Measuring Cost and Analyzing Hospital Performance

Cumulative dissertation

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Chapter 1

General Introduction

1.1 Background

Rising health expenditure has led policymakers in many countries to seek ways to improve the performance of healthcare organizations. Hospitals constitute a cornerstone of health service provision with their share of total current health expenditure ranging from 25% in Germany to 31 % in the United States, and it is believed that there is considerable potential to improve their performance (Destatis. 2021., Martin, A. B. et al. 2021). Since the 1980s, the healthcare service industry worldwide has faced a wide range of policy interventions to tackle the rising healthcare costs. Some of these interventions in developed countries such as Germany and the United States include payment systems based on diagnosis-related groups (DRG), reforms in hospital planning such as competition regulation, and the introduction of quality assurance systems. Performance evaluation in the health care sector, therefore, is essential for hospitals to properly compete in order to determine their shortages with respect to rival sectors based on the determined inputs and outputs. Definition of hospital performance varies depending on contexts. The definition used in the medical literature frequently refers to the quality of care, whether in terms of process or outcomes (Schreyögg, J. 2019). Processes measures are prerequisite for evaluating the quality of care outcomes, including all activities during meetings with patients. Outcome measures, however, include improvements or changes in the patient's health as related to the efforts of care, such as in-hospital and post-hospitalization mortality and readmission. Hospital performance is defined in the economic literature mainly in terms of financial performance and efficiency.

Given that the hospital sector is the most resource-intensive component of the health care system, a pressing task for research is to understand the driving factors of hospital performance in terms of both quality of care and financial performance.

Based on available research evidence, different patient and hospital-level factors can affect hospital performance. However, there are still gaps in the health economic literature concerning hospital performance that need to be addressed. In the next part, the goal of this dissertation is provided.

1.2 Research Goals

The goal of this dissertation is to give insight into the factors that affect hospital performance in terms of both quality of care and financial performance in three studies:

- Study 1 (chapter 2) provides a systematic review of previous studies analyzing the link between cost/price and quality of care;
- Study 2 (chapter 3) provides empirical evidence of the impact of competition on quality of care from administrative data focused on acute myocardial infarction (AMI) conditions in Germany;
- Study 3 (chapter 4) provides empirical evidence of the impact of hospital size on the financial performance in California state relying on an administrative dataset.

1.3 Outline

The dissertation consists of three studies, each of which addresses hospital performance from a different perspective. An overview of the three main studies of this dissertation is shown in figure 1.1.

Chapter 2 studies the association between hospital cost/price and the quality of care. The main goal of this study is to provide a systematic review of existing research on the link between cost/price and quality of care and to identify sources of heterogeneity across studies. We classified cost measures into the following two categories: (i) accounting costs reflecting the best use of hospital resources (measured by the providers' accounting system or cost-to-charge ratio), and (ii) costs due to inefficiency (i.e., costs associated with waste or inefficiency. The price measures were based on price/reimbursement, reflecting the payment that hospitals or other healthcare providers receive for providing medical services to patients (this could be a DRG-based payment or other reimbursement and price changes). The quality-of-care measures were classified into two categories: 1) outcome (e.g., mortality, readmission, complication/morbidity, quality of life indexes, and composite measures), and 2) process measurements.

The search process for each relationship (cost-quality and price-quality) was defined separately. Based on systematic database searches, citation searches, and cross-referencing, we identify 2225 studies. Afterward, based on the inclusion and exclusion criteria, 47 studies (225 associations) were included in the review, including nine studies that analyzed the price-quality relationship and 38 studies that assessed the cost-quality relationship. The results reveal no general relationship between cost/price and quality of care. However, when accounting for endogeneity, the evidence suggests a positive relationship. In addition, the relationship seems to depend on the condition and the specific utilization.

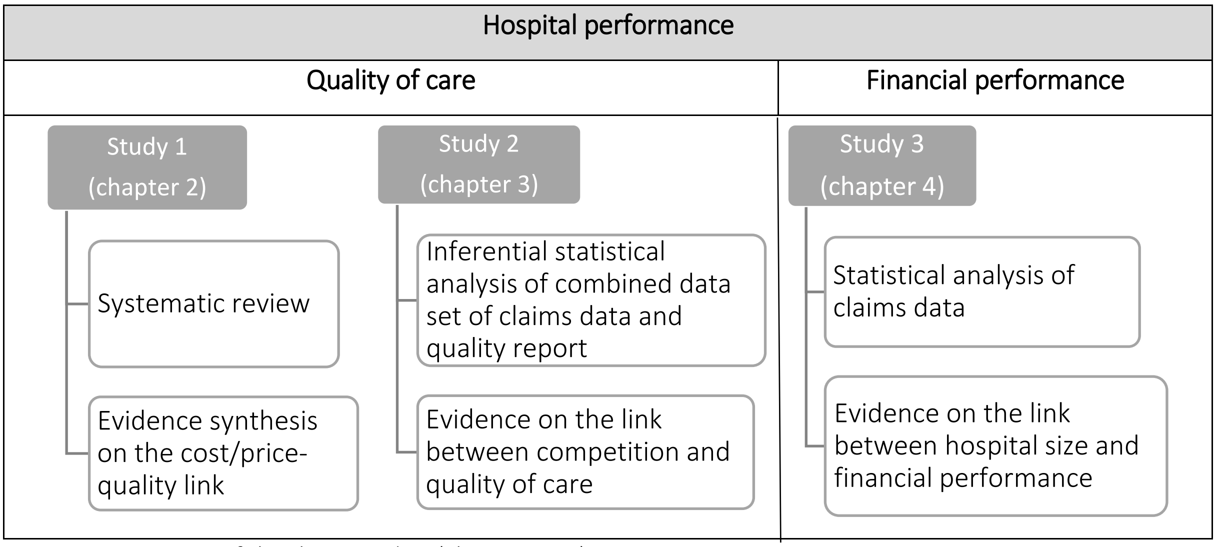

Figure 1.1 Overview of the three studies (chapters 2-4)

Additionally, different countries/regions have different regulations for quality assurance, which clearly affects cost and quality. Therefore, policymakers should be prudent with the measures used to reduce hospital costs to avoid endangering the quality of care, especially in resource-sensitive settings. This review also suggests that more research is needed to generate robust evidence regarding the association between cost/price and the quality of care.

Chapter 3 aims to provide evidence of the impact of hospital competition on quality of care, focusing on AMI admissions in Germany. Chapter 3 draws on a combination of three datasets: 63,439 patient records with AMI as a primary diagnosis from 2015-19 from a large statutory health insurer; hospital characteristics from hospital quality reports; and geographical characteristics of hospitals and patients from the INKAR database over five years (2015-19). We assessed the quality of care in terms of in-hospital and post-hospitalization mortality and cardiac-related readmission. To measure the competition faced by hospitals, we employed the distance-weighted method, which assigns weights to individual hospitals by their number of AMI admissions and inversely by distance.

Two-stage least squares model was applied to investigate the causal effect of hospital competition on quality of care. In doing so, we (a) accounted for endogeneity using an instrumental variable approach and controlling for a comprehensive list of factors that might alter the competition-quality relationship, and (b) included both in-hospital and longer-term mortality and readmission.

It is concluded that patients treated in high competition markets were 8.04% and 10.2% more likely to die within 30 days or 2 years of admission, and 13.33% and 4.8% more likely to be readmitted within 7 days or 2 years of discharge, respectively, than patients treated in low competition markets. It reveals that hospital competition does not lead to better health outcomes for AMI patients in Germany. Therefore, additional measures, such as sanctions for deviations from quality benchmarks, should be considered to achieve quality improvement.

Chapter 4 analyze the impact of hospital size on financial performance in California State using the concept of economies of scale. The sample consists of all medical/surgical acute care hospitals operating in California between 2015 and 2019, resulting in a sample size of 1519 hospital-year observations for an average of 304 hospitals per year. To estimate the link between hospital size and financial performance, linear and quadratic regression analyses were applied. Financial performance is measured using DuPont analysis, operating revenue, and cost per adjusted patient days. In addition, many control variables are included to account for additional factors that might be related to financial performance. The study's findings showed highly mixed evidence of the association between hospitals' size and financial performance. Results show a significant marginal negative non-linear relationship between hospital size and returns on assets, while no relationship is found between size –operating profit margin and size/leverage ratio link.

In closing, our study suggested that larger hospitals tend to have better financial performance than smaller ones within the hospital sector in California, and it may be safe to say that hospitals within this state that are considering expansion or merging with other hospitals have a higher chance of achieving better financial performances. It can be mainly attributed to the economies of scale perspective, which takes place after 140 beds. However, when it comes to the diseconomies of scale perspective, this latter may seem to be influenced in a very large hospital (i.e., 794 beds).

Finally, based on the findings of the three studies presented in chapters 2-4, chapter 5 draws general conclusions and provides an outlook for future research.

Chapter 2

A systematic review of the association between hospital cost/price and the quality of care

2.1 Introduction

Providing high-quality healthcare services at a reasonable cost is among the main policy goals in many countries (Häkkinen, Rosenqvist et al. 2015). In recent decades, hospital reimbursement systems underwent substantial revisions in many countries to reduce spending and increase the quality of care. Hence, hospital prices have been subject to changes. In general, hospital pricing mechanisms range from fee-for-service price lists to global budgets, and diagnosis-related group (DRG) payments have spread across numerous countries (Brown 2014). DRG systems in various countries often rely on hospitals' cost information and are subject to changes over time. Theoretical works predict that increasing DRG prices provide incentives for hospitals to attract more patients (Hodgkin and McGuire 1994). Several empirical studies analyzed the impact of a change in reimbursement or price on hospital efficiency and the number of patients treated. For instance, Dafny (2005) analyzed how hospitals respond to changes in DRG prices in the US and found no volume changes with DRGs subjected to the largest price increase (Dafny 2005). Street et al. (2007) reviewed the impact of the introduction of a DRG system in Australia, Denmark, Norway, and Sweden. Their findings suggest that DRGs increased hospital efficiency by reducing the length of hospital stays and increasing hospital case volumes (Street, Vitikainen et al. 2007). Januleviciute et al. (2016) investigated the impact of DRG price changes in Norwegian hospitals. Their findings provide evidence that hospitals react to this incentive by showing that an increase in prices leads to an increase in the number of patients treated (Januleviciute, Askildsen et al. 2016).

Changes in price might also affect the hospital quality in several ways. First, if hospitals increase their volume after a price increase, the increase in volume could lead to a higher quality due to institutional learning effects (Fleming 1991, Siciliani 2014). Additionally, higher prices might enable hospitals to spend more money (i.e., increase resources) on service provision, which might also have positive effects on the quality of care. However, hospitals might also be unwilling or unable to adjust their volume or resource input and instead maximize profits such that a price change has no effect on the quality of care.

Limited empirical evidence exists regarding the effect of price/price changes on hospital quality of care. Drawing upon evidence suggesting that a link exists between cost and quality appears to be fruitful because DRG prices in most countries are based on hospital cost information such that costs and prices are closely related. Several studies have investigated the cost-quality relationship, revealing highly heterogeneous characteristics and findings. This link is among the more controversial topics in health policy (Hussey, Wertheimer et al. 2013), and several potential mechanisms can explain the relationship between cost and quality. As outlined above, increases in resources (i.e., cost) could lead to quality increases. For instance, some technologies may lead to the increased use of medical personnel, material supplies, or training. In particular, some technologies may improve the efficiency of care delivery by reducing the procedure time, length of stay, or number of hospitalizations, thereby increasing the capacity of hospitals to treat additional patients. Consequently, the overall cost may increase, but such technology is likely to result in improved health outcomes for a higher number of patients. Some other technologies can help extend survival (e.g., in patients with life-threatening or chronic conditions), which may result in higher spending due to extended years of health care utilization. However, in parallel, a given technology also allows individuals to live additional years with a higher quality of life or an improved health state, which could provide potential cost savings (Sorenson, Drummond et al. 2013). However, if resources are not used efficiently and effectively, changes in cost might be unrelated to the quality of care. In some instances, quality improvements may even decrease costs. Therefore, some technologies may reduce staff or time requirements or shift care to less costly care settings (e.g., inpatient to outpatient) while simultaneously improving the quality of care; for instance, percutaneous transluminal coronary angioplasty (PTCA) may facilitate a reduction in spending. The PTCA outcome improved following the introduction of coronary stents, leading to the reduced occurrence of restenosis, heart attacks, emergency CABG, and mortality (Sorenson, Drummond et al. 2013). In contrast, poor quality leads to higher costs, such as costs associated with readmissions and treatment of (avoidable) complications. Finally, the relationship between cost and quality might not be linear and unidirectional and might depend on the level of quality and cost. For instance, a U-shaped relation could exist in which increases in low levels of quality are associated with decreases in cost (if poor quality drives costs) until a certain threshold is reached; after reaching the threshold, further quality increases require increases in resources and, hence, higher cost. Simultaneously, one could imagine the opposite scenario in the form of an inverted U-shaped relationship in which quality increases initially require more resources and result in higher costs, and after a certain threshold is reached, synergy effects lead to increases in quality and simultaneous decreases in cost.

In summary, both price and cost can relate in various ways to hospital quality of care. In addition, several critical design characteristics may alter the association between cost/price and the quality of care (Hussey, Wertheimer et al. 2013). Therefore, it is essential to separate the results based on defined key characteristics. In this study, we assess whether the results systematically vary depending on (i) the cost/price measures used; (ii) the quality measures used; (iii) the country in which the study was conducted; (iv) the clinical condition(s) investigated; and (v) the methodological approach used, particularly the degree to which studies approximate the causal effect based on the method used to address confounding.

We conducted a systematic review to synthesize the evidence regarding the association between hospital cost/price and the quality of care and identify sources of heterogeneity across studies. To date, only one systematic review performed by Hussey et al. (2013) has analyzed the association between cost and the quality of care (Hussey, Wertheimer et al. 2013); however, some questions remain unanswered. First, their review only focuses on the association between cost measures and the quality of care; these authors do not consider price/reimbursement. Therefore, an overview of the price-quality relationship is lacking. Second, these authors exclude studies involving non-US data sources. Therefore, an overview of cross-country comparisons is lacking. Finally, an overview of whether the results differ depending on the clinical condition is lacking. This paper addresses these gaps in the literature and considers studies published since 2012, substantially increasing the quantity of evidence.

Accordingly, this study aims to provide an overview of the existing evidence regarding how price affects the quality of care in the hospital setting. Therefore, we conduct a literature review of studies analyzing the association between price and the quality of care in hospitals. However, because few studies investigating this relationship exist and prices often rely on the costs of hospital care, we additionally provide a literature review of studies investigating the relationship between hospital cost and the quality of care.

2.2 Methods

This review is reported in accordance with The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (Moher, Liberati et al. 2009) guidelines. A review protocol was developed to identify all published articles investigating the association between hospital cost/price and the quality of care.

2.2.1 Search strategy and data sources

We defined the search process for each relationship ('cost-quality' & 'price-quality') separately.

In the literature review of the cost-quality of care relationship, we first included all 29 studies identified by Hussey et al. (2013) at the hospital level. Then, a three-step search process was used to identify new studies. First, by applying the problem, intervention, comparison, and outcome framework (Schardt, Adams et al. 2007), we derived the primary keywords. Then, a limited preliminary search was performed using ScienceDirect, Scopus, and PubMed to analyze the primary keywords in the titles, abstracts, and keywords. Following this analysis, the final keywords were selected (the search was restricted to the titles and abstracts), and the search strategy was developed. The search strategy was tailored to individual databases based on their criteria but always followed the PICO framework (see Appendix A for the full electronic search strategy used to search PubMed as an example).

A systematic search was performed by following the search strategy using 4 electronic bibliographic databases, namely, PubMed (MedLine), Scopus, EconLit (ProQuest), and ScienceDirect, from 2012 to 2018[1], and the search was repeated to identify studies published between 1990 and 2012 (the time horizon of Hussey et al. (2013)), while the results were restricted to studies outside the US.

Additionally, the references cited in the relevant studies were manually searched to identify additional relevant studies.

The retrieved articles were stored in EndNote (version X8). First, duplicate studies were excluded. Second, the title and abstract of each study were reviewed by two independent reviewers (SJ and VW) to exclude irrelevant articles. In cases in which it was difficult to determine the relevance of an article based on the abstract, the full text was retrieved and examined by two reviewers (SJ and VW) independently to determine whether to include the paper. Then, the full texts of the relevant articles were examined by two reviewers (SJ and VW) separately using the selection criteria. All disagreements were resolved by either discussion or the involvement of a third researcher (JS).

For the literature review of the price-quality of care relationship, we conducted ad hoc searches and consultations with experts to derive an initial list of relevant studies, yielding four initial relevant studies (Cutler 1993, Duggan 2000, Dafny 2005, Stargardt, Schreyögg et al. 2014). While attempting to derive

[1] The authors continued to add new results up to March 2019.

keywords from these studies for a more systematic review, it became evident that the studies' wordings were highly heterogeneous such that no common keywords could be identified. Searching by terms, such as 'price', 'quality of care', and 'hospitals', yielded overflowing lists with less than 1% of the results being relevant to our context. Therefore, we decided to rely on backward and forward searching of the initial studies while assuming that we could identify the most relevant and influential studies concerning the "price-quality" association.

2.2.2 Selection criteria

The studies were included if they were published, analyzed the association between cost/price and the quality of care in the hospital setting, employed quantitative methodology and were available (full text) in English.

We restricted the quality of care measurement to outcome and process measures as valid and reliable indicators of what actually occurs in medical practice (Krousel-Wood 1999). Moreover, we restricted the cost/price measures to monetary measures. Eight studies included by Hussey et al. (2013) were excluded because they relied on a care intensity index, which is a nonmonetary measure (4 studies), composite quality measure (i.e., composite measure of 30-day mortality and kidney transplant volume), which was not based on outcome or process measures (1 study), patient experience (1 study), caregiver rating of the patients' quality of death (1 study), and a structure measure (1 study).

No restrictions were imposed on the study design or duration. Articles were excluded if they were reviews or nonprimary articles (newspaper articles, editorials, book chapters, and conference abstracts).

2.2.3 Data extraction

To ensure that all data relevant to the question of interest of the review were collected, the data were entered into two tables.Table 2.1 provides information regarding the characteristics of each study, e.g., the population and data years. Table 2.6 (see Appendix) provides information regarding each finding, i.e., association. As one study can have more than one finding, this table is more detailed and includes information regarding the type of cost/price measure, type of quality measure, and clinical condition investigated per association tested. All disagreements were resolved by either discussion or the involvement of a third researcher (JS).

The extracted data included the articles' title, author, year of the study, the country in which the study was conducted, samples and years of data collection, study design, clinical condition(s) investigated, types of quality measures, types of cost/price measures, methodological approach, and the direction of the association/causality between hospital cost/price and the quality of care. As some studies reported more than one result (i.e., different countries, conditions, and quality and/or cost measures), the number of data entries ("results," "associations") exceeds the number of studies.

