followed by total hip replacement surgery. Hip arthrosis is a common, especially among elderly patients, and has a lifetime prevalence of 27.7% [36]. While there are several conservative treatments or pharmacological treatments, total hip replacement is a valid option for patients not responding to other treatment types [37]. In contrast to femoral neck fracture, it is not an emergency indication requiring timely treatment, but it can increase in severity over time. Mortality after elective total hip replacement is much lower compared to emergency cases, with an inpatient mortality rate of 0.18% [34] and a mortality rate of 0.3% in the 30 days after surgery [38]. In the US, inpatient mortality and deep vein thrombosis, irrespective of the underlying diagnosis, have been estimated to be 0.33% and 0.68%, respectively, for total hip replacement and 3.04% and 1.36%, respectively, for partial hip replacement [39].

Country setting

Germany represents a favourable setting for our research question for several reasons. First, patients have free choice of hospitals for elective and emergency care, and they are able to exercise this choice in practice because the density of hospital beds in Germany is high. Indeed, Germany has one of the highest number of beds per inhabitant among the member countries of the Organisation for Economic Co-operation and Development (OECD) [40], with patients being able to choose among almost 2000 hospitals with almost 500,000 hospital beds [41]. Hospitals have the right to decline patients if they find they do not need treatment, or if they are unable to provide appropriate treatment [42, 43].

Over the past 20 years, Germany has introduced a number of policies to improve quality of care and increase transparency about quality to reduce information asymmetries and empower patients to make informed choices. For example, it introduced mandatory, nationwide quality reports that hospitals must be published each year [44]. Additionally, some statutory health insurers [45] and private organisations such as the "Initiative Qualitätsmedizin" [46] report quality measures publicly. Given that prices are fixed, the idea behind these measures is to foster competition among hospitals with regard to quality; however transparency about quality may affect hospitals differently depending on their ownership type [47].

Three types of hospital ownership co-exist in Germany: public (PUB), private not-for-profit (NFP) and private for-profit (FP) [48]. Especially before 2010, the German hospital market underwent a process of consolidation, acquisition and reorganisation, leading to fewer hospitals overall, more private hospitals and increased competition [7]. In Germany, prices are fixed for all hospitals irrespective of their ownership status, geographic location or the type of services they provide. Operating costs are paid almost exclusively through diagnosis-related groups (DRGs). For this reason, hospitals in Germany cannot compete based on prices as they would, for example, the US, but have to distinguish themselves from their competitors based on quality. Because of the way the German DRG system is set up, hospital reimbursement is based largely on quantity and not quality. As a result, there is no distorting redistribution mechanism of financial incentives based on quality of care. However, hospitals may differ from one another in the extent to which they have access to additional financial means. In contrast to public hospitals, FP and NFP hospitals might be more likely to have access to these, albeit to different degrees. Public hospitals are owned by municipalities or regional governments and rely on funding from them for most of their capital expenditure. If surpluses are generated, these are reinvested or are distributed to the public owner. In contrast, NFP hospitals are owned by social, charitable or religious organisations and rely on their funding for much of their capital expenditure and can claim some forms of tax relief. However, any surplus they generate may be used only to fund operations that contribute to their charitable goal or stated mission (also described as "non-distribution constraint" [4]). FP hospitals, on the other hand, are allowed to generate and distribute a surplus to shareholders or investors [49, 50]. In addition, hospitals can receive financial support for investments such as new medical devices or building a new ward, which are then paid by the state irrespective of the hospital's ownership type. The results of a recent study suggest, however, that public hospitals may receive more generous financial support than NFP and FP hospitals [51]. The extent to which this neutralises FP hospitals' better access to financial means is unclear.

Data

We combined three data sets for our analysis. First, we used hospital claims data from 2012 to 2016 from all hospitals in Germany that are reimbursed through the German system of DRGs. We extracted data on patient characteristics and hospital stay from this data set. Our variables included patient age, sex, postal code of residence, diagnoses (coded via the ICD-10-GM system), procedures (coded via "Operationen- und Prozedurenschlüssel" (OPS) codes), length of stay, and an identifier for the hospital in which the patient was treated. We used these variables to identify our patients of interest and to construct our outcome variables and the Elixhauser score for risk adjustment [52, 53]. Second, we used information on hospital characteristics from publicly available mandatory quality reports filed by hospitals in Germany. The reports included information on hospital ownership, number of hospital beds, staffing, number of procedures, and the address of the hospital. Third, we added regional data from the INKAR website [54], which includes information on population demographics and economic variables at the county level (German: Landkreise).

Our analysis consisted of all patients older than 65 years who had either (a) the emergency diagnosis of femoral neck fracture (ICD: S72.00-S72.08) and subsequently received a total or partial hip joint implant (OPS Codes 5-820.0-5-820.9, 5-820.x) or (b) the non-emergency diagnosis of hip joint arthrosis (ICD: M16.0-M16.9) and subsequently received a total joint implant (OPS starting with 5-820.0, 5-820.2, 5-820.8, 5-820.x). We chose this age restriction because the treatments under investigation are more common in this age group. We excluded patients for whom a hospital or a known postal code region could not be identified, as well as cases for which no reimbursement was reported. To exclude outpatient cases, we included only those patients who had a length of stay of at least one day. Lastly, we excluded patients with diagnoses that indicated the presence of other severe diseases, such as diagnoses related to cancer or polytrauma accidents, based on criteria from the Research Institute of the Federal Association of the AOK (WidO) [45] in order to avoid these disturbing the analysis (see Appendix A for a full list of diagnoses).

We defined four outcome variables to assess the quality of care. The first was the dummy variable "post-surgery adverse events", which was equal to one if at least one of the following three diagnoses was coded: deep vein "thrombosis/embolism in lower limbs" (ICD: I80.1-I80.3; I82:2; I82.8), "pulmonary embolism" (ICD: I26) or "hospital-acquired pneumonia" (ICD: U69.0). The second was the dummy variable "surgery-related adverse events", which took the value of one if at least one adverse event in either of the following categories was coded: (1) general surgery-related adverse events (ICD: T81), such as accidental puncture or rupture of surgical wounds, or foreign objects left in the body after surgery (ICD: T81), or (2) a specific adverse event related to hip implantation, such as infections or mechanical complications because of implantation of prosthesis (T84.04; T84.5; 8;9). Appendix B gives a more detailed description of the underlying diagnose used for the two outcomes. The third outcome variable was the dummy variable "inpatient mortality", which equalled one if a patient died during hospital stay under investigation, or in the 30 days after surgery if the patient was readmitted during this time to the hospital for the same medical reason and died there; it did not include patients who died outside of the hospital. The fourth outcome variable was length of stay, which was counted as the number of days the patient stayed in hospital.

To determine the distance between a patient's residence and the nearest hospital, we calculated the geographical centroid of each of the 8169 postal codes in our data set based on OpenStreetMap data [55]. If a postal code consisted of more than one area, we chose the area with the largest surface volume to calculate the centroid and omitted other areas, thus yielding a unique centroid. This was the case for 556 areas.

To identify a hospital's location, we chose the exact address in the hospital's quality report. If a hospital consisted of several sites, we identified the main one based on the hospital's main identifier and summed up the information of the satellite sites. We merged regional variables based on the location of the hospital. We calculated distances using the shortest distance between two points based on the World Geodetic System 84.