Table 2.1 Characteristics of included studies (on the study level)

Study. (year), country	Sample characteristics and size	Data years
Auerbach et al (2010), USA	81,289 patients age≥18 cared for by 1,451 physicians at 164 hospitals admitted for CABG	2003-2005
Birkmeyer et al. (2012), USA	patients (age≥65&<99) undergoing the following 4 procedures: CABG (1,060 hospitals, 221,894 patients), hip replacement (1,839 hospitals, 219,777 patients), abdominal aortic aneurysm repair (728 hospitals, 57,522 patients), colectomy procedures (1,227 hospitals, 73,772 patients)	2005-2007
Bradbury et al. (1997), USA	11,043 cholecystectomies performed by 218 surgeons in 43 Pennsylvanian hospitals	1990-1991
Bradbury et al. (1994), USA	total of 51,394 adults' admissions age>17 with one of the 10 most frequently occurring DRGs, in 43 Pennsylvania hospitals	1989-1990
Broderick et al. (2015), USA	148,348 adult patients age≥18 with diverticulitis who underwent partial colectomy	1998-2010
Carey & Burgess (1999), USA	the group of 137 non-psychiatric VA hospitals	1988-1993
Chan et al. (2015), USA	all pediatric admissions age<18 from Kids' Inpatient Database undergoing congenital heart surgery from 38 states in 2006 and 44 states in 2009	2006-2009
Chen et al. (2010), USA	adults age>65 with a primary diagnosis of CHF (in 3,146 hospitals, 518,473 discharges, and 400,068 unique patient) or pneumonia (in 3,152 hospitals, 443,564 discharges, and 399,841 unique patient)	2006
Cohen et al (2015), Canada	cohort of 30,939 first-time AMI patients 40 <age <105 admitted to Ontario hospitals with a most responsible diagnosis of AMI (ICD-10 code [I21])	2007-2010
Cutler (1995), USA	almost 30,000 Medicare recipients, with over 40,000 hospital admissions for the elderly age≥65 in the six New England states	1981-1988
Dafny (2005), USA	all admissions to DRG pairs in hospitals financed under PPS	1986-1991
Deily and McKay (2006), USA	417 acute care Florida hospitals	1999-2001
Doyle (2015), USA	first strategy: "non-deferrable" emergent 351,701 Medicare beneficiaries hospitalized through ED. second strategy: the universe of elderly hospital	(1) 2002-2008 Medicare patients

	inpatient admissions in New York within 5 miles of an ambulance referral boundary	(2) secondary analysis NYC (2000–2006)
Duggan (2000), USA	newborns in 397 general acute care Californian hospitals	1990-1995
Fleming (1991), USA	Medicare beneficiaries discharged in 656 hospitals	1985
Gani et al. (2016), USA	239,195 patients age>18 in 3,498 hospitals undergoing an elective cardiothoracic or gastrointestinal procedure from NIS Database	2012
Glance et al. (2010), USA	67,124 trauma patients admitted to 73 trauma centers from Nationwide Inpatient Sample, with a principal diagnosis of trauma (ICD-9-CM: 800 & 959.9) to a Level I or II trauma centers with American hospitals	2006
Gupta et al. (2017), USA	917,663 patients at 47 hospitals from 1 day through 18 years old admitted to a PICU during their hospital stay	2004-2015
Gutacker et al. (2013), UK	data from the PROMs program cover from April 2009 to March 2010 and are published at hospital-level by the NHS Information Centre for all providers of NHS-funded care	2009-2010
Haas et al. (2013), Germany	101 psychosomatic patients with somatoform pain disorder at Charite Universitaetsmedizin, Berlin	2006-2010
Hadley et al. (2011), USA	17,438 elderly age>64, who entered the Medicare Current Beneficiary Survey	1991-1999
Häkkinen et al. (2014), [Finland, France, Germany, Spain, Sweden]	patient-level data from 5 European countries in the treatment of the AMI (100* hospitals) and stroke (93* hospitals). *(number of hospitals and cases varied by country)	2008-2009
Häkkinen et al. (2015), [Finland, Hungary, Italy, Norway, and Sweden]	around 250 European hospitals in 5 countries used patient-level data [For Italy, we only had data from one region (Lazio, population 5.5 million), And one town (Turin, population 0.9 million). Stroke data for Norway were not available.]	Finland (2007-8), Hungary(2007-8), Italy(2007-8), Sweden(2007-8), Norway(2009).
Hvenegaard et al. (2010), Denmark	3,754 patients admitted for vascular surgery in six vascular departments	2004
Jha et al. (2009), USA	Medicare patients discharged from 4,048 acute care hospitals with index AMI (2,236), CHF (2,807) or Pneumonia (2,857).	2004
Kaestner and Silber (2010), USA	8,529,595 Medicare patients from 3,321 hospitals who were admitted to hospitals for surgery (general, orthopedic and vascular), and medical conditions (AMI, CHF, stroke, and GI bleeding)	2001-2005

Kang et al. (2017), Korea	69 hospitals that treated 6,599 AMI episodes: (40 general tertiary hospitals accounted for 4,957 AMI episodes, and 29 general hospitals accounted for 1,642 AMI episode)	2008
Kittelsen et al. (2015), major Nordic countries (Norway, Sweden, Finland, and Denmark)	160 acute somatic hospitals with a 24-hour emergency department or at least 2 medical or surgical specialties in 4 major Nordic countries	2008-2009
Kruse&Christenden (2013), Denmark	20,325 admission for vascular surgery at 9 vascular surgery department (depending on the patient-level and department-level)	2005-2009
Lagu et al. (2011), USA	166,931patients age≥18 with sepsis at 309 hospitals	2004-2006
lee et al. (2013), Japan	3,958 patient admitted with stroke to hospitals in Kyoto Prefecture	2009-2010
Mckay and Deily (2008), USA	a national sample of 3,384 short-term, acute-care hospitals [with at least 16 beds and 100 discharges] in the US in 1999, and 3,343 observations in 2000, and 3,183 observations in 2001, for a total of 9,910 across the three years	1999–2001
Morey et al. (1992), USA	301 US hospitals	1983
Mukammel et al. (2001), USA	Medicare fee-for-service patients in all nonfederal, acute-care, short-term hospitals (1,927 hospitals in 134 metropolitan statistical areas, with five or more acute-care hospitals) dead because of all causes and acute myocardial infarction, congestive heart failure, pneumonia, stroke, cardiac artery bypass graft procedures, and hip-replacement surgery.	1990
Mukammel et al. (2002), USA	338 acute care hospitals in California	1982-1989
Ong et al. (2009), USA	3,999 elderly age≥65 Medicare beneficiaries hospitalized with a principal diagnosis of heart failure at six California teaching hospitals [depends on looking forward and looking back cohort)	2001-2005
Osnabrugge et al. (2014), USA	42,839 patients across 17 centers performing CABG	2003-2013
Pasquali et al. (2015), USA	30,670 children age<18 undergoing congenital heart surgery in 27 hospitals	2006-2010
Picone et al. (2003), USA	5,332 elderly Medicare beneficiaries' age≥65 admitted to hospitals with primary diagnoses of hip fracture, stroke, coronary heart disease, or congestive heart failure for stays of 30 days or less.	1984-1995

Ramley et al. (2011), USA	2,545,352 patients admitted with one of the following conditions; AMI, CHF, acute stroke, gastrointestinal hemorrhage, hip fracture, pneumonia at 208 Californian hospitals in The Dartmouth Atlas of Health Care	1999-2008
Romely et al. (2013), USA	Nationwide Inpatient Sample of 2,635,510 patients admitted to 1,201 US acute care hospitals for 6 major medical conditions	2003-2007
Romely et al. (2014), USA	35,446 children age<18 undergoing surgery for CHF admitted to 332 US acute care hospitals	2003, 2006, and 2009
Saleh et al. (2012), USA	48,574 pneumonia patients age>18 admitted to 189 New York hospitals	2005
Sasaki et al. (2017), Japan	20,926 patients from 261 acute care hospitals enrolled in the QIP	2010-2011
Schreyögg & Stargardt (2010), USA	116 VHA hosptals with 35,279 patients with hospitalization for AMI	2000-2006
Stargardt et al. (2014), Germany	patients with an admission for AMI, insured in TK in 318 German hospitals	2004-2006
Yeh et al. (2014), USA	a 20% stratified sample of HCUP-NIS discharges with a primary diagnosis of acute pancreatitis from community US hospitals	2010

2.2.4 Data analysis

The extracted data were analyzed using a narrative format. As the studies were highly heterogeneous, a meta-analysis was not performed.

The main study outcome of interest was the direction and statistical significance of the reported association between the hospital cost/price and the quality of care. We evaluated the direction of the association by indicating whether the association was (significantly linear/nonlinear) positive, (significantly linear) negative, (significantly) U-shaped/inverted U-shaped, or not significant.

Statistically significant ($p < 0.1$) results were classified according to the direction of the association. Some empirical studies revealed a simple, linear cost-quality relationship and assumed a constant marginal cost associated with quality improvement. A linear positive (negative) association implies that the higher the hospital cost/price, the higher (lower) the quality of care. If different ordered categories were compared with a reference group, when either at least 75% of the coefficients reported were significantly linear positive/negative or all coefficients were in the same direction with at least one being significant, the direction of the association was classified as positive/negative.

Additionally, some other studies assumed that the marginal cost may vary over the range of quality. These studies allowed for a nonlinear association between costs and quality by including the squared terms in their estimation model. If the squared term was significant, the associations were coded as nonlinear. Such significant nonlinear associations were further categorized into the following three possible forms: (i) U-shaped relationship (i.e., in the lower range of quality, quality improves as costs decrease; however, after a certain threshold, higher quality can only be achieved with higher costs); (ii) inverted-U relationship (i.e., in the lower range of quality, quality improves with increasing costs; however, after a threshold, significant quality improvement can be achieved with relatively small increments in cost (decreasing marginal cost); and (iii) nonlinear positive relationship (i.e., quality improvement is achieved with increasing costs but decreasing marginal returns) (see Figures 2.1 and 2.2). These forms were identified based on the authors' reports. In the results section, we merged the significant linear positive and nonlinear positive relationships due to their positive direction. Studies that did not find/report a significant result ($p > 0.1$) were coded as not significant.

The quality of care measures were classified into the following two categories: outcome (e.g., mortality, readmission, complication/morbidity, quality of life indexes, and composite measures) and process measurements. Process indicators vary depending on the clinical conditions investigated; therefore, we classified the process indicators based on the clinical condition (i.e., process measures for coronary artery bypass grafting (CABG), pneumonia, congestive heart failure (CHF), acute myocardial infarction (AMI), and stroke). For instance, two process measures for CABG are prophylactic antibiotic administered on the day of the intervention and antibiotic discontinued within 48 hours.

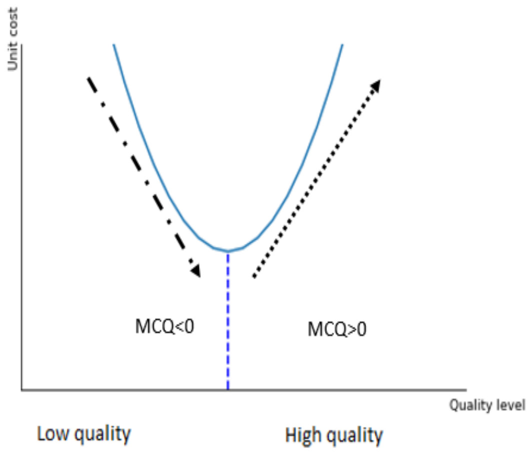

Figure 2.1 U-shaped cost-quality relationship

MCQ = Marginal cost of quality

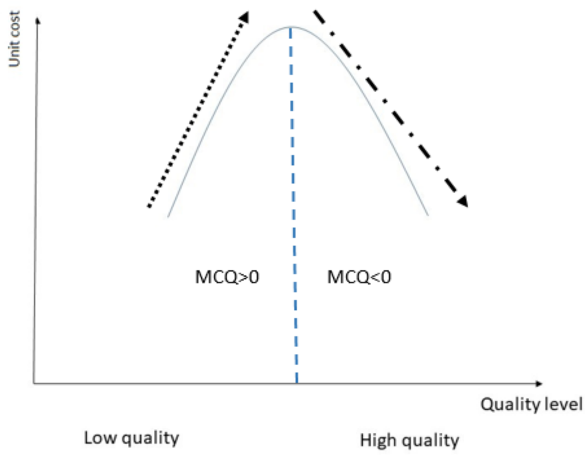

Figure 2.2 Inverted-u-shaped cost-quality relationship

MCQ = Marginal cost of quality

The quality of care measures were classified into the following two categories: outcome (e.g., mortality, readmission, complication/morbidity, quality of life indexes, and composite measures) and process

measurements. Process indicators vary depending on the clinical conditions investigated; therefore, we classified the process indicators based on the clinical condition (i.e., process measures for coronary artery bypass grafting (CABG), pneumonia, congestive heart failure (CHF), acute myocardial infarction (AMI), and stroke). For instance, two process measures for CABG are prophylactic antibiotic administered on the day of the intervention and antibiotic discontinued within 48 hours.

The cost measures were classified into the following two categories: (i) accounting costs reflecting the best use of hospital resources (measured by the providers' accounting system or cost-to-charge ratio) and (ii) costs due to inefficiency, i.e., costs associated with waste or inefficiency, obtained from a cost frontier analysis or data envelopment analysis. As very few studies assessed cost due to inefficiency, we do not differentiate the two categories in the results section.

The price measures were based on price/reimbursement, which reflects the payment that hospitals or other healthcare providers receive for providing medical services to patients (this could be a DRG-based payment or other reimbursement and price changes).

The clinical conditions were classified into the following 6 main categories: (i) AMI, (ii) CHF, (iii) pneumonia, (iv) stroke, (v) CABG, and (vi) hip replacement/fracture. We further aggregated various surgical procedures that had fewer than 5 associations into one category named other surgical procedures, which included vascular surgery, colectomy, abdominal aortic aneurysm repair, cholecystectomy, general surgery, orthopedic surgery, cardiothoracic or gastrointestinal operation, knee replacement surgery, varicose vein surgery, and groin hernia surgery. Moreover, we aggregated all diverse medical conditions with fewer than 5 associations into one category named other medical conditions, which included circulatory system diseases, cerebrovascular disorder, bronchitis and asthma, cardiac arrhythmia, angina pectoris, gastrointestinal hemorrhage, esophagitis, nutritional disorders, sepsis, emergency medical conditions, pediatric critical care, psychosomatic patients with somatoform pain disorder, and acute pancreatitis. Studies that either considered no specific conditions or all patients overall were categorized as indeterminate.

The countries were classified into twelve categories, including the USA, Canada, the UK, Germany, Italy, Spain, France, Hungary, Japan, Korea, Nordic countries (i.e., Sweden, Norway, Finland, and Denmark), and associations based on pooled sample countries.

The systematic search included the years between 1990 and 2018. We distinguished among the following three periods of approximately ten years each: (i) 1990-1999, (ii) 2000-2009, and (iii) 2010-2018.

We classified the studies' methods by the degree to which they approximated the causal effect based on the method used to address confounding as follows: (i) experimental studies, including RCT and natural or quasi-experiments (e.g., difference-in-difference design); none of our reviewed studies used an experimental design; (ii) nonexperimental studies using techniques that control for unobservables, such as an instrumental variable approach; (iii) studies controlling for observables to adjust for confounding via a regression approach (e.g., panel or cross-section); and (iv) studies using a correlation analysis.

2.3 Results

In total, 4416 articles were retrieved from the systematic search for studies newer than 2012 and studies conducted outside the US between 1990 and 2012. After removing duplicates, 2225 articles remained. Following the exclusion of articles based on the titles or abstracts, 54 articles were subjected to full-text reading. The full texts of the included studies were independently examined by two reviewers. On the basis of the inclusion and exclusion criteria, 22 articles were included through the systematic search (see Figure 2.3).

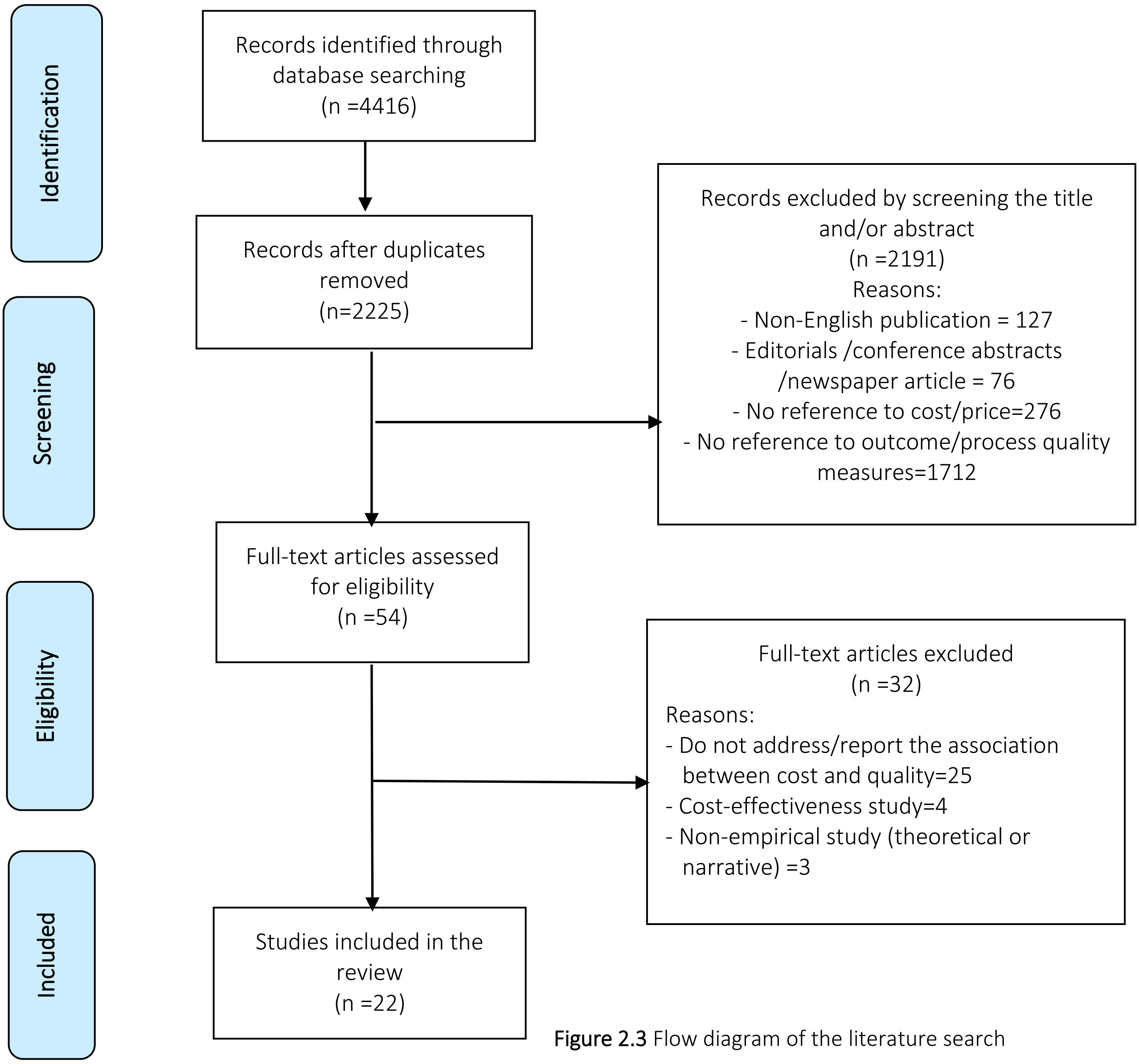

Figure 2.3 Flow diagram of the literature search

In addition, 21 studies included by Hussey et al. and four initial studies investigating the 'price-quality' relationship were added to our final review (i.e., a total of 47 studies). No additional articles were identified by searching the reference lists of these four studies. Moreover, all studies identified through the forward search had already been detected by the systematic search processes targeting the cost-quality relationship.
In total, 47 studies were included in the review, including nine studies that analyzed the price-quality relationship and 38 studies that assessed the cost-quality relationship. In these 47 studies, 225 associations between cost/price and quality measures were reported. The data extracted from the included studies are presented in Table 2.1, and in the appendix, Table 2.5 (study level), and Table 2.6 (association level).

Most studies (66%) were conducted in the USA, 29% of the studies were conducted in Europe, and the remaining 5% of the studies were conducted in Asia. Additionally, most studies (69%) were published between 2010 and 2018.

The evidence regarding the association between cost/price and the quality of care is summarized in Appendix C. The included studies were widely heterogeneous in terms of the cost measures, quality measures, clinical conditions, countries, and methods used to control for observables and unobservable.

Overall, 74 (33%) associations between the unit cost/price and the unit quality were significantly positive, 33 (15%) associations were significantly negative, 11 (5%) associations were significantly U-shaped/inverted-U-shaped, and 105 (47%) associations were not significant.

2.3.1 Findings by cost/price measurement

Among the included studies, cost/price was assessed via multiple indicators (Table 2.2). Of the 225 associations, 165 (73%) associations were based on cost measures (accounting costs or costs due to inefficiency), while 60 (27%) associations relied on price/reimbursement measures. Compared to the studies using cost measures, a larger share of the significant positive associations occurred in the studies based on price measures (33% vs. 37%, respectively). Overall, the results of the associations were more mixed among the cost measure associations.

Table 2.2 Overview on study findings on the cost/price-quality relationship in total and for different subcategories

	Sign. Linear/non-linear positive	Sign. linear negative	Sign. non-linear U-shaped/ inverted U-shaped	Not sign.	<u>Total</u>
	(n) (% of ni)	(n) (% of ni)	(n) (% of ni)	(n) (% of ni)	**(n_i) (% of 225)**
<u>Total</u>	**76 (33%)**	**33 (15%)**	**11 (5%)**	**105 (47%)**	**225 (100%)**
Cost/price measure					
Price/reimbursement	22 (37%)	7 (11%)	0 (0%)	31 (52%)	**60 (27%)**
Cost (aggregate)	54 (33%)	26 (16%)	11 (6%)	74 (45%)	**165 (73%)**
Quality of care measure					
<u>Outcome</u>	**62 (32%)**	**26 (14%)**	**11 (6%)**	**93 (48%)**	**192 (85%)**
- Mortality	56 (40%)	12 (9%)	4 (3%)	68 (49%)	140 (62%)
- Readmission	3 (25%)	1 (8%)	3 (25%)	5 (42%)	12 (5%)
- Complication/morbidity	0 (0%)	12 (46%)	1 (4%)	13 (50%)	26 (12%)
- Quality of Life Index (QoL)	3 (23%)	1 (8%)	3 (23%)	6 (46%)	13 (6 %)
- Composite measure	0 (0%)	0 (0%)	0 (0%)	1 (100%)	1 (0.5%)
<u>Process measures</u>	**14 (43%)**	**7 (21%)**	**0 (0%)**	**12 (36%)**	**33 (15%)**
- Process (unspecified)	1 (100%)	0 (0%)	0 (0%)	0 (0%)	1 (0.5%)
- CABG process measure	2 (29%)	3 (43%)	0 (0%)	2 (29%)	7 (3%)
- Pneumonia process measure	0 (0%)	4 (33%)	0 (0%)	8 (67%)	12 (5%)
- CHF process measure	4 (80%)	0 (0%)	0 (0%)	1 (20%)	5 (2%)
- AMI process measure	1 (100%)	0 (0%)	0 (0%)	0 (0%)	1 (0.5%)
- Stroke process measure	6 (86%)	0 (0%)	0 (0%)	1 (14%)	7 (3%)
Clinical conditions					
AMI	21 (70%)	0 (0%)	0 (0%)	9 (30%)	**30 (13.5%)**
CHF	12 (63%)	4 (21%)	0 (0%)	3 (16%)	**19 (8%)**
Pneumonia	1 (5%)	6 (30%)	0 (0%)	13 (65%)	**20 (9%)**

Stroke	14 (50%)	0 (0%)	2 (7%)	12 (43%)	**28 (12.5%)**
CABG	2 (18%)	4 (36%)	0 (0%)	5 (45%)	**11 (5%)**
Hip fracture/replacement	1 (8%)	1 (8%)	4 (33%)	6 (50%)	**12 (5%)**
other surgical procedures	5 (16%)	12 (38%)	3 (9%)	12 (38%)	**32 (14%)**
other medical conditions	11 (22%)	4 (8%)	2 (4%)	32 (65%)	**49 (22%)**
not available conditions	9 (38%)	2 (8%)	0 (0%)	13 (54%)	**24 (11%)**
Country					
Canada	2 (100%)	0 (0%)	0 (0%)	0 (0%)	**2 (1%)**
Germany	2 (50%)	0 (0%)	0 (0%)	2 (50%)	**4 (2%)**
Italy	3 (75%)	0 (0%)	0 (0%)	1 (25%)	**4 (2%)**
Nordic countries (Denmark, Estonia, Finland, Iceland, Norway, Sweden)	8 (25%)	4 (1%)	3 (9%)	17 (53%)	**32 (14%)**
Japan	6 (60%)	0 (0%)	0 (0%)	4 (40%)	**10 (4%)**
Korea	0 (0%)	0 (0%)	0 (0%)	1 (100%)	**1 (0.5%)**
France	0 (0%)	0 (0%)	0 (0%)	2 (100%)	**2 (1%)**
Hungary	2 (50%)	0 (0%)	1 (25%)	1 (25%)	**4 (2%)**
Spain	0 (0%)	0 (0%)	0 (0%)	2 (100%)	**2 (1%)**
UK	1 (9%)	1 (9%)	3 (27%)	6 (55%)	**11 (5%)**
USA	49 (33%)	28 (19%)	4 (3%)	67 (45%)	**148 (66%)**
Pooled Sample	3 (60%)	0 (0%)	0 (0%)	2 (40%)	**5 (2.5%)**
Year					
1990-1999	3 (8%)	5 (14%)	4 (11%)	25 (68%)	**37 (16%)**
2000-2009	14 (41%)	2 (6%)	0 (0%)	18 (53%)	**34 (15%)**
2010-2019	59 (38%)	26 (17%)	7 (5%)	62 (40%)	**154 (69%)**
Methods					

Correlation	2 (25%)	0 (0%)	0 (0%)	6 (75%)	**8** **(4%)**
Cfo - regression approach	47 (29%)	29 (18%)	5 (3%)	82 (50%)	**163** **(72%)**
CfU – IV approaches	27 (50%)	4 (7%)	6 (11%)	17 (32%)	**54** **(24%)**

CfO – Controlling for Observables
CfU – Controlling for Unobservables
IV - Instrumental Variable

2.3.2 Findings by the quality of care measurement

As presented in Table 2.2, the quality of care was assessed using different outcome and process indicators. The outcome indicators comprised the following five main categories: mortality, readmission, complication/morbidity, composite measures, and quality of life indexes. These five categories consist of several subcategories or different measures. Mortality comprises in-hospital, infant and posthospital mortality (i.e., 30-days, 6-month, 1-year, 2-year, 3-year mortality, and time to death with a maximum of 365 days). Readmission covers return periods of 14 days, 30 days, and one year. The quality of life indexes include generic PROM (such as the EQ-5D and EQ-VAS), condition-specific PROM (including the Oxford Hip Score, Oxford Knee Score, and Aberdeen Varicose Vein Questionnaire), the Health Activity Limitations index, and the overall functioning of mental health (MCS-8 score).

In total, 192 (85%) associations relied on the outcome quality of care measures, while only 33 (15%) associations were based on process measures. The most commonly used outcome measure was mortality (140 of 192, 73%). Among the 140 studies using mortality, most relied on the 30-day mortality (63 of 140, 45%) or in-hospital mortality (57 of 140, 41%).

The share of nonsignificant associations reported when process measures were used was lower than that when outcome measures were used (36% to 48%). The shares of both significant positive and significant negative associations using process measures were higher than those using outcome measures. When further differentiating among the types of outcome measures, the share of significant negative associations was especially high using complications/comorbidities as the quality measure. This result is intuitive because as a negative quality outcome, complications have the highest potential to increase costs (i.e., the lower the quality and the greater the number of complications, the higher the costs).

2.3.3 Findings by clinical condition(s)

Of the reviewed studies, 89% of the studies focused on specific conditions, and the other 11% of the studies considered either no specific conditions or all patients. Of those that focused on specific condition(s), the most commonly studied conditions were surgical procedures (32 of 201, 16%), AMI (30 of 201, 15%), stroke (28 of 201, 14%), pneumonia (20 of 201, 10%), and CHF (19 of 201, 9%). The most positive evidence of an association between cost/price and the quality of care was observed in AMI, CHF, and stroke. Among the 30 studies investigating AMI, 21 (70%) studies found a significantly positive association; of the 19 studies investigating CHF, 12 (63%) studies found a significantly positive association; and of the 28 studies investigating stroke, 14 (50%) studies found a significantly positive association. Relatively higher shares of significantly negative associations were found in the other surgical procedures (12 of 32 associations, 38%), CABG (4 of 11, 36%), and pneumonia (6 of 20, 30%). The share of nonsignificant associations was especially high in the other medical conditions (32 of 49, 65%) and pneumonia (13 of 20, 65%).

2.3.4 Findings by country

In total, 148 of 225 or 66% of all associations were based on US data. The second most frequent data source was Nordic countries (Denmark, Sweden, Finland, and Norway), with an aggregate of 32 associations. Only two other countries – Japan and the UK – yielded at least 10 associations. Among the countries with at least ten associations, the findings of two data origins deviate substantially from the overall distribution of findings as follows: the Japanese data had a high share of significantly positive findings (6 of 10, 60%), and the UK data had a high share of U-shaped associations (27%).

2.3.5 Findings by year

Most studies were conducted during the last period (from 2010 to 2018, representing 69% of all associations), and the share of nonsignificant associations decreased over time (from 68% in 1990-1999 to 40% in 2010-2018). The most mixed results were reported during the period from 2000 to 2009.

2.3.6 Findings by methodological approach

The included studies exhibited considerable heterogeneity in methodology. Of the 225 associations, 8 (4%) studies used a correlation analysis, 163 (72%) studies controlled for observables via a regression analysis (e.g., panel or cross-section), and 54 (24%) studies controlled for unobservables using instrumental variables to address confounding.

As the degree of sophistication and approximation of the true causal effect increased, the share of nonsignificant associations decreased (from 75% in the studies using correlation analyses to 32% in the studies using IV analyses). Of all methods, the IV approach yielded the highest share of positive associations (50% compared to 29% or less in the studies using other methods).

2.3.7 Findings by price measurement sub-section

In the final step, we focused on the findings of studies using price as these studies have not been previously subjected to a literature review. In particular, we aim to assess whether a distinct picture emerges regarding findings solely based on the price-quality relationship. The 60 associations included are divided by the previously used categorizations and summarized in Table 2.3. In total, as already displayed in Table 2.2, the associations are slightly more often significantly positive, and no study found a U-shaped relationship between price and the quality of care.

Regarding the quality of care measurement, 53 (88%) associations relied on an outcome quality measure, while only 7 (12%) associations were based on process measures. The most commonly used outcome measure was mortality (40 of 53, 75%). Process measures were investigated only in the case of stroke, and when process measures were used, the share of nonsignificant associations was lower than that when outcome measures were used (14% to 39%). Of the reviewed studies investigating the price-quality association, the most commonly studied conditions were medical conditions (24 of 56, 43%). The most positive evidence was observed in stroke, AMI, and CHF. In total, 83% of all associations were based on US data, and the Japanese data had a high share of significantly positive findings (6 of 9, 60%). Most studies were conducted during the last period (from 2010 to 2018, representing 50% of all associations), and the share of nonsignificant associations decreased over time (from 85% in 1990-1999 to 17% in 2010-2018). Of all methods, the IV approach yielded the highest share of positive associations (87.5% compared to 67% or less in studies using other methods).

Table 2.3 Overview on study findings on the price-quality relationship in total and for different subcategories

	Sign. linear positive	Sign. linear negative	Not sign.	**Total**
	(n) (% of ni)	(n) (% of ni)	(n) (% of ni)	**(ni)** **(% of 60)**
Total Price/reimbursement	*22* *(37%)*	*7* *(11.5%)*	*31* *(51.5%)*	*60* *(100%)*
Quality of care measure				
Outcome	**16** **(30%)**	**7** **(13%)**	**21** **(39%)**	**53** **(88%)**
- Mortality	16 (40%)	4 (10%)	20 (50%)	**40** **(67%)**
- Readmission	0 (0%)	0 (0%)	1 (100%)	**1** **(1%)**
- Complication/morbidity	0 (0%)	3 (25%)	9 (75%)	**12** **(20%)**
Process measures	**6** **(86%)**	**0** **(0%)**	**1** **(14%)**	**7** **(12%)**
- Stroke process measure	6 (86%)	0 (0%)	1 (14%)	**7** **(12%)**
Clinical conditions				

AMI	4 (67%)	0 (0%)	2 (33%)	**6 (10%)**
CHF	2 (67%)	1 (34%)	0 (0%)	**3 (5%)**
Stroke	9 (75%)	0 (0%)	3 (25%)	**12 (20%)**
Pneumonia	0 (0%)	1 (34%)	2 (66%)	**3 (5)**
Hip fracture/replacement	1 (100%)	0 (0%)	0 (0%)	**1 (1.5%)**
other surgical procedures	4 (57%)	3 (43%)	0 (0%)	**7 (11.5%)**
other medical conditions	2 (8.5%)	2 (8.5%)	20 (83%)	**24 (40%)**
not available conditions	0 (0%)	0 (0%)	4 (100%)	**4 (7%)**
Country				
Germany	1 (100%)	0 (0%)	0 (0%)	**1 (2%)**
Japan	6 (60%)	0 (0%)	3 (40%)	**9 (15%)**
USA	15 (30%)	7 (14%)	28 (56%)	**50 (83%)**
Year				
1990-1999	1 (4%)	3 (11%)	22 (85%)	**26 (43%)**
2000-2009	0 (0%)	0 (0%)	4 (100%)	**4 (7%)**
2010-2018	21 (70%)	4 (13%)	5 (17%)	**30 (50%)**
Methods				
CfO a. multivariable model (cross-section)	6 (67%)	0 (0%)	3 (34%)	**9 (15%)**
CfO b. multivariate model	9 (21%)	7 (16%)	27 (63%)	**43 (72%)**
CfU – IV approaches	7 (87.5%)	0 (0%)	1 (12.5%)	**8 (13%)**

CfO – Controlling for Observables
CfU – Controlling for Unobservables
IV - Instrumental Variable

2.4 Discussion

In this study, we conducted a systematic literature review to identify and summarize evidence regarding the association between cost/price and the quality of care in the hospital setting. To the best of our knowledge, this study represents the first comprehensive systematic literature review focusing on the association between cost/price and the quality of care that is not geographically restricted. The most frequent finding in our included studies was a nonsignificant association between price/cost and the quality of care (47% of all associations). We conducted a systematic review to synthesize the evidence regarding the association between hospital cost/price and the quality of care and identify sources of heterogeneity across studies. To date, only one systematic review performed by Hussey et al. (2013) analyzed the association between cost and the quality of care and aggregated and reported the results at the study level (Hussey, Wertheimer et al. 2013). Our findings are partially contradictory to those reported by Hussey et al. (2013), who found nonsignificant or mixed findings in only 26% of their studies. Some differences can be explained by our inclusion of price instead of only costs, the inclusion of the clinical conditions investigated in each paper, the addition of countries other than the US, and the longer time frame, all leading to increases in the share of nonsignificant findings. Moreover, a large part might also be due to differences in the classification of the results and the level of aggregation (study level versus association level).

In summary, we find highly mixed evidence of the association. One potential explanation is the multiple ways that price and cost can relate to the quality of care. Another explanation might be the high heterogeneity across the included studies. Most notably, the overall pattern of the relationships between hospitals' price-quality and cost-quality were quite similar. Indeed, some variations can be explained by the studies' characteristics. In particular, we find that the proportion of studies that detected a significantly positive association is higher when a) price/reimbursement is used (instead of cost); b) process measures are used (instead of outcome measures); c) the focus is on AMI, CHF, and stroke patients (instead of patients with other clinical conditions or all patients); and d) the methodological approach used to address confounding is more sophisticated. In the following, we discuss the extent to which these results can be explained to increase our understanding of the cost/price-quality of care relationship.

Regarding our findings, the share of positive associations between cost/price and the quality of care is higher when price is assessed instead of cost. One potential mechanism implies that in the face of a price increase for a particular diagnosis or treatment, more patients may be admitted to the hospital (i.e., volume increases), which could lead to a higher quality of care due to institutional learning (Fleming 1991, Gaynor, Seider et al. 2005, Brekke, Siciliani et al. 2011). Moreover, higher prices might enable hospitals to spend more on service provision, which might have a positive effect on the quality of care. This line of argument is supported by prior evidence showing that when the price/cost margins are high, hospitals may compete in quality to attract more patients (Dranove and White 1998). This view is also consistent with the traditional profit-maximization model of hospital behavior, which predicts that a reduction in price will lead to a reduction in quality (Hodgkin and McGuire 1994). However, the profit-maximization model might not adequately describe a hospital's decision making because a high proportion of hospitals are organized as not-for-profit institutions. Therefore, as described in Newhouse's (1970) theory of nonprofit behavior, hospitals use the excess of payments over costs for those patient groups that are profitable to expand the quality of services (Newhouse 1970, Bazzoli, Chen et al. 2008).

Based on our findings, the share of positive associations between cost/price and the quality of care is higher when process rather than outcome measures are assessed. Process measures might be more sensitive to changes in a hospital's cost/price and more reflective of the factors under the hospital's control than outcome measures (Volpp, Konetzka et al. 2005). Moreover, changes in process measures might affect the hospital cost. For example, providing appropriate care frequently requires additional physician visits and medications (Nuckols, Escarce et al. 2013).

Regarding our findings, the share of positive associations between cost/price and the quality of care is higher when the focus is on AMI, CHF, and/or stroke patients (instead of patients with other clinical conditions or all patients). Notably, in contrast to many other conditions, AMI, CHF, and stroke are emergency conditions. For these conditions, the steering and organization of emergency pathways (e.g., centralization and telemedicine) lead to an increase in patients, and costs are higher due to 24/7 infrastructure and operation (contingency) costs. In this case, quality (particularly mortality measures) should also increase because of the volume/outcome relationship.

Based on our findings, the share of positive associations between cost/price and the quality of care is higher when the methodological approach used to address confounding is more advanced. Endogeneity is clearly an issue in the price/cost-quality relationship, e.g., due to the high risk of omitted variable bias (e.g., insufficient risk adjustment, unobserved variations in hospital equipment and organization of service provision). If methods that more appropriately rule out endogeneity bias find stronger support, this might imply that the other studies underestimate the true effect.

During our analysis, we observed that only a small share of studies tested for a nonlinear cost-quality relationship. Among these studies, U-shaped/inverted U-shapes relationships were assessed mostly in studies using more advanced econometric methods (e.g., the IV approach) and those concentrating on hip fracture/replacement conditions.

The current systematic review is subject to several limitations. First, the heterogeneity in the studies' criteria limited our ability to perform a quantitative synthesis or any other comparisons across the studies. In addition, this review was limited by the quality of the included studies. Moreover, there is a possibility of publication bias because no gray literature was searched, and non-English language publications were excluded.

Although our study may answer important questions regarding the association between cost/price and the quality of care, other related questions may remain unanswered. Given our findings, we observed some differences in the associations between surgical and medical conditions. Future work could explain the reason for these differences. Additionally, we focus on several critical design characteristics that may alter the association between cost/price and the quality of care; however, some other characteristics, such as market characteristics (e.g., competition), might be able to explain some differences in the cost/price-quality relationship[2]. For example, hospitals with a large number of beds relative to the population size might have more competition for nurses, which increases labor costs (Dranove, Shanley et al. 1993). This review also suggests that more research is needed to generate robust evidence regarding the association between cost/price and the quality of care.

2.5 conclusion

In conclusion, our review suggests that there is no general relationship between cost/price and the quality of care. However, when accounting for endogeneity, the evidence suggests that a positive relationship exists. Thus, the potential to increase the quality of care while maintaining or reducing the price and cost levels is low for several conditions, while for other conditions, the evidence is inconclusive. Additionally, the relationship appears to depend on the condition and the specific resource utilization. Moreover, different countries/regions have different regulations for quality assurance (e.g., staffing regulation, mortality and morbidity-conferences, technology use, and minimum volumes), which clearly has an effect on cost and quality. Therefore, policy makers should be prudent with the measures used to reduce hospital costs to avoid endangering the quality of care, especially in resource-sensitive settings.

[2] None of the included studies controlled for such covariates.

2.6 Appendix

Table 2.4 Detailed search strategy MEDLINE (Pubmed) (search date: March 2019)

Population:	
#1	"inpatient*" [MeSH Terms] OR "patient*" [MeSH Terms] OR "hospital patient*" [MeSH Terms] OR "hospital inpatient*" [MeSH Terms] OR "hospital admission*" [MeSH Terms] OR "hospital*" [MeSH Terms]
Intervention:	
#2	"inpatient spending*" [Title/Abstract] OR "cost*" [Title/Abstract] OR "price*" [Title/Abstract] OR "Diagnosis related group**" [Title/Abstract] OR "DRG*" [Title/Abstract] OR "hospital price*" [Title/Abstract] OR "hospital payment"[Title/Abstract] OR "hospital expenditure"[Title/Abstract] OR "hospital charge*" OR" hospital reimbursement" [Title/Abstract] OR "cost-quality trade-off*" [Title/Abstract])) AND NOT ("cost-effective*"[Title] OR "home care" [Title] OR "nursing home" [Title] OR "cost-utility"[Title])
Outcome:	
#3	("Quality of Health Care" OR "Quality of Care" OR "Postoperative Complications" OR "Postoperative Complications" OR "Quality of Life"[MeSH Terms])
#4	"quality" [Title/Abstract] OR "outcome*" [Title/Abstract] OR "outcome assessment*" [Title/Abstract] OR "quality of life" [Title/Abstract] OR "surgical infection" [Title/Abstract] OR "complication* "[Title/Abstract] OR "morbidity" [Title/Abstract] OR "mortality" [Title/Abstract] OR "death*" [Title/Abstract] OR "survival*" [Title/Abstract] OR "readmission*" [Title/Abstract]
#5	(#3 OR #4) AND #2
#6	#1 OR #5

Source: Authors' representation based on the PICOS framework

Table 2.5 Detailed information on studies included in literature review

Author name(s)	Article title	Journal name	E-mail	Affiliation
AUERBACH, A. D.*, HILTON, J. F., MASELLI, J., PEKOW, P. S., ROTHBERG, M. B. & LINDENAUER, P. K.	Case volume, quality of care, and care efficiency in coronary artery bypass surgery	Archives of internal medicine	ada@medicine.ucsf.edu	Department of Medicine Hospitalist Group, University of California, San Francisco
BIRKMEYER, J. D.*, GUST, C., DIMICK, J. B., BIRKMEYER, N. J. & SKINNER, J. S.	Hospital quality and the cost of inpatient surgery in the United States	Annals of surgery	jbirkmey@umich.edu	Center for Healthcare Outcomes & Policy, AnnArbor, MI
BRADBURY, R. C.*, GOLEC, J. H. & STEEN, P. M.	Relating hospital health outcomes and resource expenditures	Inquiry	rbradbury@clarku.edu	School of Management, Clark University
BRADBURY, R.*, GOLEC, J. & STEEN, P.	Toward a systems quality paradigm: relating health outcomes, resource expenditures, and appropriateness of cholecystectomy patients	Health services management research	rbradbury@clarku.edu	School of Management, Clark University
BRODERICK, R. C.*, FUCHS, H. F., HARNSBERGER, C. R., CHANG, D. C., MCLEMORE, E., RAMAMOORTHY, S. & HORGAN, S.	The price of decreased mortality in the operative management of diverticulitis	Surgical endoscopy	rbroderick@ucsd.edu	Division of Minimally Invasive Surgery, Department of Surgery, Center for the Future of Surgery, University of California Sann Diego,
CAREY, K.* & BURGESS JR, J. F.	On measuring the hospital cost/quality trade-off	Health economics	kathleen.carey@med.va.gov	US Department of Veterans Affairs Management Science Group, Bedford, MA, USA
CHAN, T*., KIM, J., MINICH, L. L., PINTO, N. M. & WAITZMAN, N. J.	Surgical volume, hospital quality, and hospitalization cost in congenital heart surgery in the United States	Pediatric cardiology	titus.chan@seattlechildrens.org	Division of Critical Care Medicine and the Heart Center, Department of Pediatrics, Seattle Children's Hospital, University of Washington
CHEN, L. M.*, JHA, A. K., GUTERMAN, S., RIDGWAY, A. B., ORAV, E. J. & EPSTEIN, A. M.	Hospital cost of care, quality of care, and readmission rates: penny wise and pound foolish?	Archives of internal medicine	lenac@umich.edu	Division of General Medicine, Department of Internal Medicine, University of Michigan