Methods

OLS regression

For our first specification, we present the results of the OLS regression as a reference. The regression can be formalised as follows:

$$y_{iht} = \gamma_0 + \gamma_1 \, FP_{iht} + \gamma_2 \, NFP_{iht} + \gamma_3 \, PAT_{iht} + \gamma_4 \, HOSP_{iht} + \gamma_5 \, REG_{ht} + \vartheta_{iht} + \varepsilon_{iht}, \qquad (1)$$

where y_{iht} represents the respective outcome (post-surgery adverse events, surgical adverse events, inhospital mortality or length of stay) of patient i in hospital h in year t. The outcome is either a dummy of the adverse events, inhospital death, or the length of hospital stay in days per hospital episode.

γ_0 represents a constant and FP_{iht} a dummy variable of patient i at hospital h at time t. FP_{iht} takes the value of one if the ownership type of the hospital in which the patient was treated was FP. NFP_{iht} is a dummy variable with the value of one if the ownership type of the hospital in which the patient was treated was NFP. Public hospitals are the reference group. PAT_{iht} is a vector of control variables at the patient level, which includes the gender of the patient, the Elixhauser score and age categories in five-year intervals as a risk adjustment. $HOSP_{iht}$ is a vector of control variables of the hospital in which the patient was treated. It includes the total number of hospital beds and the ratio of total cases per physician (in full-time equivalents). Furthermore, it includes the number of relevant cases per hospital, which indicates the volume of all cases of the diagnosis-procedure combination (i.e., the number of total hip implants among patients with a femoral fracture or hip arthrosis in the hospital). Two dummy variables indicate whether the hospital is a teaching hospital (i.e., supports the practical education of medical students from an affiliated medical faculty of a university hospital), or a university hospital (i.e., provides the theoretical and practical education of medical students in a medical faculty), as well as the Herfindahl Hirschman index (HHI) calculated within a 30-km radius of the ICD chapter and with cases of the musculoskeletal system and connective tissue. REG_{ht} is a vector of control variables related to the region in which the hospital is located. It includes the number of general practitioners per 100,000 inhabitants, the share of inhabitants older than 65 years, the unemployment rate, and the median income adjusted for purchasing power parity. Additionally, we included year fixed effects ϑ_{iht}. The error term ε_{iht} is clustered at the hospital level.

Instrumental variable regression

We expected the results of the OLS regression to be biased because patient assignment to a given hospital is probably not random and is influenced by several factors, such as patient choice or physician referral behaviour. In cases where an unobserved component of illness severity affects either of these examples, the OLS estimates of hospital quality will be biased [23].

We therefore tested an instrumental variable approach using the following two instruments: (i) differential distances to the hospitals with different ownership types and (ii) the share of hospitals with a given ownership type in a region. These two approaches have been used frequently to account for potential patient selection with regard to different ownership types (e.g. [22–24, 56] for differential distances and [57] for share of hospitals with different ownership types).

Regarding the first of the two instruments, we argue that it satisfies both of the conditions needed to be considered valid: (i) it must be uncorrelated with unobserved severity of illness, and (ii) it correlates with other variables that predict hospital choice. The differential distances between the closest hospital with either FP or NFP ownership and the closest public hospital should satisfy this condition for the following reasons: first, although individuals might prefer areas in which they have easy access to a hospital, they are unlikely to choose their residence based on the hospital's ownership type. Second, it is also unlikely that patients choose their residency based on the quality of a hospital's care. Although evidence suggests that patients prefer hospitals with higher quality [58], the extent to which extent they would base their choice of residence on that information is unknown, especially with respect to specific diseases or treatments. In appendix C, we provide a table with descriptive statistics on the closest hospitals. It suggests that there are only minor differences between the closest hospital types, especially with regard to patient characteristics, thus supporting the argument that the instrument is uncorrelated with the severity of illness.

Regarding the second instrument, we also believe that the share of a hospital type in a region is largely uncorrelated with patient severity, and our arguments in support of this mainly follow those we posited for the first instrument. As described above, we do not believe that patients choose their residence based on the availability of hospitals with a certain ownership type; however, a higher share of one hospital ownership type within a region naturally increases the likelihood that a patient living in this region will attend a hospital with this ownership type.

The first stage of the two-stage least squares approach (2SLS) for the two ownership types can be written as follows:

$$FP_{iht} = \pi_0 + \pi_1\, dist^{FP\_PUB}{}_{iht} + \pi_2\, dist^{NFP\_PUB}{}_{iht} + \pi_3\, share^{FP}{}_{ht} + \pi_4\, share^{NFP}{}_{ht} + \pi_5\, PAT_{iht} + \pi_6\, HOSP_{iht} + \pi_7\, REG_{ht} + \vartheta_{iht} + \mu_{iht} \quad (2a)$$

$$NFP_{iht} = \delta_0 + \delta_1\, dist^{NFP\_PUB}{}_{iht} + \delta_2\, dist^{FP\_PUB}{}_{iht} + \delta_3\, share^{FP}{}_{ht} + \delta_4\, share^{NFP}{}_{ht}\delta_5\, PAT_{iht} + \delta_6\, HOSP_{iht} + \delta_7\, REG_{ht} + \vartheta_{iht} + \omega_{iht}, \quad (2b)$$

where FP and NFP are the presumably endogenous ownership dummies of the chosen hospital. On these, we use the continuous variable differential distances for the different ownership types of the hospital, i.e., PUB vs. FP or NFP, denoted by $dist^{FP\_PUB}$ and $dist^{NFP\_PUB}$, as well as the share of FP ($share^{FP}{}_{ht}$) and NFP hospitals ($share^{NFP}{}_{ht}$) in the region that treat the indication, and we add all other covariates at the patient, hospital and regional levels.

The second stage can be formalised as:

$$y_{iht} = \beta_0 + \beta_1\, \widehat{FP}_{iht} + \beta_2\, \widehat{NFP}_{iht} + \beta_3\, PAT_{iht} + \beta_4\, HOSP_{iht} + \beta_5\, REG_{ht} + \vartheta_{iht} + e_{iht}, \quad (3)$$

where y_{iht} represents the respective outcome variables (post-surgery adverse events, surgery-related adverse events, in-hospital death) of a patient i in hospital h in year t. $\widehat{FP}_{iht}$ and $\widehat{NFP}_{iht}$ are the predicted values of the first stage (2a/2b), and again all exogenous variables are included. In the results section, we focus mainly on the estimators for β_1 and β_2. We tested our instrumental variable model for the endogeneity of the regressor of ownership using the generalised method of moments (GMM) distance test, as well as the Kleibergen-Paap Wald rk test for weak identification and the Kleinberg Paap LM statistics for underidentification.

Entropy Balancing

A second concern regarding the analysis is the selection of hospitals into their ownership type [16]. OLS regression and instrumental variable approaches with an instrument at the patient level may be biased if hospitals have a different endowment in (a) characteristics that are observable to us, such as a specialisation in a particular procedure, differences in hospital staffing or the number of beds on a certain ward, or (b) factors that are not observable to us such as management style or their profit maximisation function. In the approaches described above, we added hospital variables as control variables, but with entropy balancing we attempted to take a different approach because we believe that hospital characteristics may be one of the main drivers of differences in quality. We therefore added an analysis with entropy balancing [59] at the hospital level to weight the FP and NFP hospitals with the observables of the reference group (i.e., public hospitals). This allowed for a closer inspection of results in which we corrected for observables at the hospital level.