Author name(s)	Article title	Journal name	E-mail	Affiliation
COHEN, D*., MANUEL, D. G., TUGWELL, P., SANMARTIN, C. & RAMSAY, T.	Does Higher Spending Improve Survival Outcomes for Myocardial Infarction? Examining the Cost-Outcomes Relationship Using Time-Varying Covariates	Health services research	deborah.cohen@rogers.com	Department of Population Health, University of Ottawa, Institute for Clinical Evaluative Sciences
CUTLER, D. M. *	The incidence of adverse medical outcomes under prospective payments	National Bureau of Economic Research	dcutler@harvard.edu	Department of Economics at Harvard University
DAFNY, L. S.*	How do hospitals respond to price changes?	American Economic Review	l-dafny@kellogg.northwestern.edu	Kellogg School of Management, Northwestern University
DEILY, M. E. *& MCKAY, N. L.	Cost inefficiency and mortality rates in Florida hospitals	Health Economics	med4@lehigh.edu	Department of Economics, Lehigh University, USA
DOYLE JR, J. J.*, GRAVES, J. A., GRUBER, J. & KLEINER, S. A*.	Measuring returns to hospital care: Evidence from ambulance referral patterns.	Journal of Political Economy	skleiner@cornell.edu	Department of Policy Analysis and Management Cornell University
DUGGAN, M. G.*	Hospital ownership and public medical spending	The Quarterly Journal of Economics	mgduggan@stanford.edu	Stanford University Department of Economics
FLEMING, S. T.*	The relationship between quality and cost: pure and simple?	Inquiry	stflem2@uky.edu	Health Services Management Department, University of Missouri-Columbia
GANI, F., EJAZ, A., MAKARY, M. A. & PAWLIK, T. M.*	Hospital markup and operation outcomes in the United States	Surgery	tpawlik1@jhmi.edu	Department of Surgery, a Johns Hopkins University School of Medicine, Baltimore
GLANCE, L. G.*, DICK, A. W., OSLER, T. M., MEREDITH, W. & MUKAMEL, D. B.	The association between cost and quality in trauma: is greater spending associated with higher-quality care?	Annals of surgery	Laurent_Glance@urmc.rochester.edu	University of Rochester Medical Center
GUPTA, P.* & RETTIGANTI, M.	Relationship of Hospital Costs With Mortality in Pediatric Critical Care: A Multi-Institutional Analysis	Pediatric critical care medicine	pgupta2@uams.edu	1Division of Pediatric Cardiology, Department of Pediatrics, Arkansas Children's Hospital, the University of Arkansas for Medical Sciences
GUTACKER, N.*, BOJKE, C., DAIDONE, S., DEVLIN, N. J., PARKIN, D. & STREET, A.	Truly inefficient or providing better quality of care? analysing the relationship between risk-adjusted hospital costs and patients'health outcomes	Health economics	nils.gutacker@york.ac.uk	The University of York, Centre for Health Economics, York, UK

Author name(s)	Article title	Journal name	E-mail	Affiliation
HAAS, L.*, STARGARDT, T., SCHREYOEGG, J., SCHLÖSSER, R., KLAPP, B. F. & DANZER, G.	The trade-off between costs and quality of care in the treatment of psychosomatic patients with somatoform pain disorder	Applied health economics and health policy	laura.haas@charite.de	Department of Psychosomatic Medicine, Charite´ Center for Internal Medicine and Dermatology, Charite´ Universitaetsmedizin, Luisenstr.
HADLEY, J.*, WAIDMANN, T., ZUCKERMAN, S. & BERENSON, R. A.	Medical spending and the health of the elderly	Health services research	jhadley1@gmu.edu	Department of Health Administration and Policy, College of Health and Human Services, George Mason University
HÄKKINEN, U.*, ROSENQVIST, G., IVERSEN, T., REHNBERG, C., SEPPÄLÄ, T. T. & GROUP, E. S.	Outcome, use of resources and their relationship in the treatment of AMI, stroke and hip fracture at European hospitals	Health economics	unto.hakkinen@thl.fi	National Institute for Health and Welfare, Centre for Health and Social Economics, Finland
HÄKKINEN, U.*, ROSENQVIST, G., PELTOLA, M., KAPIAINEN, S., RÄTTÖ, H., COTS, F., GEISSLER, A., OR, Z., SERDÉN, L. & SUND, R.	Quality, cost, and their trade-off in treating AMI and stroke patients in European hospitals	Health Policy	unto.hakkinen@thl.fi	Centre for Health and Social Economics, National Institute for Health and Welfare, Finland
HVENEGAARD,A.*, NIELSEN ARENDT, J., GYRD-HANSEN, D. & STREET, A.	Exploring the relationship between costs and quality-Does the joint evaluation of costs and quality alter the ranking of Danish hospital departments?	The European Journal of Health Economics	ah@dsi.dk	Danish Institute for Health Services Research, University of Southern Denmark, Odense, Denmark
JHA, A. K.*, ORAV, E. J., DOBSON, A., BOOK, R. A. & EPSTEIN, A. M.	Measuring efficiency: the association of hospital costs and quality of care	Health Affairs	ajha@hsph.harvard.edu	Harvard School of PublicHealth
KAESTNER, R. & SILBER, J. H.	Evidence on the efficacy of inpatient spending on Medicare patients	The Milbank quarterly	kaestner@uic.edu	Institute of Government and Public Affairs, University of Illinois
KANG, H.-C. & HONG, J.-S.*	Association between costs and quality of acute myocardial infarction care hospitals under the Korea National Health Insurance program	Medicine	jshong@cju.ac.kr	Department of Healthcare Management, Cheongju University College of Health Sciences

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KITTELSEN, S. A.*, ANTHUN, K. S., GOUDE, F., HUITFELDT, I. M., HÄKKINEN, U., KRUSE, M., MEDIN, E., REHNBERG, C., RÄTTÖ, H. & GROUP, E. S.	Costs and quality at the hospital level in the Nordic countries	Health economics	sverre.kittelsen@frisch.uio.no	Frisch Centre, Oslo, Norway
KRUSE, M.* & CHRISTENSEN, J	Is quality costly? Patient and hospital cost drivers in vascular surgery	Health economics review	makr@kora.dk	Danish Institute for Local and Regional Government Research
LAGU, T., ROTHBERG, M. B., NATHANSON, B. H., PEKOW, P. S., STEINGRUB, J. S. & LINDENAUER, P. K.	The relationship between hospital spending and mortality in patients with sepsis	Archives of internal medicine	lagutc@gmail.com	Center for Quality of Care Research, Baystate Medical Center
LEE, J., MORISHIMA, T., PARK, S., OTSUBO, T., IKAI, H.& IMANAKA, Y. *	The association between health care spending and quality of care for stroke patients in Japan	Journal of Health Services Research & Policy	imanaka-y@umin.net	Department of Healthcare Economics and Quality Management, School of Public Health, Graduate School of Medicine, Kyoto University
MCKAY, N. L. & DEILY, M. E.	Cost inefficiency and hospital health outcomes	Health Economics	nmckay@phhp.ufl.edu	Department of Health Services Research, Management, and Policy, University of Florida
MOREY, R. C., FINE, D. J., LOREE, S. W., RETZLAFF-ROBERTS, D. L. & TSUBAKITANI, S.	The trade-off between hospital cost and quality of care: An exploratory empirical analysis	Medical Care	n.a.	Department of Health Systems Management, School of Public Health and Tropical Medicine, Tulane University
MUKAMEL, D. B., ZWANZIGER, J. & BAMEZAI, A.	Hospital competition, resource allocation and quality of care	BMC Health Services Research	dana_mukamel@urm.rochester.edu	University of Rochester Medical Center, Rochester, New York
MUKAMEL, D. B., ZWANZIGER, J. & TOMASZEWSKI, K. J.	HMO penetration, competition, and risk-adjusted hospital mortality	Health services research	dana_mukamel@urm.rochester.edu	University of Rochester Medical Center, Rochester, New York
ONG, M. K.*, MANGIONE, C. M., ROMANO, P. S., ZHOU, Q., AUERBACH, A. D., CHUN, A., DAVIDSON, B., GANIATS, T. G., GREENFIELD, S. & GROPPER, M. A.	Looking forward, looking back: assessing variations in hospital resource use and outcomes for elderly patients with heart failure.	Circulation: cardiovascular quality and outcomes	michael.ong@ucla.edu	David Geffen School of Medicine at the University of California, Los Angeles, Department of Medicine, Division of General Internal Medicine & Health Services Research

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OSNABRUGGE, R. L., SPEIR, A. M., HEAD, S. J., JONES, P. G., AILAWADI, G., FONNER, C. E., FONNER JR, E., KAPPETEIN, A. P. & RICH, J. B.*	Cost, quality, and value in coronary artery bypass grafting	The Journal of thoracic and cardiovascular surgery	jeffrich2014@cox.net	Norfolk, Va
PASQUALI, S. K.*, JACOBS, J. P., BOVE, E. L., GAYNOR, J. W., HE, X., GAIES, M. G., HIRSCH-ROMANO, J. C., MAYER, J. E., PETERSON, E. D. & PINTO, N. M.	Quality-cost relationship in congenital heart surgery	The Annals of thoracic surgery	pasquali@med.umich.edu	University of Michigan, C.S. Mott Children's Hospital
PICONE, G. A.*, SLOAN, F. A., CHOU, S.-Y. & TAYLOR JR, D. H.	Does higher hospital cost imply higher quality of care?	Review of Economics and Statistics	gpicone@usf.edu	University of South Florida, Duke University and National Bureau of Economic Research
ROMLEY, J. A.*, CHEN, A. Y., GOLDMAN, D. P. & WILLIAMS, R.	Hospital costs and inpatient mortality among children undergoing surgery for congenital heart disease	Health services research	romley@rand.org	Leonard D. Schaeffer Center for Health Policy and Economics, University of Southern California, Los Angeles
ROMLEY, J. A.*, JENA, A. B. & GOLDMAN, D. P.	Hospital spending and inpatient mortality: evidence from California: an observational study	Annals of internal medicine	romley@rand.org	Leonard D. Schaeffer Center for Health Policy and Economics, University of Southern California
ROMLEY, J. A.*, JENA, A. B., O'LEARY, J. F. & GOLDMAN, D. P.	Spending and mortality in US acute care hospitals	The American journal of managed care	romley@rand.org	Leonard D. Schaeffer Center for Health Policy and Economics, University of Southern California, Los Angeles
SALEH, S.*, CALLAN, M. & KASSAK, K.	The association between the hospital quality alliance's pneumonia measures and discharge costs	Journal of Health Care Finance	ss117@aub.edu.lb	Department of Health Management and Policy, American University of Beirut. USA
SASAKI, N., KUNISAWA, S., IKAI, H. & IMANAKA, Y. *	Differences between determinants of in-hospital mortality and hospitalization costs for patients with acute heart failure: a nationwide observational study from Japan.	BMJ Open	imanaka-y@umin.net	Department of Healthcare Economics and Quality Management, Kyoto, University Graduate School of Medicine, Kyoto, Japan

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SCHREYÖGG, J.* & STARGARDT, T.	The Trade-Off between costs and outcomes: The case of acute myocardial infarction	Health services research	jonas.schreyoegg@uni-hamburg.de	Institute for Health Care Management and Health Economics, School of Business, Economics and Social Sciences, University of Hamburg
STARGARDT, T.*, SCHREYÖGG, J. & KONDOFERSKY, I.	Measuring the relationship between costs and outcomes: the example of acute myocardial infarction in German hospitals	Health Economics	Tom.Stargardt@uni-hamburg.de	Hamburg Center for Health Economics, Hamburg University, Germany
YEH, J. L.*, WU, S. & WU, B. U.	Regional cost variation for acute pancreatitis in the US.	JOP. Journal of the Pancreas, 15, 448-454.	Joseph.L.Yeh@kp.org	Department of Gastroenterology, Kaiser Permanente Los Angeles Medical Center. Los Angeles, California, USA

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Table 2.6 Reported relationship between cost/price and quality (on the association level)

Study (year)	Country	Cost/price measure (type)	Quality measure (type)	Condition	Method	Association
Auerbach et al. (2010)	USA	hospital cost per discharge from cost accounting system and/or Medicare cost to charge ratio (total cost)	prophylactic antibiotic not administrated on an operative day (process CABG)	CABG	cfo (cross-section)	n.s.
Auerbach et al. (2010)	USA	hospital cost per discharge from cost accounting system and/or Medicare cost to charge ratio (total cost)	Antibiotic not discontinued within 48 hour (process CABG)	CABG	cfo (cross-section)	negative
Auerbach et al. (2010)	USA	hospital cost per discharge from cost accounting system and/or Medicare cost to charge ratio (total cost)	miss the serial compression device use for Venus thromboembolism prevention in 2 days after surgery	CABG	cfo (cross-section)	negative
Auerbach et al. (2010)	USA	hospital cost per discharge from cost accounting system and/or Medicare cost to charge ratio (total cost)	use of aspirin in 2 days after surgery (process CABG)	CABG	cfo (cross-section)	positive
Auerbach et al. (2010)	USA	hospital cost per discharge from cost accounting system and/or Medicare cost to charge ratio (total cost)	do not use of β blockers in 2 days after surgery (process CABG)	CABG	cfo (cross-section)	n.s.
Auerbach et al. (2010)	USA	hospital cost per discharge from cost accounting system and/or Medicare cost to charge ratio (total cost)	do not use of statin drugs in 2 days after surgery (process CABG)	CABG	cfo (cross-section)	positive
Auerbach et al. (2010)	USA	hospital cost per discharge from cost accounting system and/or Medicare cost to charge ratio (total cost)	the number of missed quality measure (process CABG)	CABG	cfo (cross-section)	negative

Birkmeyer et al. (2012)	USA	Medicare payments for all services from admission date to 30 days after discharge (total cost)	30 days mortality from index procedure (outcome)	CABG	cfo (cross-section)	n.s.
Birkmeyer et al. (2012)	USA	Medicare payments for all services from admission date to 30 days after discharge (total cost)	complication rate (outcome)	CABG	cfo (cross-section)	negative
Birkmeyer et al. (2012)	USA	Medicare payments for all services from admission date to 30 days after discharge (total cost)	30 days mortality from index procedure (outcome)	Hip replacement	cfo (cross-section)	n.s.
Birkmeyer et al. (2012)	USA	Medicare payments for all services from admission date to 30 days after discharge (total cost)	complication rate (outcome)	Hip replacement	cfo (cross-section)	negative
Birkmeyer et al. (2012)	USA	Medicare payments for all services from admission date to 30 days after discharge (total cost)	30 days mortality from index procedure (outcome)	Abdominal aortic aneurysm repair	cfo (cross-section)	n.s.
Birkmeyer et al. (2012)	USA	Medicare payments for all services from admission date to 30 days after discharge (total cost)	complication rate (outcome)	Abdominal aortic aneurysm repair	cfo (cross-section)	negative
Birkmeyer et al. (2012)	USA	Medicare payments for all services from admission date to 30 days after discharge (total cost)	30 days mortality from index procedure (outcome)	Colectomy procedures	cfo (cross-section)	n.s.

Birkmeyer et al. (2012)	USA	Medicare payments for all services from admission date to 30 days after discharge (total cost)	complication rate (outcome)	Colectomy procedures	cfo (cross-section)	negative
Bradbury et al. (1997)	USA	total charges, and ancillary charges (price)	In-hospital major morbidity defined as continued clinical instability by the presence of key clinical findings (KCFs) (outcome)	Cholecystectomy procedure	cfo (control for time)	negative
Bradbury et al. (1994)	USA	total charges, and ancillary charges (price)	in-hospital mortality (outcome)	aggregated 10 DRGs	cfo (control for time)	n.s.
Bradbury et al. (1994)	USA	total charges, and ancillary charges (price)	morbidity defined as continued clinical instability determined by the presence of KCFs (outcome)	aggregated 10 DRGs	cfo (control for time)	negative
Bradbury et al. (1994)	USA	total charges, and ancillary charges (price)	in-hospital mortality (outcome)	DRG 14 /specific cerebrovascular disorder	cfo (control for time)	n.s.
Bradbury et al. (1994)	USA	total charges, and ancillary charges (price)	morbidity defined as continued clinical instability determined by the presence of KCFs (outcome)	DRG 14 /specific cerebrovascular disorder	cfo (control for time)	n.s.
Bradbury et al. (1994)	USA	total charges, and ancillary charges (price)	in-hospital mortality (outcome)	DRG 89 / simple pneumonia and pleurisy with C.C.	cfo (control for time)	n.s.
Bradbury et al. (1994)	USA	total charges, and ancillary charges (price)	morbidity defined as continued clinical instability determined by the presence of KCFs (outcome)	DRG 89 / simple pneumonia and pleurisy with C.C. (pneumonia)	cfo (control for time)	negative
Bradbury et al. (1994)	USA	total charges, and ancillary charges (price)	in-hospital mortality (outcome)	DRG 96 /bronchitis and asthma with C.C.	cfo (control for time)	n.s.

Bradbury et al. (1994)	USA	total charges, and ancillary charges (price)	morbidity defined as continued clinical instability determined by the presence of KCFs (outcome)	DRG 96 /bronchitis and asthma with C.C.	cfo (control for time)	n.s.
Bradbury et al. (1994)	USA	total charges, and ancillary charges (price)	in-hospital mortality (outcome)	DRG I21, I22, and I 23 / AMI withcardiovascular complications	cfo (control for time)	n.s.
Bradbury et al. (1994)	USA	total charges, and ancillary charges (price)	morbidity defined as continued clinical instability determined by the presence of KCFs (outcome)	DRG I21, I22, and I23/AMI with cardiovascular complications	cfo (control for time)	n.s.
Bradbury et al. (1994)	USA	total charges, and ancillary charges (price)	in-hospital mortality (outcome)	DRG 127 / Heart failure and shock	cfo (control for time)	n.s.
Bradbury et al. (1994)	USA	total charges, and ancillary charges (price)	morbidity defined as continued clinical instability determined by the presence of KCFs (outcome)	DRG 127 / Heart failure and shock	cfo (control for time)	n.s.
Bradbury et al. (1994)	USA	total charges, and ancillary charges (price)	in-hospital mortality (outcome)	DRG 138/ Cardiac arrhythmia with C.C.	cfo (control for time)	n.s.
Bradbury et al. (1994)	USA	total charges, and ancillary charges (price)	morbidity defined as continued clinical instability determined by the presence of KCFs (outcome)	DRG 138/ Cardiac arrhythmia with C.C.	cfo (control for time)	n.s.
Bradbury et al. (1994)	USA	total charges, and ancillary charges (price)	in-hospital mortality (outcome)	DRG 140 /Angina pectoris	cfo (control for time)	n.s.
Bradbury et al. (1994)	USA	total charges, and ancillary charges (price)	morbidity defined as continued clinical instability determined by the presence of KCFs (outcome)	DRG 140 /Angina pectoris	cfo (control for time)	n.s.
Bradbury et al. (1994)	USA	total charges, and ancillary charges (price)	in-hospital mortality (outcome)	DRG 174 / Gastrointestinal hemorrhage with C.C.	cfo (control for time)	n.s.