Sensitivity analysis

Most university hospitals are publicly owned and treat severe cases not suitable for other hospitals, and they have other responsibilities, such as teaching and research. These characteristics may bias the baseline category and drive results regarding differences in quality. As a sensitivity analysis, we therefore performed the same regressions as those described above (i.e., OLS and instrumental variables) but excluded the cases treated at university hospitals.

Results

Descriptive statistics

Our case selection criteria led to the following sample (Figure 1): Using the emergency case definition (femoral fracture with total or partial hip replacement), we identified 258,782 cases with the corresponding diagnosis and procedure combination. Subsequently applying our exclusion criteria yielded a sample of 210,447 cases for analysis. Using the elective case definition (hip arthrosis with total hip replacement), we identified 710,835 cases with the corresponding diagnosis and procedure combination. Subsequently applying our exclusion criteria yielded a sample of 465,607 cases for analysis.

(Please insert Figure 1 here)

Table 1 gives summary statistics. On average, patients with the emergency condition were older (82.4 years vs. 74.8 years), more likely to be female (71.4% vs. 63.7%), and had a higher Elixhauser score (2.9 vs. 1.8) compared to the elective cases. Emergency cases also had a longer length of stay (16.3 vs. 11.9 days) and a rate of adverse events that was up to five times higher compared to the elective cases, especially for surgical adverse events (11.7% vs. 1.9%). Hospitals had fewer of the emergency cases than the elective cases (number of relevant cases: 75.0 vs. 315.6). Patients with an emergency condition were more likely to choose the nearest hospital compared to the elective case (nearest hospital chosen: 60.9% vs. 32.7%).

The comparison of different ownership types shows that public hospitals had the highest number of emergency cases (PUB: 96,123 cases, NFP: 81,002 cases, FP: 33,352 cases), relevant cases (PUB: 91.0, NFP: 61.1, FP: 60.1), and beds (PUB: 747.3 beds, NFP: 404.2 beds, FP: 435.7 beds) – a finding that may have been driven by the large share of university hospitals in our sample.

Our descriptive statistics differed for the elective care condition. NFP hospitals treated the highest number of these cases (PUB: 156,498, NFP: 197,447 cases, FP: 111,662), but FP hospitals had the highest number of relevant diagnoses per hospital (PUB 243.7, NFP: 300.0, FP: 440.3) despite having the fewest beds (PUB 604.3, FP: 362.5, NFP: 245.3). This suggests that FP hospitals have a higher rate of specialisation.

(Please insert Table 1 here)

OLS results

Table 2 gives the results of the OLS and instrumental variable regressions for the outcomes post-surgery adverse events, surgical adverse events, inpatient mortality and length of stay. "Panel A: Emergency care indication" shows the results for femur fracture with total or partial hip replacement and "Panel B: Elective care indication" shows the results for hip arthrosis with total hip replacement.

The OLS regressions for the emergency cases yielded some significant results for FP and NFP ownership compared to public ownership. In FP hospitals, inpatient mortality was 0.55% ($p<0.01$) lower than in public hospitals. In NFP hospitals, the rate of surgical adverse events was 0.33% ($p<0.1$) lower and length of stay was 0.515 ($p<0.05$) days longer than in public hospitals. Other outcomes did not differ significantly according to hospital ownership type.

The results of the OLS regression for the elective care cases were rather different. On the one hand, the rate of post-surgery adverse events in FP hospitals was 0.14% ($p<0.01$) lower than in public hospitals. On the other hand, the rate of surgical adverse events in FP hospitals was 0.25% higher ($p<0.1$) than in public hospitals, although this difference was not statistically significant. Inpatient mortality in FP hospitals was 0.05% ($p<0.05$) lower and length of stay was 0.862 days ($p<0.01$) shorter than in public hospitals. None of the results for the comparisons between NFP and public hospitals were significant.

Instrumental variable results

We obtained values for the Kleibergen-Paap Wald rk F statistic that were greater than 270 for the emergency cases and greater than 192 for the elective cases, both of which greatly exceed the frequently used rule of thumb of $F>10$ [60], as well as the measures derived by Stock and Yogo [61]. We also rejected the Kleibergen-Paap rk LM statistic test for underidentification at the $p<0.001$ level. We therefore conclude that our instruments are not weak. Regarding endogeneity, our results were less clear. We used the GMM distance test statistic to evaluate whether hospital ownership type is endogenous. In most cases, the null hypothesis was not rejected at the common significance level, except for inpatient mortality in the emergency cases. Our instrumental variable results must therefore be interpreted with caution because the instrumental variable regression may not be necessary and its results inefficient (and OLS may be sufficient). However, from a theoretical perspective and other literature, patient selection may still have taken place.

For emergency cases, the instrumental variable regression in line with the OLS results showed no differences with regard to post-surgery adverse events. The instrumental variable results confirmed the lower rate of surgical adverse events for NFP hospitals. The estimated effect even increased, indicating a difference of -0.53 % ($p<0.01$). The significant OLS results for FP hospitals were not supported by the instrumental variable results. Also, the longer length of stay for FP hospitals was no longer significant at common thresholds.

For the elective care cases, we were able to confirm the finding from the OLS regression that the rate of post-surgery adverse events in FP hospitals was lower than that in public hospitals. The estimate was -0.13 % ($p<0.05$), which is comparable to the OLS results. We were not able to confirm the finding from the OLS regression that the rate of the surgical adverse events in FP hospitals was higher than that in public hospitals. For NFP hospitals the estimate of the instrumental variable was -0.002 ($p<0.05$), which compared to the OLS the estimate is different in size and direction. We could not confirm the finding from the OLS regression that inpatient mortality in FP hospitals was lower than that in public hospitals. The results for length of stay in FP hospitals could, however, be confirmed by the instrumental variable approach. FP hospitals had a length of stay that was 0.681 days ($p<0.001$) shorter than that in public hospitals. For NFP hospitals in the instrumental variable analysis, length of stay was 0.437 days ($p<0.01$) longer than that in public hospitals.

Entropy balancing

In a further analysis, we balanced the sample so that the characteristics of the FP and NFP hospitals were comparable to those of the public hospitals. Looking at the OLS results based on the balanced sample, we could see that the results for the emergency cases differed compared to those from the main specification without balancing: whereas in the main specification we found significant differences for surgical adverse events and length of stay in NFP hospitals and for inpatient mortality and length of stay in FP hospitals, this was not the case after balancing. For the elective cases, we could confirm most of the results from the main specification, which indicated that the rate of post-surgery adverse events in FP hospitals was lower than that in public hospitals. However, the estimate in the balanced sample was -0.23 % ($p<0.001$) compared to -0.14% ($p>0.001$) in the main specification) and therefore larger in magnitude. Moreover, we could confirm that inpatient mortality in FP hospitals was lower than that in public hospitals, with the specification based on the balanced sample yielding a difference of -0.09% ($p<0.05$). Lastly, the estimate for length of stay, which was 0.835 days ($p<0.001$) shorter in FP hospitals compared to public hospitals, was consistent with the results obtained in the main specification (0.862 days ($p<0.001$)).

Looking at the instrumental variable results based on the balanced sample, we could see some differences for the emergency cases compared to the main specification: The rate of surgical adverse events in NFP hospitals no longer differed significantly from that in public hospitals. However, in FP hospitals, the rate of surgical adverse events was 0.45% ($p<0.05$), which was lower than the estimate in FP hospitals in the main specification. All other estimates were no longer significantly different from zero. For elective cases, the rate of post-surgery adverse events in FP hospitals in the balanced sample was 0.18% ($p<0.05$) lower than that in public hospitals, confirming the corresponding result from the main specification. Moreover, the length of stay in FP hospitals in the balanced sample was 0.744 days ($p<0.001$) shorter than that in public hospitals, confirming results from the main specification. All other estimates we non-significant.

Sensitivity analysis

We ran an additional sensitivity analysis that excluded university hospitals (see Appendix E), which confirmed most of our results. Although excluding university hospitals cases did not substantially affect most of our results, in most cases it did lead to slightly lower magnitudes of difference in the outcome. For the emergency cases, we did not find any significant results for any of the adverse event or hospital types after applying instrumental variable regression except for surgical adverse events in NFP hospitals (-0.00458, $p<0.05$). In contrast to our original sample with university hospitals, the prediction for the length of stay in FP hospitals was significantly lower in the OLS specification, but not in the instrumental variable specification. For elective care cases, we can confirm our results except for the instrumental variable specification for post-surgery adverse events in FP hospitals, which was no longer significant, and for the length of stay, which remained significant and negative (FP: -2.070 ($p<0.001$)).

Discussion

In this study, we analysed whether hospitals deliver care differently based on their ownership type (FP, NFP, public) and, additionally, whether this care differed in an emergency or elective care setting. To do so, we drew upon claims data from hospitals throughout Germany and examined four different quality outcomes in emergency and elective cases of hip replacement surgery.

While there are many previous studies on hospital ownership, evidence on the effects of ownership type on quality measures is inconclusive and tends to be subject to substantial methodological limitations [1]. With our instrumental variable approach, which used (i) differential distances between patients' places of residence and hospitals with different ownership types and (ii) the share of hospitals in different regions as instruments, we were able to test whether differences in quality between ownership types exist and if these differed between an elective and an emergency setting because theory expects different behaviour among different hospital types in cases where quality is less easy to observe.

To do this, we compared an emergency care indication with limited possibilities for informed decision-making, which may increase the opportunity for hospitals to lower their quality and increase profit and an elective indication with more opportunities for informed decision-making. NFP hospitals were associated with fewer surgical adverse events compared to public hospitals in our OLS and instrumental variable estimates. These results changed, however, when we matched our sample using hospital-level variables. After the matching procedure, FP hospitals appeared to provide care with fewer adverse events, at least in the instrumental variable setting. For elective care cases, we found that FP hospitals provided care with fewer post-surgery adverse events and a shorter length of stay compared to public hospitals. We again found some differences for NFP ownership compared to public ownership for the surgical adverse events. We therefore conclude that our results, after correcting for potential patient selection using instrumental variable regression, provide some evidence that NFP status is correlated with fewer surgical adverse events. Because the magnitude of these results became smaller after we balanced the sample based on hospital characteristics, and because FP hospitals then seemed to have a lower rate of adverse events, the results for the emergency cases need to be viewed with caution. It may be that these are driven more by differences in hospital characteristics that themselves differ among hospitals with different ownership types.

The results we found for the emergency indication are partly in line with those of previous studies from Germany that looked at 30-day and one-year mortality for two emergency indications [22]. Wübker und Wuckel found that FP status had a positive effect on mortality for pneumonia patients compared to public status, but that there was no difference in this regard for AMI patients. It thus seems that quality differences for emergency indications in Germany are minimal but may differ according to treatment area or outcome measure.

For elective cases, the theory suggests that there are fewer differences in quality between hospitals compared to emergency care because quality in elective care settings may be more easily observable and therefore more easily contractible [4]. With elective cases, we found a significantly lower rate of post-surgery adverse events in FP hospitals compared to public hospitals and no significant difference for NFP hospitals compared to public hospitals. This effect was robust across specifications, unless we excluded university hospitals. Furthermore, we again found a lower rate of surgical adverse events in FP hospitals compared to public hospitals, which, however, was lower once we balanced the sample in terms of hospital characteristics. FP hospitals were associated with a shorter length of stay in all specifications compared to public hospitals, suggesting that FP hospitals may be more efficient and tend to discharge patients earlier. While the early discharge may be a result of higher efficiency, it could also indicate bloody/early discharges. In contrast, NFP hospitals had a significantly longer length of stay compared to public hospitals, at least in our main specification using instrumental variables but no balancing.

Overall, we found only small quality differences across ownership types and indications, and, with the exception of the lower rate of post-surgery adverse events in FP hospitals for elective surgery, none of these differences consistently favoured one ownership type or health care setting over another. This finding could be explained by the high level of competition in the German hospital market. Sloan [62] argued that in a market with higher competition, hospital behaviour is more homogenous. In recent years, the German hospital market has been faced with tighter competition, such as through the introduction of DRGs and the reduction of overcapacities [7]. This has led to an increase in FP ownership, as well as in specialisation and consolidation in the market. Our finding of quite consistent levels of quality may therefore simply reflect the results of increased competition, which may lead to a quality competition under fixed prices [63]. The descriptive statistics suggest that, especially for elective cases, FP hospitals have, on average, a larger case volume for total hip replacement compared to NFP or public hospitals. While we included the case volume of the underlying procedure as a control variable in the regression, there may be other variables related to the specialisation of a hospital that we could not capture properly, such as the specialisation of physicians. Unfortunately, data on these variables were not available, meaning that their effect, if present, was incorrectly attributed to differences in ownership status. Therefore, our results, especially for elective cases, could also be explained by another mechanism, namely a “practice makes perfect” hypothesis that FP have become better at specialising in certain procedures compared to public or NFP hospitals. Evidence on the effect of this mechanism is still inconclusive, however [63–66]. Lastly, we saw that FP hospitals had a significantly shorter length of stay on the average for our elective cases. While this might suggest greater efficiency leading to higher profits, it could also be the result of upcoding or premature discharge, which might lead to the revolving door syndrome. Whichever of these explanations is the case, both could have negative consequences for the payer or the patient, and affect the results of our analysis.

This paper has several strengths. First, we used a full dataset comprising all hospital inpatient cases in Germany, giving us a unique data source with a large sample size for studying differences in hospital ownership. Second, unlike many other studies, we tackled the endogeneity of hospital choice using an instrumental variable approach with two different instruments and compared a similar treatment in two health care settings – emergency and elective. This allows us to analyse if hospitals outcomes are different in an elective and emergency setting. Lastly, we could report variables related to adverse events other than mortality, thereby broadening the view on different measures of quality during major surgery.