Bradbury et al. (1994)	USA	total charges, and ancillary charges (price)	morbidity defined as continued clinical instability determined by the presence of KCFs (outcome)	DRG 174 /Gastrointestinal hemorrhage with C.C.	cfo (control for time)	n.s.
Bradbury et al. (1994)	USA	total charges, and ancillary charges (price)	in-hospital mortality (outcome)	DRG 182 / Esophagitis with C.C.	cfo (control for time)	n.s.
Bradbury et al. (1994)	USA	total charges, and ancillary charges (price)	morbidity defined as continued clinical instability determined by the presence of KCFs (outcome)	DRG 182 / Esophagitis with C.C.	cfo (control for time)	n.s.
Bradbury et al. (1994)	USA	total charges, and ancillary charges (price)	in-hospital mortality (outcome)	DRG 296 / Nutritional disorders with C.C.	cfo (control for time)	n.s.
Bradbury et al. (1994)	USA	total charges, and ancillary charges (price)	morbidity defined as continued clinical instability determined by the presence of KCFs (outcome)	DRG 296 / Nutritional disorders with C.C.	cfo (control for time)	n.s.
Carey & Burgess (1999)	USA	hospital total variable costs (total(variable) cost)	30-days mortality (outcome)	N.A	cfu (IV)	negative
Carey & Burgess (1999)	USA	hospital total variable costs (total(variable) cost)	14 days readmission (outcome)	N.A	cfu (IV)	negative
Carey & Burgess (1999)	USA	hospital total variable costs (total(variable) cost)	outpatient 30 days follow-up after inpatient discharge (process)	N.A	cfu (IV)	positive
Chan et al. (2015)	USA	total hospitalization cost for each hospital admission (total cost)	in-hospital mortality (outcome)	CHF	cfo (control for time)	negative
Chan et al. (2015)	USA	total hospitalization cost for each hospital admission (total cost)	complication rate (outcome)	CHF	cfo (control for time)	negative

Chen et al. (2010)	USA	cost per discharge calculated from cost to charge ratio (total cost)	30-days mortality (outcome)	CHF	cfo (cross-section)	positive
Chen et al. (2010)	USA	cost per discharge calculated from cost to charge ratio (total cost)	30-days readmission (outcome)	CHF	cfo (cross-section)	positive
Chen et al. (2010)	USA	cost per discharge calculated from cost to charge ratio (total cost)	discharge instructions (process CHF)	CHF	cfo (cross-section)	positive
Chen et al. (2010)	USA	cost per discharge calculated from cost to charge ratio (total cost)	left ventricular functional assessment (process CHF)	CHF	cfo (cross-section)	positive
Chen et al. (2010)	USA	cost per discharge calculated from cost to charge ratio (total cost)	angiotensin-converting enzyme inhibitor or angiotensin receptor blocker prescription for left ventricular systolic dysfunction (process CHF)	CHF	cfo (cross-section)	n.s.
Chen et al. (2010)	USA	cost per discharge calculated from cost to charge ratio (total cost)	smoking cessation counseling (process CHF)	CHF	cfo (cross-section)	positive
Chen et al. (2010)	USA	cost per discharge calculated from cost to charge ratio (total cost)	30-days mortality (outcome)	Pneumonia	cfo (cross-section)	negative
Chen et al. (2010)	USA	cost per discharge calculated from cost to charge ratio (total cost)	30-days readmission (outcome)	Pneumonia	cfo (cross-section)	n.s.
Chen et al. (2010)	USA	cost per discharge calculated from cost to charge ratio (total cost)	appropriate initial antibiotic selection (process pneumonia)	Pneumonia	cfo (cross-section)	n.s.

Chen et al. (2010)	USA	cost per discharge calculated from cost to charge ratio (total cost)	initial antibiotic timing (process pneumonia)	Pneumonia	cfo (cross-section)	negative
Chen et al. (2010)	USA	cost per discharge calculated from cost to charge ratio (total cost)	initial blood culture timing (process pneumonia)	Pneumonia	cfo (cross-section)	negative
Chen et al. (2010)	USA	cost per discharge calculated from cost to charge ratio (total cost)	influenza vaccination (process pneumonia)	Pneumonia	cfo (cross-section)	n.s.
Chen et al. (2010)	USA	cost per discharge calculated from cost to charge ratio (total cost)	pneumococcal vaccination (process pneumonia)	Pneumonia	cfo (cross-section)	negative
Chen et al. (2010)	USA	cost per discharge calculated from cost to charge ratio (total cost)	oxygenation assessment (process pneumonia)	Pneumonia	cfo (cross-section)	n.s.
Chen et al. (2010)	USA	cost per discharge calculated from cost to charge ratio (total cost)	smoking cessation counseling (process pneumonia)	Pneumonia	cfo (cross-section)	n.s.
Cohen et al. (2015)	Canada	Total hospital spending for the index AMI episode of care (total cost)	1-year mortality (outcome)	AMI	cfo (control for time)	positive
Cohen et al. (2015)	Canada	Total hospital spending for the index AMI episode of care (total cost)	time to death (max 365) (outcome)	AMI	cfo (control for time)	positive
Cutler. (1995)	USA	marginal and average reimbursement change (price)	in-hospital mortality (outcome)	circulatory system diseases	multivariate (control for time)	positive
Cutler. (1995)	USA	marginal and average reimbursement change (price)	post-discharge mortality (outcome)	circulatory system diseases	cfo (control for time)	n.s.

Cutler. (1995)	USA	marginal and average reimbursement change (price)	readmission (outcome)	circulatory system diseases	cfo (control for time)	n.s.
Dafny. (2005)	USA	price change (price)	in-hospital mortality (outcome)	N.A	cfu (IV)	n.s.
Dafny. (2005)	USA	price change (price)	in-hospital mortality (outcome)	N.A	cfo (control for time)	n.s.
Dafny. (2005)	USA	price change (price)	in-hospital mortality (outcome)	N.A	cfo (control for time)	n.s.
Deily and McKay. (2006)	USA	hospital inefficiency score (cost due to inefficiency)	risk-adjusted In-hospital mortality rate (outcome)	N.A	cfo (control for time)	positive
Deily and McKay. (2006)	USA	actual average cost (average cost)	risk-adjusted In-hospital mortality rate (outcome)	N.A	cfo (control for time)	positive
Doyle. (2015)	USA	Hospital costs per discharge, estimated using charges, and cost-to-charge ratios. (first strategy) (average cost)	1-year mortality rate (outcome)	Emergency conditions	cfu (IV)	positive
Doyle. (2015)	USA	Hospital costs per discharge, estimated using charges, and cost-to-charge ratios. (second strategy) (average cost)	1-year mortality rate (outcome)	Emergency conditions	cfu (IV)	positive
Duggan. (2000)	USA	average DSH payment (price)	infant mortality rate (outcome)	N.A	cfo (control for time)	n.s.
Fleming. (1991)	USA	(total (variable) costs)	the ratio of expected to actual in-hospital deaths (outcome)	All patients	cfo (cross-section)	n.s.

Fleming. (1991)	USA	(total (variable) costs)	the ratio of expected to actual in-hospital deaths (outcome)	medical patients	cfo (cross-section)	n.s.
Fleming. (1991)	USA	(total (variable) costs)	the ratio of expected to actual in-hospital deaths (outcome)	surgical patients	cfo (cross-section)	U-shape
Fleming. (1991)	USA	(total (variable) costs)	the ratio of expected to actual readmission within 30 days after discharge (outcome)	All patients	cfo (cross-section)	U-shape
Fleming. (1991)	USA	(total (variable) costs)	the ratio of expected to actual readmission within 30 days after discharge (outcome)	medical patients	cfo (cross-section)	U-shape
Fleming. (1991)	USA	(total (variable) costs)	the ratio of expected to actual readmission within 30 days after discharge (outcome)	surgical patients	cfo (cross-section)	U-shape
Gani et al. (2016)	USA	a markup ratio (1/cost-to-charge ratio) (total variable cost)	in-hospital mortality post-operation and failure to rescue (patients who experienced an inpatient death among patients who developed a postoperative complication) (outcome)	cardiothoracic or gastrointestinal operation	cfo (cross-section)	negative
Gani et al. (2016)	USA	a markup ratio (1/cost-to-charge ratio) (total variable cost)	post-operative complication (outcome)	cardiothoracic or gastrointestinal operation	cfo (cross-section)	negative
Glance et al. (2010)	USA	total inpatient cost derived by multiplying the total hospital charges by the group average cost-to charges (total cost)	in-hospital mortality (outcome)	Trauma	cfo (cross-section)	negative
Gupta et al. (2017)	USA	total hospital costs (direct plus indirect costs) by using hospital and department	adjusted in-hospital mortality rate (outcome)	pediatric critical care (all patients admitted to PICU)	cfo (control for time)	n.s.

		specific cost-to-charge ratios (total cost)				
Gupta et al. (2017)	USA	total hospital costs (direct plus indirect costs) by using hospital and department specific cost-to-charge ratios (total cost)	adjusted in-hospital mortality rate (outcome)	cardiac (medical/surgical) patients admitted in PICU	cfo (control for time)	n.s.
Gupta et al. (2017)	USA	total hospital costs (direct plus indirect costs) by using hospital and department-specific cost-to-charge ratios (total cost)	adjusted in-hospital mortality rate (outcome)	non- cardiac (medical/surgical) patients admitted in PICU	cfo (control for time)	n.s.
Gutacker et al. (2013)	UK	reference cost report using a top-down costing methodology (total cost)	PROM [Index of health-related QoL(EQ-5D) (outcome)	hip replacement	cfu (IV)	U-shape
Gutacker et al. (2013)	UK	reference cost report using a top-down costing methodology (total cost)	PROM [Index of health-related QoL(EQ-VAS)] (outcome)	hip replacement	cfu (IV)	U-shape
Gutacker et al. (2013)	UK	reference cost report using a top-down costing methodology (total cost)	PROM [Index of health-related QoL(OHS)] (outcome)	hip replacement	cfu (IV)	U-shape
Gutacker et al. (2013)	UK	reference cost report using a top-down costing methodology (total cost)	PROM [Index of health-related QoL(EQ-5D) (outcome)	knee replacement surgery	cfu (IV)	n.s.
Gutacker et al. (2013)	UK	reference cost report using a top-down costing methodology (total cost)	PROM [Index of health-related QoL(EQ-VAS)] (outcome)	knee replacement surgery	cfu (IV)	negative
Gutacker et al. (2013)	UK	reference cost report using a top-down costing methodology (total cost)	PROM [Index of health-related QoL(OKS)] (outcome)	knee replacement surgery	cfu (IV)	n.s.

Gutacker et al. (2013)	UK	reference cost report using a top-down costing methodology (total cost)	PROM [Index of health-related QoL(EQ-5D) (outcome)	varicose vein surgery	cfu (IV)	n.s.
Gutacker et al. (2013)	UK	reference cost report using a top-down costing methodology (total cost)	PROM [Index of health-related QoL(EQ-VAS)] (outcome)	varicose vein surgery	cfu (IV)	positive
Gutacker et al. (2013)	UK	reference cost report using a top-down costing methodology (total cost)	PROM [Index of health-related QoL(AVVQ)] (outcome)	varicose vein surgery	cfu (IV)	n.s.
Gutacker et al. (2013)	UK	reference cost report using a top-down costing methodology (total cost)	PROM [Index of health-related QoL(EQ-5D) (outcome)	groin hernia surgery	cfu (IV)	n.s.
Gutacker et al. (2013)	UK	reference cost report using a top-down costing methodology (total cost)	PROM [Index of health-related QoL(EQ-VAS)] (outcome)	groin hernia surgery	cfu (IV)	n.s.
Haas et al. (2013)	Germany	treatment cost calculated from the provider perspective mainly using bottom-up micro-costing (total cost)	The change in the overall functioning of mental health (MCS-8 score) over the treatment period [Index of health-related QoL] (outcome)	psychosomatic patients with somatoform pain disorder	cfo (cross-section)	positive
Hadley et al. (2011)	USA	total medical spending [Medicare program spending plus spending from all other sources] (total cost)	mortality after 3 years (outcome)	N.A	cfu (IV)	positive
Hadley et al. (2011)	USA	total medical spending [Medicare program spending plus spending from all other sources] (total cost)	the Health and Activity Limitations Index value [Index of health-related QoL] (outcome)	N.A	cfu (IV)	positive

Häkkinen et al. (2015)	pooled sample	use of resources during the first acute hospital episode For AMI patients, it was based on the number of inpatient days and the use of cardiovascular procedures (PCI), and (CABG) (total cost)	30-day survival (outcome)	AMI	cfu (IV)	non-linear positive
Häkkinen et al. (2015)	Finland	use of resources during the first acute hospital episode For AMI patients, it was based on the number of inpatient days and the use of cardiovascular procedures (PCI), and (CABG) (total cost)	30-day survival (outcome)	AMI	cfu (IV)	non-linear positive
Häkkinen et al. (2015)	Italy	use of resources during the first acute hospital episode For AMI patients, it was based on the number of inpatient days and the use of cardiovascular procedures (PCI), and (CABG) (total cost)	30-day survival (outcome)	AMI	cfu (IV)	non-linear positive
Häkkinen et al. (2015)	Sweden	use of resources during the first acute hospital episode For AMI patients, it was based on the number of inpatient days and the use of cardiovascular procedures (PCI), and (CABG) (total cost)	30-day survival (outcome)	AMI	cfu (IV)	non-linear positive
Häkkinen et al. (2015)	pooled sample	use of resources during the first acute hospital episode For AMI patients, it was based on the number of inpatient days and the use of cardiovascular procedures (PCI), and (CABG) (total cost)	30-day survival (outcome)	AMI	cfu (IV)	non-linear positive

Häkkinen et al. (2015)	Finland	use of resources during the first acute hospital episode For AMI patients, it was based on the number of inpatient days and the use of cardiovascular procedures (PCI), and (CABG) (total cost)	30-day survival (outcome)	AMI	cfu (IV)	non-linear positive
Häkkinen et al. (2015)	Hungary	use of resources during the first acute hospital episode For AMI patients, it was based on the number of inpatient days and the use of cardiovascular procedures (PCI), and (CABG) (total cost)	30-day survival (outcome)	AMI	cfu (IV)	non-linear positive
Häkkinen et al. (2015)	Italy	use of resources during the first acute hospital episode For AMI patients, it was based on the number of inpatient days and the use of cardiovascular procedures (PCI), and (CABG) (total cost)	30-day survival (outcome)	AMI	cfu (IV)	non-linear positive
Häkkinen et al. (2015)	Sweden	use of resources during the first acute hospital episode For AMI patients, it was based on the number of inpatient days and the use of cardiovascular procedures (PCI), and (CABG) (total cost)	30-day survival (outcome)	AMI	cfu (IV)	non-linear positive
Häkkinen et al. (2015)	pooled sample	use of resources for stroke patients using the number of inpatients days during the first 'acute' hospital episode (total cost)	30-day survival (outcome)	Stroke	cfu (IV)	n.s.

Häkkinen et al. (2015)	Finland	use of resources for stroke patients using the number of inpatients days during the first 'acute' hospital episode (total cost)	30-day survival (outcome)	Stroke	cfu (IV)	n.s.
Häkkinen et al. (2015)	Hungary	use of resources for stroke patients using the number of inpatients days during the first 'acute' hospital episode (total cost)	30-day survival (outcome)	Stroke	cfu (IV)	non-linear positive
Häkkinen et al. (2015)	Sweden	use of resources for stroke patients using the number of inpatients days during the first 'acute' hospital episode (total cost)	30-day survival (outcome)	Stroke	cfu (IV)	U-shape
Häkkinen et al. (2015)	pooled sample	use of resources for stroke patients using the number of inpatients days during the first 'acute' hospital episode (total cost)	30-day survival (outcome)	Stroke	cfu (IV)	non-linear positive
Häkkinen et al. (2015)	Finland	use of resources for stroke patients using the number of inpatients days during the first 'acute' hospital episode (total cost)	30-day survival (outcome)	Stroke	cfu (IV)	n.s.
Häkkinen et al. (2015)	Hungary	use of resources for stroke patients using the number of inpatients days during the first 'acute' hospital episode (total cost)	30-day survival (outcome)	Stroke	cfu (IV)	n.s.
Häkkinen et al. (2015)	Italy	use of resources for stroke patients using the number of inpatients days during the first 'acute' hospital episode (total cost)	30-day survival (outcome)	Stroke	cfu (IV)	non-linear positive

Häkkinen et al. (2015)	Sweden	use of resources for stroke patients using the number of inpatients days during the first 'acute' hospital episode (total cost)	30-day survival (outcome)	Stroke	cfu (IV)	U-shape
Häkkinen et al. (2015)	pooled sample	use of resources for Hip fracture patients using the number of patient days and type of surgery (total cost)	30-day survival (outcome)	Hip fracture	cfu (IV)	n.s.
Häkkinen et al. (2015)	Finland	use of resources for Hip fracture patients using the number of patient days and type of surgery (total cost)	30-day survival (outcome)	Hip fracture	cfu (IV)	n.s.
Häkkinen et al. (2015)	Hungary	use of resources for Hip fracture patients using the number of patient days and type of surgery (total cost)	30-day survival (outcome)	Hip fracture	cfu (IV)	inverted U-shape
Häkkinen et al. (2015)	Italy	use of resources for Hip fracture patients using the number of patient days and type of surgery (total cost)	30-day survival (outcome)	Hip fracture	cfu (IV)	n.s.
Häkkinen et al. (2015)	Sweden	use of resources for Hip fracture patients using the number of patient days and type of surgery (total cost)	30-day survival (outcome)	Hip fracture	cfu (IV)	n.s.
Häkkinen et al. (2014)	Finland	inpatient costs from the discharge data (total cost)	in-hospital mortality (outcome)	AMI	cfo (cross-section)	n.s.
Häkkinen et al. (2014)	Finland	inpatient costs from the discharge data (total cost)	in-hospital mortality (outcome)	Stroke	cfo (cross-section)	n.s.

Häkkinen et al. (2014)	France	inpatient costs from the discharge data (total cost)	in-hospital mortality (outcome)	AMI	cfo (cross-section)	n.s.
Häkkinen et al. (2014)	France	inpatient costs from the discharge data (total cost)	in-hospital mortality (outcome)	Stroke	cfo (cross-section)	n.s.
Häkkinen et al. (2014)	Germany	inpatient costs from the discharge data (total cost)	in-hospital mortality (outcome)	AMI	cfo (cross-section)	n.s.
Häkkinen et al. (2014)	Germany	inpatient costs from the discharge data (total cost)	in-hospital mortality (outcome)	Stroke	cfo (cross-section)	n.s.
Häkkinen et al. (2014)	Spain	inpatient costs from the discharge data (total cost)	in-hospital mortality (outcome)	AMI	cfo (cross-section)	n.s.
Häkkinen et al. (2014)	Spain	inpatient costs from the discharge data (total cost)	in-hospital mortality (outcome)	Stroke	cfo (cross-section)	n.s.
Häkkinen et al. (2014)	Sweden	inpatient costs from the discharge data (total cost)	in-hospital mortality (outcome)	AMI	cfo (cross-section)	positive
Häkkinen et al. (2014)	Sweden	inpatient costs from the discharge data (total cost)	in-hospital mortality (outcome)	Stroke	cfo (cross-section)	n.s.
Hvenegaard et al. (2011)	Denmark	net costs (calculated as the sum of costs associated with adverse events and the costs invested for providing quality services) (average cost)	30-day mortality from admission (outcome)	vascular surgery	correlation analysis	n.s.
Hvenegaard et al. (2011)	Denmark	net costs (calculated as the sum of costs associated with adverse events and the costs invested for providing quality services) (average cost)	wound complication (outcome)	vascular surgery	correlation analysis	n.s.

Jha et al. (2009)	USA	A relative cost index based on the ratio of actual costs to predicted costs (average cost)	a summary performance score based on 2 indicators: left ventricular function assessment, and ACE inhibitor for left ventricular systolic dysfunction (process CHF)	CHF	correlation analysis	positive
Jha et al. (2009)	USA	A relative cost index based on the ratio of actual costs to predicted costs (average cost)	a summary performance score based on 5 indicators: aspirin at arrival, aspirin at discharge, beta-blocker at arrival, beta-blocker at discharge, and angiotensin-converter enzyme inhibitor for left ventricular systolic dysfunction (process AMI)	AMI	correlation analysis	positive
Jha et al. (2009)	USA	A relative cost index based on the ratio of actual costs to predicted costs (average cost)	a summary performance score based on 3 indicators: initial antibiotic timing, pneumococcal vaccination, and oxygenation assessment (process pneumonia)	Pneumonia	correlation analysis	n.s.
Jha et al. (2009)	USA	A relative cost index based on the ratio of actual costs to predicted costs (average cost)	30-day hospital mortality rate (outcome)	CHF	cfo (cross-section)	n.s.
Jha et al. (2009)	USA	A relative cost index based on the ratio of actual costs to predicted costs (average cost)	30-day hospital mortality rate (outcome)	AMI	cfo (cross-section)	n.s.
Jha et al. (2009)	USA	A relative cost index based on the ratio of actual costs to predicted costs (average cost)	30-day hospital mortality rate (outcome)	Pneumonia	cfo (cross-section)	n.s.
Kaestner & Silber. (2010)	USA	total inpatient charges for the Medicare admission (price)	30-days mortality for patients experiencing complication (outcome)	general surgery	cfo (control for time))	negative

Kaestner & Silber. (2010)	USA	total inpatient charges for the Medicare admission (price)	30-days mortality for patients experiencing complication (outcome)	general surgery	cfu (IV)	positive
Kaestner & Silber. (2010)	USA	total inpatient charges for the Medicare admission (price)	30-days mortality for patients experiencing complication (outcome)	orthopedic surgery	cfo (control for time)	negative
Kaestner & Silber. (2010)	USA	total inpatient charges for the Medicare admission (price)	30-days mortality for patients experiencing complication (outcome)	orthopedic surgery	cfu (IV)	positive
Kaestner & Silber. (2010)	USA	total inpatient charges for the Medicare admission (price)	30-days mortality for patients experiencing complication (outcome)	vascular surgery	cfo(control for time)	positive
Kaestner & Silber. (2010)	USA	total inpatient charges for the Medicare admission (price)	30-days mortality for patients experiencing complication (outcome)	vascular surgery	cfu (IV)	positive
Kaestner & Silber. (2010)	USA	total inpatient charges for the Medicare admission (price)	30-days mortality (outcome)	AMI	cfo (control for time)	positive
Kaestner & Silber. (2010)	USA	total inpatient charges for the Medicare admission (price)	30-days mortality (outcome)	AMI	cfu (IV)	positive
Kaestner & Silber. (2010)	USA	total inpatient charges for the Medicare admission (price)	30-days mortality (outcome)	CHF	cfo (control for time)	negative
Kaestner & Silber. (2010)	USA	total inpatient charges for the Medicare admission (price)	30-days mortality (outcome)	CHF	cfu (IV)	positive
Kaestner & Silber. (2010)	USA	total inpatient charges for the Medicare admission (price)	30-days mortality (outcome)	Stroke	cfo (control for time)	positive

Kaestner & Silber. (2010)	USA	total inpatient charges for the Medicare admission (price)	30-days mortality (outcome)	Stroke	cfu (IV)	positive
Kaestner & Silber. (2010)	USA	total inpatient charges for the Medicare admission (price)	30-days mortality (outcome)	gastrointestinal bleeding	cfo (control for time)	negative
Kaestner & Silber. (2010)	USA	total inpatient charges for the Medicare admission (price)	30-days mortality (outcome)	gastrointestinal bleeding	cfu (IV)	positive
Kang et al. (2017)	Korea	the medical cost per episode (total cost)	30-day mortality from admission (outcome)	AMI	correlation analysis	n.s.
Kittelsen et al. (2015)	all Nordic countries(pooled dataset)	average cost per DRG [operating cost/DRG points] (average cost)	30 days mortality (outcome)	N.A	cfo (control for time)	positive
Kittelsen et al. (2015)	Denmark	average cost per DRG [operating cost/DRG points] (average cost)	30 days mortality (outcome)	N.A	cfo (control for time)	positive
Kittelsen et al. (2015)	Finland	average cost per DRG [operating cost/DRG points] (average cost)	30 days mortality (outcome)	N.A	cfo (control for time)	n.s.
Kittelsen et al. (2015)	Norway	average cost per DRG [operating cost/DRG points] (average cost)	30 days mortality (outcome)	N.A	cfo (control for time)	n.s.
Kittelsen et al. (2015)	Sweden	average cost per DRG [operating cost/DRG points] (average cost)	30 days mortality (outcome)	N.A	cfo (control for time)	n.s.
Kittelsen et al. (2015)	all Nordic countries (pooled dataset)	average cost per DRG [operating cost/DRG points] (average cost)	30 days Emergency readmission (outcome)	N.A	cfo (control for time)	n.s.

Kittelsen et al. (2015)	Denmark	average cost per DRG [operating cost/DRG points] (average cost)	30 days Emergency readmission (outcome)	N.A	cfo (control for time)	n.s.
Kittelsen et al. (2015)	Finland	average cost per DRG [operating cost/DRG points] (average cost)	30 days Emergency readmission (outcome)	N.A	cfo (control for time)	positive
Kittelsen et al. (2015)	Norway	average cost per DRG [operating cost/DRG points] (average cost)	30 days Emergency readmission (outcome)	N.A	cfo (control for time)	n.s.
Kruse&Christen den (2013)	Denmark	cost at the patient level (average cost)	30-days mortality (outcome)	vascular surgery	cfo (control for time)	negative
Kruse&Christen den (2013)	Denmark	cost at the patient level (average cost)	wound complication (outcome)	vascular surgery	cfo (control for time)	negative
Kruse&Christen den (2013)	Denmark	cost at the patient level (average cost)	surgical complication (outcome)	vascular surgery	cfo (control for time)	negative
Kruse&Christen den (2013)	Denmark	cost at the patient level (average cost)	general complication (outcome)	vascular surgery	cfo (control for time)	negative
Kruse&Christen den (2013)	Denmark	cost at the patient level (average cost)	infections [complication] (outcome)	vascular surgery	cfo (control for time)	n.s.
Kruse&Christen den (2013)	Denmark	average costs per department per year (EUR) [observed costs minus risk-adjusted costs(additional cost)] (average cost)	Probability of patients deceasing within 30 days of surgery. Risk-adjusted mortality minus observed mortality [additional mortality] (outcome)	vascular surgery	cfo (control for time)	n.s.
Kruse&Christen den (2013)	Denmark	average costs per department per year (EUR) [observed costs minus risk-adjusted costs (additional cost)] (average cost)	Probability of patients deceasing within 30 days of surgery. Risk-adjusted mortality minus observed mortality [additional mortality] (outcome)	vascular surgery	cfo (control for time)	U-shape
Lagu et al. (2011)	USA	mean observed-expected cost per case (average cost)	the severity-adjusted in-hospital mortality rate (outcome)	Sepsis	cfo (cross-section)	n.s.

Lee et al. (2013)	Japan	age-sex-adjusted spending per patient divided in quartile from 1 [the lowest spending] to 4 [the highest spending municipalities] (price)	in-hospital mortality (outcome)	(ischemic) stroke	cfo (cross-section)	n.s.
Lee et al. (2013)	Japan	age-sex-adjusted spending per patient divided in quartile (price)	30-day mortality rate (outcome)	(ischemic) stroke	cfo (cross-section)	n.s.
Lee et al. (2013)	Japan	age-sex-adjusted spending per patient divided in quartile (price)	CT or MRI scans (process stroke)	(ischemic) stroke	cfo (cross-section)	n.s.
Lee et al. (2013)	Japan	age-sex-adjusted spending per patient divided in quartile (price)	t-PA administration (process stroke)	(ischemic) stroke	cfo (cross-section)	positive
Lee et al. (2013)	Japan	age-sex-adjusted spending per patient divided in quartile (price)	Antithrombotic (process stroke)	(ischemic) stroke	cfo (cross-section)	positive
Lee et al. (2013)	Japan	age-sex-adjusted spending per patient divided into quartile (price)	In-hospital rehabilitation (process stroke)	(ischemic) stroke	cfo (cross-section)	positive
Lee et al. (2013)	Japan	age-sex-adjusted spending per patient divided into quartile (price)	early rehabilitation (process stroke)	(ischemic) stroke	cfo (cross-section)	positive
Lee et al. (2013)	Japan	age-sex-adjusted spending per patient divided into quartile (price)	dysphagia rehabilitation (process stroke)	(ischemic) stroke	cfo (cross-section)	positive
Lee et al. (2013)	Japan	age-sex-adjusted spending per patient divided in quartile (price)	Warfarin in AF patients (process stroke)	(ischemic) stroke	cfo (cross-section)	positive

Mckay and Deily, (2008)	USA	cost inefficiency score using stochastic frontier analysis calculated from the baseline cost function(IE-Baseline) and with instrumental variables(IE-IV) (cost due to inefficiency)	in-hospital mortality rate[observed in-hospital deaths/total admissions] (outcome)	N.A	cfo (control for time)	n.s.
Mckay and Deily, (2008)	USA	cost inefficiency score using stochastic frontier analysis calculated from the baseline cost function(IE-Baseline) and with instrumental variables(IE-IV) (cost due to inefficiency)	complication rate [observed complications/total admissions] (outcome)	N.A	cfo (control for time)	n.s.
Morey et al. (1992)	USA	Total cost (total cost)	the ratio of actual to predicted in-hospital mortality (outcome)	N.A	cfo (cross-section)	n.s.
Morey et al. (1992)	USA	cost inefficiency estimated using data envelopment analysis (cost due to inefficiency)	the ratio of actual to predicted in-hospital mortality (outcome)	N.A	cfo (cross-section)	positive
Mukammel et al. (2001)	USA	Expenditures per inpatient adjusted day (average cost)	risk-adjusted mortality rate within 30 days from admission (outcome)	aggregated	cfo (cross-section)	positive
Mukammel et al. (2002)	USA	hospital costs per adjusted discharge (average cost)	risk-adjusted mortality rate within 30 days from admission (outcome)	all causes (pooled conditions)	cfo (control for time)	positive
Mukammel et al. (2002)	USA	hospital costs per adjusted discharge (average cost)	risk-adjusted mortality rate within 30 days from admission (outcome)	AMI	cfo (control for time)	positive
Mukammel et al. (2002)	USA	hospital costs per adjusted discharge (average cost)	risk-adjusted mortality rate within 30 days from admission (outcome)	CHF	cfo (control for time)	positive

Mukammel et al. (2002)	USA	hospital costs per adjusted discharge (average cost)	risk-adjusted mortality rate within 30 days from admission (outcome)	pneumonia	cfo (control for time)	n.s.
Mukammel et al. (2002)	USA	hospital costs per adjusted discharge (average cost)	risk-adjusted mortality rate within 30 days from admission (outcome)	Stroke	cfo (control for time)	positive
Ong et al. (2009)	USA	total direct costs using internal cost accounting system data for each hospitalization (total cost)	mortality within 180-days after initial admission (outcome)	CHF	cfo (control for time)	positive
Osnabrugge et al. (2014)	USA	total cost using cost to charge ratio (total cost)	mortality (outcome)	CABG	correlation analysis	n.s.
Osnabrugge et al. (2014), USA	USA	total cost using cost to charge ratio (total cost)	composite measure [morbidity/mortality] (outcome)	CABG	correlation analysis	n.s.
PASQUALI et al. (2015), USA	USA	costs were estimated using hospital and department specific cost-to-charge ratios (total cost)	observed to expected in-hospital mortality (outcome)	CHF	cfo (cross-section)	negative
PASQUALI et al. (2015), USA	USA	costs were estimated using hospital and department specific cost-to-charge ratios (total cost)	complication rate (outcome)	CHF	cfo (cross-section)	n.s.
Picone et al. (2003)	USA	total cost of inpatient admission Medicare Cost Reports from the year of the index admissions to calculate the Medicare inpatient cost-to-charge ratio (total cost)	6-month mortality rate (outcome)	aggregated	cfo (control for time)	n.s.

Picone et al. (2003)	USA	total cost of inpatient admission Medicare Cost Reports from the year of the index admissions to calculate the Medicare inpatient cost-to-charge ratio (total cost)	1-year mortality (outcome)	aggregated	cfo (control for time)	positive
Picone et al. (2003)	USA	total cost of inpatient admission Medicare Cost Reports from the year of the index admissions to calculate the Medicare inpatient cost-to-charge ratio (total cost)	2-year mortality (outcome)	aggregated	cfo (control for time)	positive
Picone et al. (2003)	USA	total cost of inpatient admission Medicare Cost Reports from the year of the index admissions to calculate the Medicare inpatient cost-to-charge ratio (total cost)	6-month mortality rate (outcome)	aggregated	cfo (control for time)	n.s.
Picone et al. (2003)	USA	total cost of inpatient admission Medicare Cost Reports from the year of the index admissions to calculate the Medicare inpatient cost-to-charge ratio (total cost)	1-year mortality (outcome)	aggregated	cfo (control for time)	positive
Picone et al. (2003)	USA	total cost of inpatient admission Medicare Cost Reports from the year of the index admissions to calculate the Medicare inpatient cost-to-charge ratio (total cost)	2-year mortality (outcome)	aggregated	cfo (control for time)	positive
Picone et al. (2003)	USA	total cost of inpatient admission Medicare Cost Reports from the year of the index admissions to calculate the Medicare inpatient cost-to-charge ratio (total cost)	6-month mortality rate (outcome)	aggregated	cfu (IV)	negative

Picone et al. (2003)	USA	total cost of inpatient admission Medicare Cost Reports from the year of the index admissions to calculate the Medicare inpatient cost-to-charge ratio (total cost)	1-year mortality (outcome)	aggregated	cfu (IV)	n.s.
Picone et al. (2003)	USA	total cost of inpatient admission Medicare Cost Reports from the year of the index admissions to calculate the Medicare inpatient cost-to-charge ratio (total cost)	2-year mortality (outcome)	aggregated	cfu (IV)	n.s.
Ramley et al. (2011), USA	USA	Average hospital spending in the last two years of life and by using cost to charge ratio, converting hospital charges to cost. (Average cost)	inpatient mortality (outcome)	AMI	cfo (control for time)	positive
Ramley et al. (2011), USA	USA	Average hospital spending in the last two years of life and by using cost to charge ratio, converting hospital charges to cost. (Average cost)	inpatient mortality (outcome)	CHF	cfo (control for time)	positive
Ramley et al. (2011), USA	USA	Average hospital spending in the last two years of life and by using cost to charge ratio, converting hospital charges to cost. (Average cost)	inpatient mortality (outcome)	stroke	cfo (control for time)	positive
Ramley et al. (2011), USA	USA	Average hospital spending in the last two years of life and by using cost to charge ratio, converting hospital charges to cost. (Average cost)	inpatient mortality (outcome)	gastrointestinal hemorrhage	cfo (control for time)	n.s.

Ramley et al. (2011), USA	USA	Average hospital spending in the last two years of life and by using cost to charge ratio, converting hospital charges to cost. (Average cost)	inpatient mortality (outcome)	Hip fracture	cfo (control for time)	n.s.
Ramley et al. (2011), USA	USA	Average hospital spending in the last two years of life and by using cost to charge ratio, converting hospital charges to cost. (Average cost)	inpatient mortality (outcome)	pneumonia	cfo (control for time)	positive
Romely et al. (2013)	USA	hospital spending based on inpatient spending during the last 2 years of life among Medicare fee-for-service. (price)	risk-adjusted inpatient mortality (outcome)	AMI	cfo (control for time)	positive
Romely et al. (2013)	USA	hospital spending based on inpatient spending during the last 2 years of life among Medicare fee-for-service. (price)	risk-adjusted inpatient mortality (outcome)	CHF	cfo (control for time)	positive
Romely et al. (2013)	USA	hospital spending based on inpatient spending during the last 2 years of life among Medicare fee-for-service. (price)	risk-adjusted inpatient mortality (outcome)	Stroke	cfo (control for time)	positive
Romely et al. (2013)	USA	hospital spending based on inpatient spending during the last 2 years of life among Medicare fee-for-service. (price)	risk-adjusted inpatient mortality (outcome)	Hip fracture	cfo (control for time)	positive
Romely et al. (2013)	USA	hospital spending based on inpatient spending during the last 2 years of life among Medicare fee-for-service. (price)	risk-adjusted inpatient mortality (outcome)	Pneumonia	cfo (control for time)	n.s.

Romely et al. (2013)	USA	hospital spending based on inpatient spending during the last 2 years of life among Medicare fee-for-service. (price)	risk-adjusted inpatient mortality (outcome)	gastrointestinal hemorrhage	cfo (control for time)	n.s.
Romely et al. (2014)	USA	hospital charges were converted into costs using cost-to-charge ratios (total cost)	risk-adjusted inpatient mortality (outcome)	CHF	cfo (control for time)	positive
Saleh et al. (2012)	USA	Total average pneumonia discharges-related costs calculated from cost to charge ratio (accounting cost)	Pneumococcal vaccination (process)	pneumonia	cfo (cross-section)	n.s.
Saleh et al. (2012)	USA	Total average pneumonia discharges-related costs calculated from cost to charge ratio (accounting cost)	Administration of initial antibiotic(s) whithin four hours after arrival (process)	pneumonia	cfo (cross-section)	n.s.
Saleh et al. (2012)	USA	Total average pneumonia discharges-related costs calculated from cost to charge ratio (accounting cost)	Oxygenation assessment (process)	pneumonia	cfo (cross-section)	negative
Saleh et al. (2012)	USA	Total average pneumonia discharges-related costs calculated from cost to charge ratio (accounting cost)	Pneumonia composite score: number of pneumonia measures correctly executed divided by the number of opportunities for such correct care to be provided (process)	pneumonia	cfo (cross-section)	n.s.
Sasaki et al. (2017)	Japan	Hospitalization costs (total cost)	in-hospital mortality (outcome)	AMI	cfo (cross-section)	n.s.

Schreyögg & Stargardt. (2010)	USA	the cost incurred during the index hospitalization (total (variable) cost)	1-year mortality (outcome)	AMI	cfu (IV)	positive
Schreyögg & Stargardt. (2010)	USA	the cost incurred during the index hospitalization (total (variable) cost)	1-year readmission (outcome)	AMI	cfu (IV)	positive
Stargardt et al. (2014)	Germany	provider reimbursement rate as a proxy for the treatment cost (price)	time to death (max 365) (outcome)	AMI	cfo (control for time)	positive
Yeh et al. (2014)	USA	Total costs per hospitalization were calculated from charges using a cost-to-charge ratio (total cost)	in-hospital mortality (outcome)	Acute Pancreatitis	cfo (cross-section)	n.s.

cfo: control for observables; cfu: control for unobservable

Chapter 3

The Effect of Hospital Competition on Health Outcomes: Evidence from AMI Admissions in Germany

3.1 Introduction

Since the early 1970s, regulatory efforts in the health systems of most developed nations have focused on containing health care costs without diminishing the quality of care. To this end, a number of countries have enacted market-based health care reforms (Stadhouders, Kruse et al. 2019) designed primarily to stimulate competition in the health care market.

The hospital market accounts for a quarter of health care expenditure in Germany (Destatis. 2021). This makes this sector the main target for policymakers who want to promote efficiency and quality by motivating competition (Schmid and Ulrich 2013). Because payments are set at a fixed tariff to remove the scope for price competition, hospitals are meant to compete on quality to attract patients. However, in practice, this may mean that hospitals compete for patients by offering high-tech services and better amenities, which may result in higher costs without necessarily leading to better health outcomes.

Even though Germany has a well-established tradition of legislation and related measures on quality of care, its hospital market is relatively unregulated compared to other countries. For instance, German hospital quality reports are used only for benchmarking purposes, and the hospitals assess the quality indicators themselves. Such voluntarily monitoring processes may not have a noticeable impact on overall hospital quality improvement. The most critical point may therefore be that there are, in fact, no sanctions if a hospital performs worse in terms of outcomes than the benchmark.

Theoretical work suggests that where prices are fixed, providers compete on non-price attributes, such as service quality, to attract consumers (Brekke, Nuscheler et al. 2006). Under regulated prices, and as long as the price is set above marginal cost, competition among hospitals fosters quality improvement (Gaynor, Moreno-Serra et al. 2013). Hence, in this setting, quality levels depend on whether price-cost margins are positive or negative. On the other hand, Brekke et al. theoretically show that lower competition leads to higher quality if hospitals' degree of altruism is above a threshold level (Brekke, Siciliani et al. 2011). Several studies have found a positive effect of competition on quality. For instance, Kessler and McClellan show that AMI patients in the least competitive areas experienced a higher mortality rate than AMI patients in the most competitive areas (Kessler and McClellan 2000). Bloom et al. estimated the effect of competition on hospital management quality and mortality rate following AMI in England and found that adding rival hospitals would increase management quality and lower mortality rates (Bloom, Propper et al. 2015). Cooper et al. (Cooper, Gibbons et al. 2011) and Gaynor et al. (Gaynor, Moreno-Serra et al. 2013) also estimated the impact of competition on quality of care in AMI patients in England. Their estimates suggest that higher competition led to reduced heart attack mortality. In addition, several studies found a negative effect in the hospital setting. For example, Gowrisankaran and Town estimated the effect of competition on the quality of care in AMI patients. Their findings show that increased competition for Medicare patients appeared to reduce quality, presumably due to small (or negative) Medicare margins (Gowrisankaran and Town 2003). Mutter et al. found the same result for the relationship between hospital competition and in-hospital mortality in AMI patients (Mutter, Wong et al. 2008). Ho and Hamilton examined the effect of consolidation (i.e., less competition) on inpatient mortality and readmission for AMI. Their results suggest that competition had no impact on Medicare patients' quality of care (Ho and Hamilton 2000).

In summary, the literature shows that competition between hospitals affects health outcomes. Furthermore, some studies suggest that competition and its effects on outcomes are dependent on the regulatory regime in each country, including factors such as the regulation of competition, regulation of the quality of care, and the price regime. Moreover, no empirical studies to date have focused on the link between competition and quality in the German hospital market. While evidence from other countries exists, its transferability is probably very limited due to the unique context and characteristics of the hospital market in Germany.

In this work, we investigated the causal effect of hospital competition on the quality of care, which we assess using health outcomes, in patients in Germany with acute myocardial infarction (AMI). In doing so, we (a) accounted for endogeneity using an instrumental variable approach and controlling for a comprehensive list of factors that might alter the competition-quality relationship, and (b) included both in-hospital and longer-term mortality and readmission. We focused on AMI for three reasons. First, AMI requires immediate medical attention, making patient selection among hospitals less relevant than for other conditions. Second, AMI has a high incidence, resulting in a substantial number of hospital cases. Indeed, cardiovascular diseases are the leading cause of death in Germany, accounting for 40% of all deaths (RKI, 2021). Lastly, hospitals that provide higher quality care can achieve substantially improved outcomes, such as lower mortality rates.