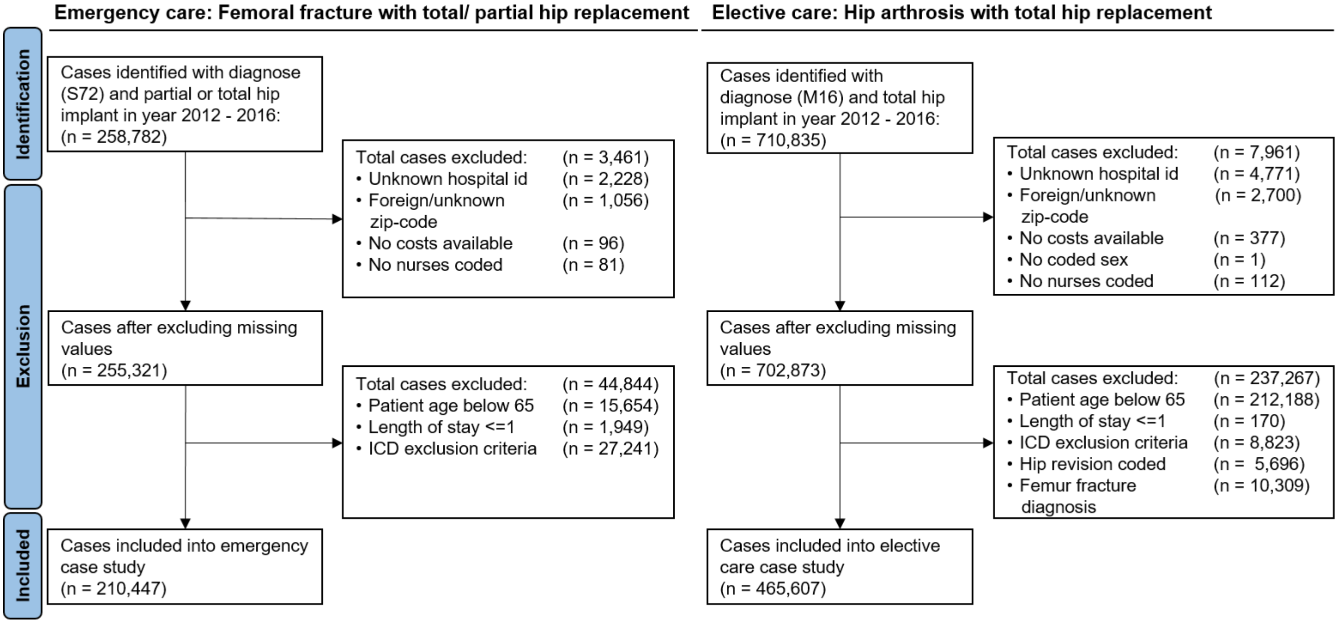
Our analysis has some important limitations. Although our sample is large, our data cover adverse events only during the hospital stay or in the 30 days after discharge in patients who were rehospitalised for reasons related to the emergency or elective hip replacement surgery. This is unfortunate because the risk for some adverse events (e.g., deep vein thrombosis) after hip replacement surgery remains elevated for a longer period after hospital discharge [64]. Moscone et al. [27] found a higher readmission rate after hip replacement for FP hospitals in Italy. Readmission would be interesting to observe in our study, as well, especially given the shorter length of stay seen in FP hospitals in our sample. However, looking at a longer post-hospitalisation window would require data that are available only from a subset of statutory health insurers in Germany [22], and this, in turn, would lead to a substantially smaller sample.

Although we used an instrumental variable approach, the formal test of endogeneity was often not satisfied, meaning that this analysis may have been unnecessary or inefficient because patient selection may not be a major problem for the indications we chose. However, because this kind of analysis is used frequently in similar applications and we expected self-selection from a theoretical point of view, we nevertheless report the results of this analysis here, albeit with the caveat that they need to be interpreted with caution. Furthermore, the only information we had on the location of patients' residence was their postal codes. While this is the case in most studies that use differential distances, more precise data might have increased the power of the instrument, especially for more rural areas. Lastly, DRGs are the main source of reimbursement for hospitals in Germany, and because these are defined by the diagnoses and procedures coded for patients, hospitals have incentives to upcode. If this behaviour differed according to ownership type, e.g., because of stronger profit-maximising incentives for FP hospitals, our results could be biased.

The few studies available on hospital ownership and quality of care in Germany suggest that the effects of the former on the latter are inconsistent and unclear, which could have different causes. Future studies could therefore take a similar analytical approach to examine additional specialties or disease areas in relation to the effect of hospital ownership. This could help provide a clearer picture, for example, of whether the greater specialization seen with some types of ownership status in certain disease areas is the cause of the quality differences or, rather, if the quality differences are due to other characteristics of the hospitals with these types of ownership status. Alternatively, the different methods and outcomes of the studies could be a reason for the differences in results – something that future research could also help elucidate. Moreover, future studies might seek to combine inpatient and outpatient data to improve our understanding of the differences among the hospital ownership types, as doing so would provide more detailed information about patients. Examples include adverse events and follow-up costs that occur over the longer term, neither of which could be considered in our study due to data limitations. Lastly, subjective parameters could also be examined as additional outcomes because these also appear to influence patient decisions and thus could lead to patients choosing particular hospitals over others. The results of a recent study show, for example, that in the field of maternal health, subjective quality differences are also a relevant factor for patients when deciding which hospital to attend [65].

Figures

Figure 1: Selection of cases for the two case-studies



Note: Figure 1 summarises the inclusion and exclusion criteria for emergency and elective care cases

Tables

Table 1: Summary statistics for emergency and elective cases by hospital type

	Emergency: Femoral fracture with total/partial hip replacement (S72)				Elective: Hip arthrosis with total hip replacement (M16)			
Outcomes	All	PUB	FP	NFP	All	PUB	FP	NFP
Length of stay [days]	16.3	16.1	15.9	16.7	11.9	12.2	10.9	12.1
Post-surgery adverse events [%]	4.6	4.7	4.4	4.6	0.6	0.7	0.5	0.6
Surgical adverse events [%]	11.7	11.6	12.7	11.4	1.9	2.0	1.7	2.0
Inpatient mortality [%]	5.6	5.7	5.4	5.7	0.2	0.2	0.1	0.2
Patient								
Age [years]	82.4	82.3	82.3	82.5	74.8	74.9	74.5	74.9
Share female [%]	71.4	70.8	71.5	72.0	63.7	62.0	63.9	65.0
Elixhauser score	2.9	2.8	3.0	2.8	1.8	1.8	1.9	1.8
Hospital								
Number relevant cases	75.0	91.8	60.1	61.1	315.6	243.7	440.3	300.0
HHI	16.1	17.8	18.8	12.9	15.9	18.2	17.7	13.1
Number of beds	567.0	747.3	435.7	404.2	428.0	604.3	245.3	362.5
Teaching hospital [%]	70.6	77.0	72.4	62.4	59.2	68.7	50.2	56.7
University hospital [%]	5.3	9.5	2.2	1.5	3.5	7.8	1.7	1.1
Cases per physician	146.8	141.3	148.3	152.8	146.1	145.2	145.6	146.9
Region								
Inhabitants older than 65 years	21.1	21.2	21.9	20.6	21.1	21.4	21.7	20.5
GPs per 100,000 inh.	67.6	67.7	69.4	66.7	68.0	67.9	69.1	67.5
Median household income (PPP- adjusted)	1,624	1,652	1,620	1,594	1,631	1,643	1,664	1,603
Unemployment rate [%]	6.9	6.3	7.2	7.5	6.8	5.9	6.8	7.4
Observation	210,477	96,123	33,352	81,002	465,607	156,498	111,662	197,447
Closest hospital chosen [%]	60.9	62.8	66.2	56.5	32.7	43.0	27.0	27.7
Distance to closest hospital [km]	5.8	6.5	5.8	4.9	6.3	7.0	6.5	5.5
Femur implant total	24.2	24.1	23.2	24.5				