Our paper is organized as follows: The next section describes the methodology used in the paper to explore the relationship between competition and quality. The third section presents the results. The fourth section discusses the results, and the final section draws conclusions and sets out the policy implications of our findings.

3.2 Methods

3.2.1 Data

In this study, we use three data sources: (1) Claims data from Techniker Krankenkasse, the largest statutory health insurer in Germany with 10.73 million insured in 2021, representing 12.9% of the German population. We obtained patient records with AMI (ICD-10: I21) from 2015-2019 from this dataset. (2) Data on hospital characteristics from the annual hospital quality reports. (3) Information on whether the patients resided in rural or urban areas in western or eastern Germany from the INKAR database.

We considered mortality and readmissions up to two years after AMI, and controlled for demographic, health status, and hospital-level variables. We included patients 20 years of age or older, admitted as inpatients, and had AMI coded as their primary diagnosis. We excluded patients if they were admitted and discharged on the same day because they had potentially been misclassified (except if they died on the day of admission). We also excluded hospitals with fewer than five AMI cases per year because such low volume suggested insufficient hospital infrastructure for treating AMI. This selection process resulted in a sample of 63,439 cases.

3.2.2 Measurement of Competition and Outcome

Herfindahl Hirschman Index (HHI), which is the sum of squared market shares of firms in a market, has been widely used as a measure of market concentration due to ease of calculation. However, it is sensitive to market definition especially when location plays an important role in customer choice, which is clearly the case in the hospital market. To measure the competition faced by hospitals more precisely, we employed the distance-weighted method, which assigns weights to individual hospitals by their number of AMI admissions and inversely by distance [14]. In this way, distant hospitals have less importance than closer hospitals but may still have an effect. We considered the competition that any given hospital in our sample faced from all other hospitals in Germany[1]. We classified hospitals in the top decile as those facing high competition and hospitals in the bottom 50% as those facing low competition. Furthermore, we checked robustness of our findings using HHI.

For each AMI case, we assessed the quality of care based on the outcome measures cumulative mortality (i.e., in-hospital mortality and 30-day, 90-day, 180-day, 365-day, 730-day post-admission mortality) and post-discharge cardiac-related readmission (i.e., 7-day, 30-day, 90-day, 180-day, 365-day, 730-day readmission; ICD 10 codes I20-I25), all of which were binary variables.

3.2.3 Covariates for Patient and Hospital Characteristics

We controlled for a rich set of patient and hospital characteristics that might affect outcomes. Patient characteristics include the entire set of controls regarding the patient's admission: age group[2], sex, comorbidities, patient residence (rural/urban), distance to the hospital, being an emergency admission (defined as being admitted via the ambulance service in our dataset), and being transferred from another hospital. Hospital characteristics are: being a university hospital, the number of nurses per bed, ownership type, and being located in western Germany. To control for the time from AMI to entering the medical system, which is critical for survival, we included the patient-hospital distance in addition to the dummy for urban residence.

The presence of confounding comorbidities in administrative datasets requires the use of risk-adjustment tools. Of the many tools available, the Charlson and Elixhauser indices are the most common. Although they are comprehensive and have a broad spectrum of use, a disease-specific risk-adjustment instrument is preferable in our case because such instruments are usually more sensitive to the condition in question and generally have better predictive performance (Tu, Austin et al. 2001). We used the Ontario Acute Myocardial Infarction Mortality Prediction Rules, which were developed to predict risk-adjusted short- and long-term mortality after AMI to adjust for comorbid conditions (Tu, Austin et al. 2001).

Revascularization (i.e., coronary artery bypass grafting (CABG) or stenting) is a very important determinant of survival in AMI cases. In our dataset, a higher share of AMI cases received revascularization in high competition areas than in low competition areas (77.5% and 75.4%, respectively, p-value<0.001). In this study, we examined the effect of hospital competition on the quality, and not the type, of treatment that patients received. Because revascularization is correlated with the competitiveness of the hospital market and is an important determinant of patient outcomes,

[1] In practice, very distant hospitals do not contribute to the measure because the weight effectively goes to zero at a distance of more than two hundred kilometers.
[2] Age groups: 50-64, 65-74, 75+ years and Reference category: 20-49 years

excluding it would lead to an omitted variable bias. We therefore included a dummy, as a control, for whether a patient received revascularization. However, receiving revascularization is endogenous, and failing to tackle the endogeneity of revascularization would lead to an inconsistent estimator for the effect of the competitiveness of the hospital market (Frölich, 2008). Hence, we used instrumental variables to address the endogeneity in the control variable following the approach in Acemoglu et al. (Acemoglu, Johnson et al. 2001), and explain our approach in detail in the next section.

We used the total number of AMIs treated by the hospital (from the hospital quality reports) to generate high-volume hospital dummies (Cutler, 2007, Nimptsch and Mansky, 2017) and a variable to indicate whether the hospital could perform revascularization. These variables were assumed to reflect the impact on outcomes of hospitals' experience treating AMI (McClellan, McNeil et al. 1994).

3.2.4 Empirical Model

To investigate the association between competition and quality of care in AMI patients, we first applied ordinary least squares (OLS) regression modeling. Because the quality of the health care provided by a hospital is not independent across patients, we corrected standard errors by clustering at the hospital level so these would be robust to arbitrary serial correlation and to heteroscedasticity in errors.

We estimated the following model separately for cumulative mortality and post-discharge cardiac-related readmission as outcomes:

$$Outcome_{iht} = \beta_0 + \beta_1 Compt_{ht} + \beta_2 (Revascularisation)_{iht} + \beta_3 X_{iht} + \beta_4 A_{ht} + \beta_5 \tau_t + \varepsilon_{iht}$$

We regressed health outcome for patient i on high and low competition dummies ($Compt$) for hospital *h* for year *t*, and a dummy variable for whether the patient received revascularization ($Revascularization$). The vectors (X) and *(A)* are the patient and hospital characteristics listed in the previous section. τ_t represents year fixed effects, and ε_{iht} is the error term.

It has been argued that the set of patients receiving revascularization is not a random set of patients with AMI, but rather excludes the sickest patients, who may not be strong enough to undergo the procedures, as well as the healthiest patients, who may not need the procedures at all. We confirmed that revascularization was endogenous to health outcomes by performing the Hausman test (Hausman, 1978). Hence, we addressed potential sources of endogeneity using instrumental variables. Assuming that patients who are more likely to benefit from invasive treatments do not select their residential location based on its distance to a high-tech medical care facility, differential distance to a hospital capable of revascularization is a good instrument for actual receipt of those procedures. We therefore employed 2-stage least squares (2SLS) regression, in which we used the differential distance in multiple categories[3] dd_i as instrument for revascularization following McClellan, McNeil, and Newhouse (McClellan, McNeil et al. 1994). Although our instrumental variable, differential distance to a hospital capable of revascularization, is likely to be strongly correlated with the probability of undergoing revascularization, it is not likely to be associated directly with the outcomes of interest (i.e., mortality and readmission) but rather indirectly through its effect on treatment allocation.

3.3 Results

Our final sample of 63,439 inpatient AMI cases in 1043 hospitals comprised patients ranging in age from 20 to 103 years (mean: 67 years). Table 3.1 reports the sample characteristics for cases by market competitiveness. Both the mortality and readmission indices were higher in high competition areas.

The differences between high and low competition areas were greater when longer-term health outcomes were considered. Summary statistics suggest a positive association between competition and mortality and readmission rates.

With regard to the 2SLS regression, the first-stage regression results (see Table 3.2) show that our instruments were reliable predictors of receiving revascularization. F-statistic for the instrument for differential distance to a hospital capable of revascularization (F-value: 129.78) was well above the common threshold of 10 for a weak correlation.

[3] We calculate the differential distance as distance from the centroid of the patient's postal code of residence to the closest hospital performing revascularization-distance from the centroid of the patient's postal code of residence to the closest hospital. Differential distance (dd) categories includes: dd < 1, 1 < dd < 2, 2 < dd < 3, 3 < dd < 6, 6 < dd < 12, 12 < dd < 15, 15 < dd < 19, 19 < dd < 23, 23 < dd < 27, 27 < dd < 32, 32 < dd < 37, 37 < dd < 42, 42 < dd < 52, 52 < dd kilometers; to account for non-linear effect of distance.

Table 3.1 Descriptive statistics

Variables	High Competition Area		Low Competition Area		All		P values for unequal variance t-test between high and low competition areas
	mean	S.D.	mean	S.D.	Mean	S.D.	
In-hospital mortality	0.070	0.255	0.062	0.241	0.065	0.247	< 0.05
30-day mortality	0.084	0.278	0.077	0.266	0.079	0.270	< 0.05
90-day mortality	0.106	0.308	0.093	0.290	0.097	0.295	< 0.001
180-day mortality	0.122	0.327	0.108	0.310	0.112	0.316	< 0.001
365-day mortality	0.144	0.351	0.127	0.333	0.133	0.339	< 0.001
730-day mortality	0.208	0.406	0.182	0.386	0.190	0.392	< 0.001
7-day readmission (cardiac-related)	0.165	0.371	0.154	0.361	0.152	0.359	< 0.05
30-day readmission (cardiac-related)	0.218	0.413	0.205	0.404	0.204	0.403	< 0.01
90-day readmission(cardiac-related)	0.419	0.493	0.373	0.484	0.376	0.484	< 0.001
180-day readmission(cardiac-related)	0.497	0.500	0.453	0.498	0.456	0.498	< 0.001
365-day readmission(cardiac-related)	0.590	0.492	0.545	0.498	0.549	0.497	< 0.001
730-day readmission(cardiac-related)	0.680	0.466	0.647	0.478	0.650	0.476	< 0.001
Patients admitted as an emergency	0.437	0.496	0.435	0.496	0.433	0.495	0.78
Patients admitted as transfers from another hospital	0.055	0.228	0.039	0.193	0.045	0.207	< 0.001
Patients admitted to high volume hospitals	0.595	0.467	0.548	0.494	0.616	0.479	< 0.001
Patients admitted to university hospitals	0.134	0.341	0.082	0.274	0.109	0.311	< 0.001
Patients who received revascularization	0.775	0.417	0.754	0.431	0.763	0.425	< 0.001
For-profit hospitals	0.160	0.366	0.186	0.389	0.173	0.378	< 0.001
Nonprofit hospitals	0.451	0.498	0.243	0.429	0.355	0.478	< 0.001
Patients resided in urban area	1.000	0.000	0.536	0.499	0.792	0.406	< 0.001
Hospital located in western Germany	0.577	0.494	0.840	0.366	0.821	0.384	< 0.001
Nurse-per-bed	0.676	0.251	0.642	0.341	0.663	0.276	< 0.001
Number of observations*	8,719		26,444		63,439		

*Reported number of observations are for the dataset used for examining in-hospital mortality

Table 3.2 First stage instrumental variable results

Variables	Outcome Received revascularization
Differential distance 0 KM	Reference
< 1 KM	0.465***
	(0.158)
1-2 KM	0.441***
	(0.158)
2-3 KM	0.437***
	(0.158)
3-6 KM	0.423***
	(0.158)
6-9 KM	0.426***
	(0.158)
9-12 KM	0.393**
	(0.158)
12-15 KM	0.387**
	(0.159)
15-19 KM	0.362**
	(0.159)
19-23 KM	0.346**
	(0.159)
23-27 KM	0.254
	(0.161)
27-32 KM	0.328**
	(0.165)
32-37 KM	0.410**
	(0.177)
37KM>	0.258
	(0.224)
Demographics, health status controls	Yes

Notes. The coefficients report the impact of differential distance on a receipt of revascularization. Robust standard errors are reported in parentheses. ***p < 0.01, **p < 0.05

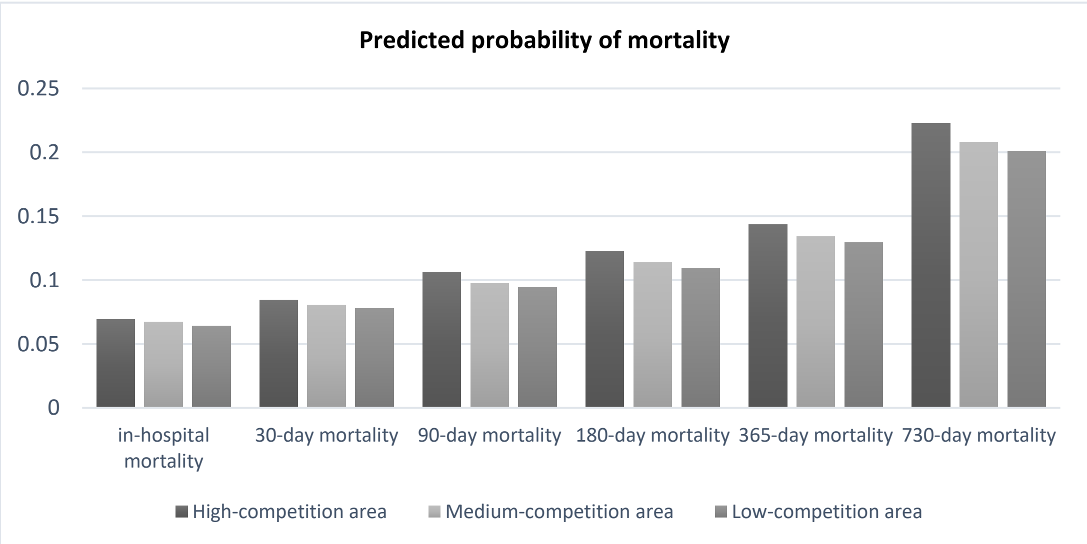
Table 3.3 reports the 2SLS results for mortality, and Figure 3.1 shows the predicted probabilities of in-hospital and post-hospitalization mortality, which we calculated using the 2SLS results as if all AMI cases had been treated in hospitals facing high, medium, or low competition. The test results comparing coefficients by the level of competition are provided below the figure. Quality of care is not statistically significantly different at hospitals facing medium and low competition, whereas it is lowest in high competition areas. Patients treated in high competition areas were more likely to die than those treated in medium or low competition areas; the difference was significant for all mortality outcomes except in-hospital mortality[4]. The difference in mortality increased depending on the length of time since admission. Patients treated in high competition markets were 8.04% more likely to die within 30 days and 11.61% more likely to die within 90 days of admission than patients treated in low competition markets. Patients admitted to high-volume hospitals experienced 1.6 and 2.9 percentage points lower in-hospital and two-year mortality rates than patients treated in low-volume hospitals, respectively in line with the volume-outcome relationship for AMI patients [18, 19].

[4] The difference was 0.5 percentage points for in-hospital mortality.

Table 3.3 2SLS estimation mortality results

Variables	in hospital	30-day	90-day	180-day	365-day	730-day
High competition area	0.002	0.004	0.009**	0.009**	0.009**	0.015***
	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)	(0.005)
Low competition area	-0.003	-0.003	-0.003	-0.004	-0.005	-0.007*
	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)	(0.004)
Emergency admit	0.008***	0.008***	0.007***	0.007***	0.007***	0.008***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)
Transfer admit	0.024***	0.025***	0.025***	0.025***	0.028***	0.035***
	(0.004)	(0.005)	(0.005)	(0.006)	(0.006)	(0.007)
Patients admitted at high volume hospitals	-0.016***	-0.018***	-0.018***	-0.021***	-0.024***	-0.029***
	(0.005)	(0.005)	(0.006)	(0.006)	(0.007)	(0.007)
Patients admitted at university hospitals	-0.001	-0.003	-0.003	-0.002	-0.002	-0.002
	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)
Patients who received revascularization	0.035	-0.018	-0.025	-0.025	-0.031	-0.02
	(0.028)	(0.03)	(0.033)	(0.035)	(0.038)	(0.042)
Hospital located in western Germany	-0.001	0.-00003	0.001	0.004	0.004	0.009
	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)

Notes. Year fixed effects, age category indicators, Ontario acute myocardial infarction mortality prediction rules indices, male, nurse-per-bed, ownership type, patients residing in urban area , and distance between patient and hospital are included as controls in the regressions. Robust standard errors are reported in parentheses. ***p < 0.01, **p < 0.05, * p < 0.1



Mortality					
in-hospital	30-day	90-day	180-day	365-day	730-day
HC > MC (0.466)	HC > MC (0.226)	HC > **MC (0.011)	HC > **MC (0.014)	HC > **MC (0.018)	HC >*** MC (0.001)
HC > LC (0.131)	HC > *LC (0.066)	HC > ***LC (0.002)	HC > ***LC (0.001)	HC > ***LC (0.001)	HC > ***LC (0.0001)
LC < MC (0.198)	LC < MC (0.257)	LC < MC (0.265)	LC < MC (0.116)	LC < *MC (0.101)	LC < *MC (0.066)

Notes. HC, MC, and LC denote high, medium, and low competition areas, respectively. ***p < 0.01, **p < 0.05, * p < 0.1

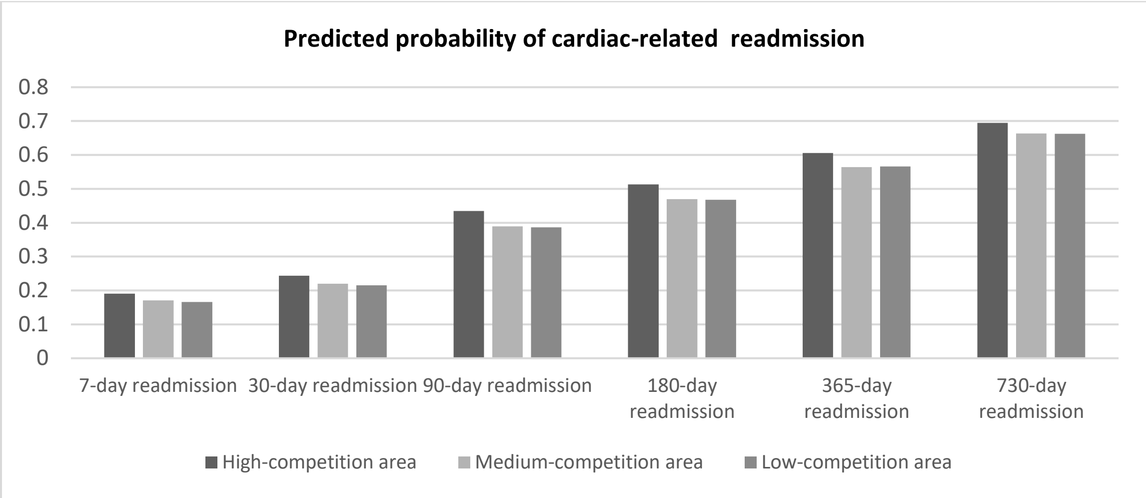
Figure 3.1 Comparison of mortality probabilities by the level of competition faced by hospitals

2SLS cardiac-related readmission results are reported in Table 3.4 and Figure 3.2 shows the predicted probabilities of cardiac-related readmission by hospitals facing high, medium, or low competition. P-values of the tests comparing coefficients by the level of competition are provided below the figure. Patients treated in high competition areas were significantly more likely to be readmitted than patients treated in low competition areas from seven days to two years post-discharge; however, the difference in the probability of readmission between high and low competition markets increased from 2.4 percentage points for 7-day readmission up to 4.8 percentage points for 90-day readmission and declined from 4.3 percentage points for 1-year readmission to 3.3 percentage points for 2-year readmission. The results also show that patients who underwent revascularization were significantly less likely to be readmitted to the hospital compared to those who did not.

Table 3.4 2SLS estimation readmission results (cardiac-related)

Variables	7-day	30-day	90-day	180-day	365-day	730-day
High competition area	0.020***	0.024***	0.045***	0.043***	0.042***	0.032***
	(0.005)	(0.006)	(0.007)	(0.007)	(0.007)	(0.007)
Low competition area	-0.004	-0.004	-0.003	-0.002	0.001	-0.001
	(0.004)	(0.004)	(0.005)	(0.005)	(0.005)	(0.005)
Emergency admit	0.008**	0.004	0.008*	0.008*	0.007	0.006
	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Transfer admit	0.052***	0.040***	0.011	0.004	0.013	0.017*
	(0.008)	(0.009)	(0.011)	(0.011)	(0.011)	(0.01)
Patients admitted at	0.023***	0.029***	-0.005	-0.014	-0.015	-0.014
high volume hospitals	(0.009)	(0.01)	(0.011)	(0.012)	(0.012)	(0.011)
Patients admitted at	0.009	0.002	0.012	0.018**	0.023***	0.020***
university hospitals	(0.006)	(0.007)	(0.008)	(0.008)	(0.008)	(0.007)
Patients who received	-0.639***	-0.609***	-0.373***	-0.314***	-0.287***	-0.215***
revascularization	(0.057)	(0.064)	(0.075)	(0.076)	(0.076)	(0.072)
Hospital located in	-0.012***	-0.013**	-0.049***	-0.043***	-0.028***	-0.022***
western Germany	(0.005)	(0.005)	(0.006)	(0.006)	(0.006)	(0.006)

Notes. Year fixed effects, age category indicators, Ontario acute myocardial infarction mortality prediction rules indices, male, nurse-per-bed, ownership type, patients residing in urban area , and distance between patient and hospital are included as controls in the regressions. Robust standard errors are reported in parentheses. ***p < 0.01, **p < 0.05, * p < 0.1



Readmission (cardiac-related)					
7-Day	30-Day	90-Day	180-Day	365-Day	730-Day
HC > ***MC (0.0002)	HC > ***MC (<0.0001)	HC > ***MC (<0.0001)	HC > ***MC (<0.0001)	HC > ***MC (<0.0001)	HC > ***MC (<0.0001)
HC > ***LC (0.0001)	HC > ***LC (0.0001)	HC > ***LC (0.0001)	HC > ***LC (0.0001)	HC > ***LC (0.0001)	HC > ***LC (0.0001)
LC < MC (0.289)	LC <MC (0.322)	LC <MC (0.527)	LC <MC (0.688)	LC > MC (0.781)	LC < MC (0.835)

Notes. HC, MC, and LC denote high, medium, and low competition areas, respectively. ***p < 0.01, **p < 0.05

Figure 3.2 Comparison of (cardiac-related) readmission probabilities by level of competition faced by hospitals

2SLS results for all-cause readmission are similar to cardiac-related readmission results and are reported in Appendix, Table 3.5[5]. Comorbidities and the rest of the patient- and hospital-level variables had the expected signs or were not significant, so we excluded these from the regression tables.