Note: HHI= Herfindahl Hirschman Index, based on a 30km radius and cases of the ICD chapter of the musculoskeletal system and connective tissue, GPs = general practitioners; ppp = purchasing power parity adjusted, inh. = inhabitants, Appendix D provides additional information on standard error

Table 2: OLS and IV regression results for the emergency an elective care indication

Panel A: Emergency indication: Femur fracture

ICD S72	Post surgery adv. events		Surgical adverse events		Inpatient mortality		Length of stay	
	OLS	IV	OLS	IV	OLS	IV	OLS	IV
For-profit (FP)	-0.0034	0.0008	-0.0011	-0.0018	-0.0055***	-0.000468	-0.486	-0.205
	(0.0028)	(0.0040)	(0.0020)	(0.0030)	(0.0020)	(0.00290)	(0.312)	(0.448)
Not-for-profit (NFP)	0.0017	0.003	-0.0033*	-0.0053**	-0.0014	0.000349	0.515**	0.456
	(0.0023)	(0.0033)	(0.0018)	(0.0024)	(0.0017)	(0.00229)	(0.255)	(0.332)
Kleibergen-Paap Wald F statistic		273.1		272.9		273.1		273.1
Underidentification p-value		<0.001		<0.001		<0.001		<0.001
GMM distance test statistic p-value		0.298		0.484		0.0191		0.392
No. observations	210,477	210,477	210,477	210,477	210,477	210,477	210,477	210,477
No. hospitals	1,137	1,137	1,137	1,137	1,137	1,137	1,137	1,137

Panel B: Elective indication: Hip arthrosis

ICD M16	Post surgery adv. events		Surgical adverse events		Inpatient mortality		Length of stay	
	OLS	IV	OLS	IV	OLS	IV	OLS	IV
For-profit (FP)	-0.0014***	-0.0013*	0.0025*	0.0003	-0.0005**	-0.0003	-0.862***	-0.682***
	(0.0005)	(0.0007)	(0.00133)	(0.0021)	(0.0002)	(0.0003)	(0.174)	(0.232)
Not-for-profit (NFP)	-0.0005	-0.0002	0.000650	-0.0022*	0.0002	0.0005	0.137	0.437**
	(0.0004)	(0.0006)	(0.00116)	(0.0012)	(0.0002)	(0.0003)	(0.153)	(0.206)
Kleibergen-Paap Wald F statistic		192.3		189.5		192.3		192.3
Underidentification p-value		<0.001		<0.001		<0.001		<0.001
GMM distance test statistic p-value		0.916		0.294		0.312		0.220
No. observations	465,607	465,607	465,607	465,607	465,607	465,607	465,607	465,607
No. hospitals	1,131	1,131	1,131	1,131	1,131	1,131	1,131	1,131

*** p<0.01, ** p<0.05, * p<0.1, clustered standard error in parentheses; Public hospitals are the reference category; OLS= Ordinary least squares; IV= Instrumental Variable

Table 3: OLS and IV regression results for the emergency an elective care indication with entropy balancing on hospital variables

Panel A: Emergency indication: Femur fracture

ICD S72	Post surgery adv. events		Surgical adverse events		Inpatient mortality		Length of stay	
	OLS	IV	OLS	IV	OLS	IV	OLS	IV
For-profit (FP)	-0.0026	0.00025	-0.0019	-0.0045**	-0.0038	-0.0014	0.0759	-0.0311
	(0.0043)	(0.0050)	(0.0018)	(0.00212)	(0.0033)	(0.0041)	(0.560)	(0.704)
Not-for profit (NFP)	0.0040	-0.0001	-0.0008	-0.00220	0.0010	0.0008	0.282	0.135
	(0.0049)	(0.0055)	(0.0034)	(0.00303)	(0.0049)	(0.0049)	(0.453)	(0.534)
Kleibergen-Paap Wald F statistic F		98.92		98.92		98.92		98.92
Underidentification p-value		<0.001		<0.001		<0.001		<0.001
GMM distance test statistic p-value		0.284		0.626		0.0191		0.662
No. observations	210,477	210,477	210,477	210,477	210,477	210,477	210,477	210,477
No. hospitals	1,137	1,137	1,137	1,137	1,137	1,137	1,137	1,137

Panel B: Elective indication: Hip arthrosis

ICD M16	Post surgery adv. events		Surgical adverse events		Inpatient mortality		Length of stay	
	OLS	IV	OLS	IV	OLS	IV	OLS	IV
For-profit (FP)	-0.0023***	-0.0018**	0.0002	-0.0015	-0.0009**	-0.0007	-0.835***	-0.744***
	(0.0006)	(0.0008)	(0.0016)	(0.0016)	(0.0004)	(0.0005)	(0.183)	(0.216)
Not-for-profit (NFP)	-0.0013	-0.0014	0.0007	-0.0017	0.0001	0.0002	0.0570	0.165
	(0.0009)	(0.0010)	(0.0017)	(0.0018)	(0.0004)	(0.0005)	(0.172)	(0.223)
Kleibergen-Paap Wald F statistic		157.3		157.3	x	157.3		157.3
Underidentification p-value		<0.001		<0.001	x	<0.001		x
GMM distance test statistic p-value		0.511		0.123	x	0.125		0.311
No. observations	465,607	465,607	465,607	465,607	465,607	465,607	465,607	465,607
No. hospitals	1,131	1,131	1,131	1,131	1,131	1,131	1,131	1,131

*** p<0.01, ** p<0.05, * p<0.1, clustered standard error in parentheses; Public hospitals are the reference category; OLS= Ordinary least squares; IV= Instrumental Variable

Appendix

Appendix A: Exclusion criteria for emergency and elective indications

Table A1: Exclusion criteria for emergency and elective indications

Emergency indication ICD S72		Elective indication ICD M16	
Exclusion ICD-Code	**Name of exclusion diagnosis**	**Exclusion ICD-Code**	**Name of exclusion diagnosis**
C	Malignant neoplasm	C	Malignant neoplasm
D00 - D09	In situ neoplasms	D00 - D09	In situ neoplasms
M08; M09	Juvenile Arthritis	M80.05	Postmenopausal osteoporosis with pathological fracture: pelvic region and thigh
M85.05	Fibrous dysplasia (monostotic): pelvic region and thigh	M80.85	Other osteoporosis with pathological fracture: pelvic region and thigh
M85.45; M85.55; M85.65	Bone cyst: pelvic region and thigh	M84.15	Non-union of the fracture (pseudarthrosis): pelvic region and thigh
M90.75	Bone fracture in neoplasms: pelvic region and thigh	M84.85; M84.95	(other) changes in bone continuity: pelvic region and thigh
M80.05	Postmenopausal osteoporosis with pathological fracture: pelvic region and thigh	M85.05	Fibrous dysplasia (monostotic): pelvic region and thigh
M96.88	Other diseases of the musculoskeletal system after medical procedures	M85.45; M85.55; M85.65	Bone cyst: pelvic region and thigh
Q65.0; Q65.1	Inherent luxation of the hip joint	M90.75	Bone fracture in neoplasms: pelvic region and thigh
Q68.3; Q68.5	Inherent bending of the hip joint	M96.88	Other diseases of the musculoskeletal system after medical procedures
S02	Skullcap fracture	Q65.0; Q65.1	Inherent luxation of the hip joint
S04	Cranial nerve injury	S32.4	Fracture of acetabulum
S05.4 - 8	Injury of the eyeball		
S06.4 - 8	Brain haemorrhage trauma		
S06.33; S06.34; S06.38	Circumscribed cerebral hematoma		
S07	Crushing injury of the head		
S2[4-8]	Injury to intrathoracic organs		
S32;	Fracture of the lumbar spine and pelvis		
S3[4-8]	Different injuries in the lumbar, abdominal and pelvis region		
S42	Fracture of the shoulder and upper arm		
S43.0-3	Luxation of the shoulder joint		
S44.0-4	Injury of nerves at the upper arm		

S45.0-2	Injury of arteries axillaries and/or brachialis		
S47	Crushing injury of the shoulder and upper arm		
S48	Traumatic amputation of the shoulder and upper arm		
S5[2-5; 7-8]	Fractures of the forearm		
S6[2-5; 7-8]	Fractures of the wrist		
S72.2-4;7-8	Fractures of the femur		
S73.0	Luxation of the hip		
S7[7-8]	Crushing injury of the hip and thigh		
S82	Fracture of the lower leg, including the upper ankle joint		
S83.0 - 3	Fractures of the knee joint		
S84.0 - 1; 7	Injury of nerves at the lower leg		
S85.0 - 2; 7	Injury of the popliteal arteries		
S87	Crushing injury of the lower leg		
T07	Multiple Injuries		

Note: Authors' own representation based on the selection of WidO [45]; ICD = International Classification of Diseases

Appendix B: List of Diagnoses for the analysed variables

Post-surgery adverse events	I80.1-I80.3	Thrombosis, phlebitis and thrombophlebitis of other deep vessels of the lower extremities (including deep vein thrombosis)
	I82.2	Thrombosis of the v. cava
	I82.8	Embolism and thrombosis of other specified veins
	I26	Pulmonary embolism
	U69.0	Hospital-acquired pneumonia
Surgical adverse events	T81	General complications of surgery (bleeding and hematoma, shock, accidental puncture or laceration, rupture of a surgical wound, infection after surgery, foreign body, vascular complications).
	T84.0	Mechanical complication due to a hip joint endoprosthesis
	T84.5	Infection and inflammatory reaction due to joint endoprosthesis
	T84.8	Other complications due to orthopaedic endoprostheses, implants or grafts
	T84.9	Unspecified complication due to orthopaedic endoprosthesis

Appendix C: Summary statistics of the closest hospital to a patient

Table A2: Summary statistics of the closest hospital to a patient

	Emergency: Femoral fracture with total/partial hip replacement (S72)			Elective: Hip arthrosis with total hip replacement (M16)		
	PUB	FP	NFP	PUB	FP	NFP
Outcomes						
Length of stay [days]	16.1	16.3	16.6	11.8	11.5	12.2
	(9.39)	(9.70)	(10.0)	(4.49)	(4.68)	(4.92)
Post-surgery adverse events [%]	4.5	4.52	4.8	0.6	0.6	0.6
	(20.80)	(20.77)	(21.37)	(7.81)	(7.85)	(7.87)
Surgical adverse events [%]	11.4	12.6	11.7	1.8	1.9	2.0
	(31.74)	(33.22)	(32.20)	(13.36)	(13.9)	(14.10)
Inpatient mortality [%]	5.5	5.7	5.7	0.17	0.2	0.2
	(22.86)	(23.12)	(23.26)	(4.21)	(4.59)	(4.66)
Patient						
Age [years]	82.4	82.4	82.4	74.7	74.7	74.9
	(7.33)	(7.33)	(7.31)	(5.70)	(5.68)	(5.75)

Share female [%]	71.3	71.4	71.5	62.8	63.6	64.9
	(45.24)	(45.18)	(45.16)	(0.48)	(0.48)	(0.48)
Elixhauser comorb.	2.9	3.0	2.9	1.8	1.9	1.8
	(1.91)	(1.95)	(1.93)	(1.43)	(1.47)	(1.45)
Hospital						
Number relevant cases	76.4	69.0	76.3	335.0	380.9	325.4
	(49.47)	(57.58)	(88.46)	(325.89)	(409.16)	(309.18)
HHI	18.0	18.4	12.9	17.6	17.9	12.9
	(13.58)	(16.68)	(12.34)	(12.95)	(14.75)	(11.56)
Number of beds	555.32	523.8	596.7	416.4	402.3	456.5
	(483.74)	(567.73)	(816.74)	(427.63)	(481.88)	(572.11)
Teaching hospital [%]	73.9	72.7	66.2	60.6	60.0	57.1
	(43.94)	(44.56)	(47.31)	(48.86)	(48.99)	(49.50)
University hospital [%]	6.2	3.5	5.0	3.7	2.8	3.6
	(24.14)	(18.40)	(21.87)	(18.88)	(16.55)	(18.61)
Cases per physician	145.5	147.7	147.8	145.2	147.4	146.3
	(37.65)	(37.15)	(41.95)	(42.41)	(60.76)	(46.33)
Region						
Inhabitants older 65	21.2	21.8	20.6	21.1	21.7	20.7
	(2.41)	(2.80)	(2.13)	(0.03)	(0.03)	(0.02)
GPs per 100,000 inh.	67.8	69.1	66.6	68.3	69.5	66.8
	(11.81)	(16.52)	(13.60)	(12.65)	(16.47)	(15.39)
Inhabitants with academic degree [%]	13.9	13.9	14.6	14.4	14.5	14.7
	(6.71)	(6.54)	(7.10)	(7.16)	(7.04)	(7.09)
Unemployment rate [%]	6.1	7.2	7.6	6.1	7.0	7.4
	(2.82)	(2.83)	(2.75)	(2.74)	(2.67)	(2.73)
Observation	88,967	38,895	83,604	199,446	92,767	173,501
Closest hospital chosen [%]	68.1	57.0	55.1	33.6	32.5	31.29
	(46.61)	(49.51)	(49.74)	(47.24)	(46.83)	(46.37)
Dist. closest hosp. [km]	6.5	6.1	4.8	6.9	6.6	5.3
	(5.24)	(5.32)	(4.28)	(5.36)	(5.56)	(4.53)

Note: Standard deviation in parentheses, HHI = Herfindahl Hirschman Index, based on a 30 km-radius and the cases of the ICD chapter of the musculoskeletal system and connective tissue, comorb. = comorbidities; GPs = general practitioners; inh.= inhabitants; Standard errors in parentheses

Appendix D: Descriptive statistics including standard error

Table A4: Descriptive statistics including standard error

	Emergency: Femoral fracture with total/partial hip replacement (S72)				Elective: Hip arthrosis with total hip replacement (M16)			
Outcomes	All	PUB	FP	NFP	All	PUB	FP	NFP
Length of stay [days]	16.3	16.1	15.9	16.7	11.9	12.2	10.9	12.1
	(9.61)	(9.45)	(9.51)	(9.85)	(4.70)	(4.82)	(4.28)	(4.74)
Post-surgery adverse events [%]	4.6	4.7	4.4	4.6	0.6	0.7	0.5	0.6
	(21.02)	(21.23)	(20.45)	(20.10)	(7.84)	(8.60)	(6.98)	(7.67)
Surgical adverse events [%]	11.7	11.6	12.7	11.4	1.9	2.0	1.7	2.0
	(32.15)	(32.04)	(33.27)	(31.80)	(13.75)	(13.88)	(12.97)	(14.06)
Inpatient mortality [%]	5.6	5.7	5.4	5.7	0.2	0.2	0.1	0.2
	(23.06)	(23.12)	(22.68)	(23.11)	(4.46)	(4.82)	(3.64)	(4.58)
Patient								
Age [years]	82.4	82.3	82.3	82.5	74.8	74.9	74.5	74.9
	(7.32)	(7.33)	(7.35)	(7.29)	(5.72)	(5.74)	(5.63)	(5.75)
Share female [%]	71.4	70.8	71.5	72.0	63.7	62.0	63.9	65.0
	(7.14)	(45.46)	(45.13)	(44.90)	(0.48)	(48.5)	(0.48)	(47.7)
Elixhauser comorb.	2.9	2.8	3.0	2.8	1.8	1.8	1.9	1.8
	(1.93)	(1.92)	(1.95)	(1.92)	(1.44)	(1.44)	(1.47)	(1.43)
Hospital								
Number relevant cases	75.0	91.8	60.1	61.1	315.6	243.7	440.3	300.0
	(68.87)	(93.83)	(30.71)	(29.53)	(319.11)	(232.45)	(455.85)	(258.21)
HHI	16.1	17.8	18.8	12.9	15.9	18.2	17.7	13.1
	(13.99)	(13.57)	(16.93)	(12.46)	(13.05)	(13.12)	(13.53)	(12.15)
Number of beds	567.0	747.3	435.7	404.2	428.0	604.3	245.292	362.5
	(649.93)	(889.5)	(309.66)	(216.78)	(496.89)	(764.36)	(245.29)	(216.96)
Teaching hospital [%]	70.6	77.0	72.4	62.4	59.2	68.7	50.2	56.7
	(45.55)	(42.05)	(44.73)	(48.47)	(49.15)	(46.36)	(50.00)	(49.55)
University hospital [%]	5.3	9.5	2.2	1.5	3.5	7.8	1.7	1.1
	(22.30)	(29.36)	(14.69)	(12.00)	(18.34)	(26.77)	(12.96)	(10.41)
Cases per physician	146.8	141.3	148.3	152.8	146.1	145.2	145.6	146.9
	(39.35)	(38.77)	(37.01)	(40.00)	(48.01)	(39.82)	(72.09)	(35.23)
Region								
Inhabitants older than 65 years	21.1	21.2	21.9	20.6	21.1	21.4	21.7	20.5
	(2.42)	(2.40)	(2.83)	(2.12)	(2.50)	(2,46)	(3.01)	(2.32)
GPs per 100,000 inh.	67.6	67.7	69.4	66.7	68.0	67.9	69.1	67.5

	(13.52)	(11.65)	(16.96)	(13.91)	(14.55)	(12.68)	(12.93)	(16.63)
Median household income (PPP adjusted)	1,624 (200.78)	1,652 (219,6)	1,620 (218.7)	1,594 (161.4)	1,631 (203.3)	1,643 (200.9)	1,664 (238.0)	1,603 (178.7)
Unemployment rate [%]	6.9	6.3	7.2	7.5	6.8	5.9	6.8	7.4
	(2.87)	(2.91)	(2.85)	(2.67)	(2.79)	(2.92)	(2.57)	(2.64)
Observation	210,477	96,123	33,352	81,002	465,607	156,498	111,662	197,447
Closest hospital chosen [%]	60.9 (48.79)	62.8 (48.34)	66.2 (47.30)	56.5 (49.57)	32.7 (46.85)	43.0 (46.93)	27.0 (44.39)	27.7 (44.78)
Dist. closest hosp. [km]	5.8	6.5.	5.8	4.9	6.3	7.0	6.5	5.5
	(4.96)	(5.27)	(5.06)	(4.34)	(5.20)	(5.39)	(5,58)	(4,69)
Femur implant total	24.2	24.1	23.2	24.5				

Note: HHI = Herfindahl Hirschman Index, based on a 30 km-radius and cases of the ICD chapter of the musculoskeletal system and connective tissue, GPs = general practitioners; PPP = purchasing power parity; inh. = inhabitants; Standard errors in parenthesis.

Appendix E: Sensitivity analysis

Table 5: OLS and IV regression results for the emergency an elective care without university

Panel A: Emergency indication: Femur fracture

ICD S72	Post surgery adv. events		Surgical adverse events		Inpatient mortality		Length of stay (LOS)	
	OLS	IV	OLS	IV	OLS	IV	OLS	IV
For-profit (FP)	-0.0017	0.000231	-0.0007	-0.0013	-0.0052**	-0.0001	-0.532*	-0.167
	(0.0029)	(0.00401)	(0.0021)	(0.0030)	(0.002)	(0.0029)	(0.320)	(0.454)
Not-for-profit (NFP)	0.0025	0.00448	-0.0027	-0.0046*	-0.0013	0.0001	0.434*	0.343
	(0.0023)	(0.00326)	(0.0018)	(0.00237)	(0.0017)	(0.0023)	(0.255)	(0.333)
Kleibergen-Paap Wald F statistic		302.9		303		302.9		302.9
Underidentification p- value		<0.001		<0.001		<0.001		<0.001
GMM distance test statistic p-value		0.514		0.490		0.0247		0.228
No. observations	210,477	199,400	210,477	199,400	210,477	199,400	210,477	199,400
No. hospitals	1,137	1,137	1,137	1,137	1,137	1,137	1,137	1,137

Panel B: Elective indication: Hip arthrosis

ICD M16	Post surgery adv. events		Surgical adverse events		Inpatient mortality		Length of stay (LOS)	
	OLS	IV	OLS	IV	OLS	IV	OLS	IV
For-profit (FP)	-0.0011**	-0.0011	0.0027*	0.00013	-0.0005**	-0.0002	-0.902***	-0.667***
	(0.0005)	(0.0007)	(0.0014)	(0.0022)	(0.0002)	(0.0003)	(0.178)	(0.231)
Not-for-profit (NFP)	-0.0003	-0.0002	0.0009	-0.0023*	0.0001	0.0004	0.094	0.407**
	(0.0004)	(0.0006)	(0.0012)	(0.0012)	(0.0002)	(0.0003)	(0.154)	(0.205)
Kleibergen-Paap Wald F statistic		186.5		183.5		186.5		186.5
Underidentification p- value		<0.001		<0.001		<0.001		
GMM distance test statistic p-value		0.991		0.149		0.227		0.168

No. observations	465,607	449,374	465,607	449,374	465,607	449,374	465,607	449,374
No. hospitals	1,131	1,131	1,131	1,131	1,131	1,131	1,131	1,131

*** p<0.01, ** p<0.05, * p<0.1, clustered standard error in parenthesis; Public hospitals are the reference category; OLS= Ordinary least squares; IV= Instrumental variable

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