To test the robustness of our findings, we performed a number of sensitivity analyses. We tested whether the functional form impacted our results. In the base model, we estimated a linear relationship between competition and quality, thereby re-estimating competition-quality relationships using the logistic model [6]. We also ran various specification tests. First, we calculated the HHI with a 20 km radius to define markets and used it to measure competitiveness in lieu of the distance-weighted measure[7].

[5] Figure 3.3 in Appendix shows the predicted probabilities of all-cause readmission by hospitals facing high, medium, or low competition.

[6] Tables 3.6, 3.7, and 3.8 in Appendix report the main findings of our OLS regressions modeling the effect of hospital competition on cumulative mortality, cardiac-related, and all-cause readmission, respectively. We found that higher hospital competition was associated with higher post-discharge mortality and readmission for AMI patients. Patients treated in high competition areas had 0.7 percentage points higher probability of dying in the hospital or within 30 days than patients treated in low competition areas and the difference was insignificant. However, for longer durations post-admission, patients treated in high competition areas were significantly more likely to die than patients treated in low competition areas; indeed, the longer the duration considered, the greater the difference in the probability of cumulative mortality between high and low competition areas. The findings of our analysis of the effect of competition on quality of care using logistic regression were in line with the OLS results (see Tables in the appendix 3.9, 3.10, and 3.11).

[7] Tables 3.12, 3.13, and 3.14 in Appendix report the 2SLS results obtained using HHI instead of distance-weighted measure of competition for cumulative mortality, cardiac-related, and all-cause readmission, respectively.

Second, we excluded university hospitals and hospitals with multiple sites. Third, since non-ST-segment elevation myocardial infarction is less likely to require revascularization, we repeated the analysis after excluding non-ST-segment elevation (ICD code: I21.4) from our sample. Our results were qualitatively robust to each of these sensitivity analyses.

3.4 Discussion

Our study is the first to focus empirically on the effect of hospital competition on quality of care in Germany. To do so, we investigated the effect of hospital competition on health outcomes for AMI patients. Our results show that the level of competition does not affect quality of care as long as it is not very high. This finding can be partly explained by the limited effect of quality differential on hospital choice (Marshall, Shekelle et al. 2000); when quality is not a very important factor in patients' hospital choice decision, hospitals are unlikely to exert efforts to improve quality in order to attract patients. However, patients admitted to hospitals in high competition areas are more likely to die or be readmitted than patients admitted to hospitals in low competition areas. Importantly, the differences in quality between high and low competition areas manifested themselves in longer-term mortality and readmissions similar to the impact of revascularization on mortality (Cutler DM. 2007).Therefore, focusing on in-hospital mortality alone, as has frequently been the case in both academic and policy contexts due to data limitations might be misleading. Taking account of longer-term outcomes, at least for AMI patients, would appear to be crucial.

We examined patients' length of stay (LOS) as a possible explanation for worse outcomes in highly competitive areas. If hospitals in highly competitive areas discharge patients more quickly to free up beds, these patients may indeed end up having worse outcomes than the ones admitted to hospitals in low competition areas (Thomas, Guire et al. 1997). To test whether this potential effect might be of relevance to our study, we investigated the LOS by competitiveness of the hospital market. LOS did not differ significantly between high and low competition markets. Hence, in our sample of AMI patients, the difference in quality between high and low competition markets was not due to differences in the discharge behavior of hospitals.

There can be several explanations for the elevated effect of competition on longer-term health outcomes. Hospitals in high competition markets are presumably more likely to have higher staff turnover than hospitals in low competition markets, leading to worse post-acute follow-up and worse outcomes in the longer time frame. Alternatively, patients' hospital selection is likely highly correlated over time. Patient treated for AMI in a hospital is likely to go to the same hospital with other health problems. If quality of a hospital is correlated across treatment of diseases, hospitals facing high competition might be worse at treating other diseases leading to worse health outcomes in the longer term.

Our results are in line with those of the few previous studies that have analyzed the link between competition and quality of care under a fixed price setting (Gowrisankaran and Town 2003, Propper, Burgess et al. 2004, Mutter, Wong et al. 2008, Brekke, Siciliani et al. 2011, Palangkaraya and Yong 2013, Liao, Lu et al. 2018, Moscelli, Gravelle et al. 2021). However, our findings stand in contrast to several theoretical and empirical studies whose results suggest that higher hospital competition with fixed prices leads to improvements in the quality of care, such as lower mortality (Kessler and McClellan 2000, Gaynor 2006, Bloom, Propper et al. 2015).

Our findings can potentially be explained by the specific regulatory regime in Germany. For instance, one potential reason for our findings could be the lack of quality regulation in Germany. Because a hospital that performs worse than the benchmark is not sanctioned for doing so, it is allowed to compete with other hospitals on the number/volume of patients without focusing on maintaining a certain level of quality of care. Additionally, there is considerable diversity in the extent to which hospitals in Germany have established systems to implement clinical guidelines, which are not mandatory in Germany (Legido-Quigley and Nolte 2008). Hospitals in high competition areas may be under more pressure and therefore less likely to adhere strictly to clinical guidelines, which in turn might lead to lower quality care. Moreover, if hospitals have a high level of altruism, which we cannot measure, quality is expected to be low in high competition markets (Brekke, Siciliani et al. 2011). Additionally, others have hypothesized that hospitals in low competition markets in Germany are more likely to agree with the hospital planning authorities on hospital infrastructure that enables the convergence of demand and supply (Tiemann and Schreyögg 2009).

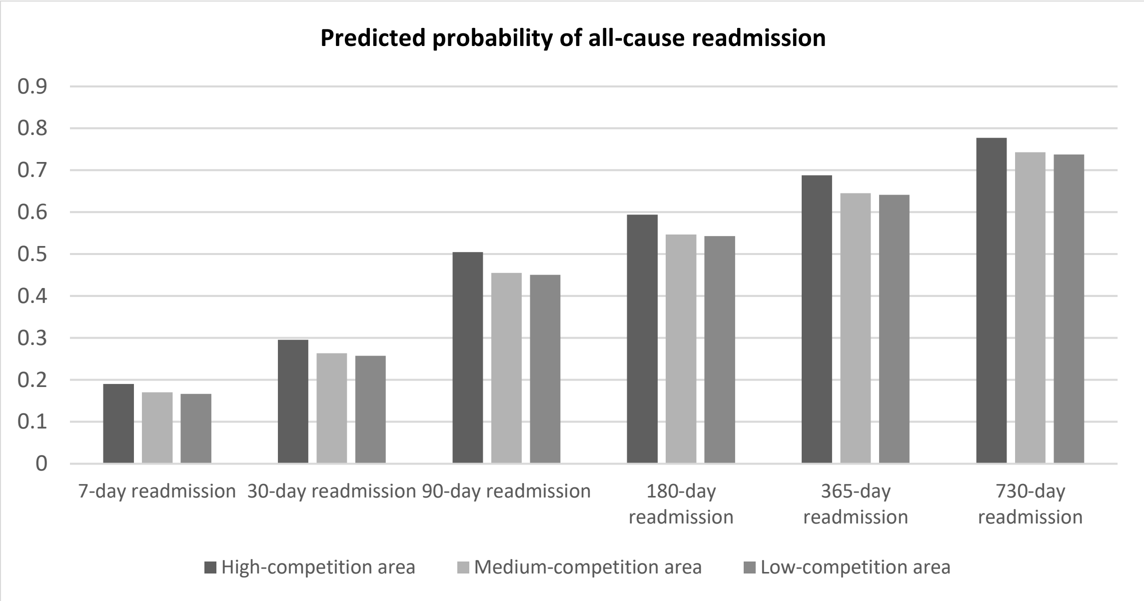
Our study has a number of strengths. First, our patient dataset is large, affording great statistical power and allowing us to derive robust estimates and track patients over time, enabling us, in turn, to consider longer-term outcomes. Second, we were able to account for the endogeneity of revascularization in AMI patients to health outcomes to estimate the effect of competition on quality consistently. Third, we use a distance-based competition measure, which (a) takes into account the fact that hospitals mainly compete with nearby hospitals and (b) does not require market boundaries. Lastly, our dataset contains a large amount of geographic information and patient and hospital characteristics, allowing us to control appropriately for variables that might alter the association between competition and quality.

Our study also has limitations. Although we take account of several characteristics that may alter the association between competition and quality of care, there are others, such as physician’s experience, that we do not observe. (Tay 2003, Wright, Tergas et al. 2016). Even though we measure the quality of care using cumulative mortality and readmission, it would be important in future research to investigate the impact of competition on process dimensions of quality of care. In particular, process indicators are important as a management tool and improvement in process measures can improve downstream outcome measures, such as readmissions and mortality.

3.5 Conclusion

Using a rich dataset and accounting for endogeneity by means of instrumental variable regression, we provide evidence of a negative impact of hospital competition on the quality of AMI care as measured in terms of in-hospital mortality, mortality after discharge, and readmission AMI in Germany. Our results may call into question policies that stimulate competition in health care in Germany. However, the desirability of such policies requires a complete welfare analysis, which is beyond the scope of this paper. If policies promoting competition in health care are continued or strengthened in Germany, it would be advisable to monitor the quality of care more closely and to consider mechanisms for sanctioning hospitals that deviate substantially from quality benchmarks.

3.6 Appendix



Readmission (all-cause)					
7-day	30-day	90-day	180-day	365-day	730-day
HC > ***MC (0.0002)	HC > ***MC (<0.0001)	HC > ***MC (<0.0001)	HC > ***MC (<0.0001)	HC > ***MC (<0.0001)	HC > ***MC (<0.0001)
HC > ***LC (0.0001)	HC > ***LC (0.0001)	HC > ***LC (0.0001)	HC > ***LC (0.0001)	HC > ***LC (0.0001)	HC > ***LC (0.0001)
LC < MC (0.289)	LC < MC (0.173)	LC < MC (0.381)	LC < MC (0.458)	LC < MC (0.424)	LC < MC (0.258)

Notes: HC, MC, and LC denote high, medium, and low competition areas, respectively. ***p < 0.01

Figure 3.3 Comparison of (all-cause) readmission probabilities by level of competition faced by hospitals

Table 3.5 2SLS estimation readmission results (all-cause)

Variables	7-day	30-day	90-day	180-day	365-day	730-day
High competition area	0.020***	0.032***	0.049***	0.047***	0.043***	0.035***
	(0.005)	(0.006)	(0.007)	(0.007)	(0.007)	(0.006)
Low competition area	-0.004	-0.006	-0.005	-0.004	-0.004	-0.005
	(0.004)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Emergency admit	0.008**	0.005	0.004	0.005	0.001	-0.001
	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Transfer admit	0.052***	0.054***	0.020*	0.011	0.013	0.017*
	(0.008)	(0.01)	(0.011)	(0.011)	(0.01)	(0.01)
Patients admitted at high volume hospitals	0.023***	0.022**	-0.012	-0.014	-0.014	-0.012
	(0.009)	(0.01)	(0.011)	(0.011)	(0.011)	(0.01)
Patients admitted at university hospitals	0.009	0.005	0.013*	0.019**	0.023***	0.016**
	(0.006)	(0.007)	(0.008)	(0.008)	(0.007)	(0.007)
Patients who received revascularization	-0.639***	-0.615***	-0.373***	-0.352***	-0.311***	-0.244***
	(0.057)	(0.066)	(0.075)	(0.076)	(0.073)	(0.067)
Hospital located in western Germany	-0.012***	-0.009*	-0.045***	-0.036***	-0.021***	-0.018***
	(0.005)	(0.005)	(0.006)	(0.006)	(0.006)	(0.005)

Notes. Competition calculated based on distance-weighted measures. Year fixed effects, age category indicators, Ontario acute myocardial infarction mortality prediction rules indices, male, nurse-per-bed, ownership type, patients residing in urban area and distance between patient and hospital are included as controls in the regressions. Robust standard errors are reported in parentheses. ***p < 0.01, **p < 0.05, * p < 0.1

Table 3.6 OLS Estimation-Mortality Results

Variables	In-Hospital	30-Day	90-Day	180-Day	365-Day	730-Day
High competition area	0.003	0.004	0.009***	0.010***	0.010**	0.016***
	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)	(0.006)
Low competition area	-0.004	-0.003	-0.003	-0.005	-0.006	-0.008
	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)	(0.005)
Emergency admit	0.008***	0.008***	0.007***	0.007***	0.007**	0.008**
	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)
Transfer admit	0.024***	0.024***	0.025***	0.024***	0.028***	0.034***
	(0.005)	(0.006)	(0.007)	(0.007)	(0.007)	(0.009)
Patients admitted at high volume hospitals	-0.003	-0.010***	-0.009***	-0.010***	-0.011***	-0.011***
	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)
Patients admitted at university hospitals	0.002	-0.001	-0.001	0.0005	0.001	0.003
	(0.004)	(0.004)	(0.005)	(0.005)	(0.006)	(0.007)
Patients who received revascularization	-0.050***	-0.070***	-0.084***	-0.098***	-0.112***	-0.136***
	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)	(0.005)
Hospital located in western Germany	-0.002	-0.001	-0.0001	0.003	0.003	0.007
	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)	(0.005)

Notes. Competition calculated based on distance-weighted measures. Year fixed effects, age category indicators, Ontario acute myocardial infarction mortality prediction rules indices, male, nurse-per-bed, ownership type, patients residing in urban area , and distance between patient and hospital are included as controls in the regressions. Robust standard errors clustered at the hospital level are reported in parentheses. ***p < 0.01, **p < 0.05

Table 3.7 OLS estimation-readmission results (cardiac-related)

Variables	7-day	30-Day	90-Day	180-Day	365-Day	730-Day
High competition area	0.016*	0.020**	0.043***	0.041***	0.040***	0.030**
	(0.008)	(0.009)	(0.014)	(0.015)	(0.015)	(0.012)
Low competition area	-0.002	-0.002	-0.002	-0.001	0.003	0.0001
	(0.006)	(0.007)	(0.01)	(0.01)	(0.009)	(0.008)
Emergency admit	0.005	0.001	0.006	0.006	0.005	0.004
	(0.004)	(0.004)	(0.006)	(0.006)	(0.006)	(0.005)
Transfer admit	0.060***	0.048***	0.017	0.009	0.018	0.021
	(0.015)	(0.015)	(0.015)	(0.015)	(0.013)	(0.012)
Patients admitted at high volume hospitals	-0.037***	-0.030***	-0.045***	-0.049***	-0.048***	-0.040***
	(0.005)	(0.005)	(0.008)	(0.008)	(0.008)	(0.007)
Patients admitted at university hospitals	-0.004	-0.01	0.004	0.011	0.017	0.015
	(0.011)	(0.011)	(0.017)	(0.016)	(0.017)	(0.015)
Patients who received revascularization	-0.205***	-0.184***	-0.088***	-0.061***	-0.042***	-0.025***
	(0.007)	(0.007)	(0.008)	(0.008)	(0.008)	(0.006)
Hospital located in western Germany	-0.007	-0.008	-0.046***	-0.041***	-0.025**	-0.020**
	(0.007)	(0.007)	(0.013)	(0.012)	(0.012)	(0.01)

Notes. Competition calculated based on distance-weighted measures. Year fixed effects, age category indicators, Ontario acute myocardial infarction mortality prediction rules indices, male, nurse-per-bed, ownership type, patients residing in urban area , and distance between patient and hospital are included as controls in the regressions. Robust standard errors clustered at the hospital level are reported in parentheses. ***p < 0.01, **p < 0.05, * p < 0.1

Table 3.8 OLS estimation-readmission results (all-cause)

Variables	7-day	30-Day	90-Day	180-Day	365-Day	730-Day
High competition area	0.016*	0.028***	0.047***	0.045***	0.041***	0.033***
	(0.008)	(0.009)	(0.012)	(0.013)	(0.012)	(0.009)
Low competition area	-0.002	-0.004	-0.003	-0.002	-0.003	-0.004
	(0.006)	(0.007)	(0.01)	(0.01)	(0.009)	(0.007)
Emergency admisson	0.005	0.002	0.002	0.003	-0.001	-0.002
	(0.004)	(0.004)	(0.006)	(0.006)	(0.006)	(0.005)
Transfer admission	0.060***	0.061***	0.025*	0.015	0.017	0.020*
	(0.015)	(0.015)	(0.015)	(0.014)	(0.012)	(0.011)
Patients admitted at high volume hospitals	-0.037***	-0.033***	-0.045***	-0.047***	-0.044***	-0.035***
	(0.005)	(0.005)	(0.008)	(0.008)	(0.007)	(0.006)
Patients admitted at university hospitals	-0.004	-0.007	0.006	0.012	0.017	0.011
	(0.011)	(0.011)	(0.017)	(0.016)	(0.016)	(0.013)
Patients who received revascularization	-0.205***	-0.216***	-0.135***	-0.112***	-0.096***	-0.077***
	(0.007)	(0.008)	(0.008)	(0.007)	(0.007)	(0.005)
Hospital located in western Germany	-0.007	-0.005	-0.042***	-0.034***	-0.018*	-0.016*
	(0.007)	(0.007)	(0.012)	(0.012)	(0.01)	(0.008)

Notes. Competition calculated based on distance-weighted measures. Year fixed effects, age category indicators, Ontario acute myocardial infarction mortality prediction rules indices, male, nurse-per-bed, ownership type, patients residing in urban area , and distance between patient and hospital are included as controls in the regressions. Robust standard errors clustered at the hospital level are reported in parentheses. ***p < 0.01, * p < 0.1

Table 3.9 Logistic estimation-mortality results

Variables	In-Hospital	30-Day	90-Day	180-Day	365-Day	730-Day
High competition area	0.069	0.076	0.137**	0.121**	0.106**	0.131**
	(0.076)	(0.068)	(0.062)	(0.059)	(0.054)	(0.053)
Low competition area	-0.049	-0.037	-0.034	-0.051	-0.051	-0.064
	(0.061)	(0.054)	(0.052)	(0.048)	(0.046)	(0.044)
Emergency admit	0.201***	0.162***	0.119***	0.099***	0.084**	0.078**
	(0.052)	(0.045)	(0.04)	(0.037)	(0.034)	(0.032)
Transfer admit	0.436***	0.372***	0.302***	0.259***	0.252***	0.257***
	(0.08)	(0.078)	(0.078)	(0.074)	(0.068)	(0.068)
Patients admitted at high volume hospitals	-0.057	-0.179***	-0.132***	-0.129***	-0.130***	-0.102***
	(0.056)	(0.048)	(0.044)	(0.041)	(0.037)	(0.037)
Patients admitted at university hospitals	0.024	-0.011	0.015	0.042	0.046	0.059
	(0.084)	(0.083)	(0.077)	(0.072)	(0.068)	(0.061)
Patients who received revascularization	-1.040***	-1.146***	-1.121***	-1.104***	-1.078***	-1.043***
	(0.051)	(0.044)	(0.038)	(0.038)	(0.034)	(0.032)
Hospital located in western Germany	-0.024	-0.005	0.001	0.036	0.023	0.055
	(0.063)	(0.058)	(0.054)	(0.052)	(0.047)	(0.045)

Notes. Competition calculated based on distance-weighted measures. Year fixed effects, age category indicators, Ontario acute myocardial infarction mortality prediction rules indices, male, nurse-per-bed, ownership type, patients residing in urban area , and distance between patient and hospital are included as controls in the regressions. Robust standard errors clustered at the hospital level are reported in parentheses. ***p < 0.01, **p < 0.05

Table 3.10 Logistic estimation-readmission results (cardiac-related)

Variables	7-day	30-Day	90-Day	180-Day	365-Day	730-Day
High competition area	0.128*	0.129**	0.187***	0.172***	0.170**	0.140**
	(0.068)	(0.058)	(0.06)	(0.062)	(0.067)	(0.06)
Low competition area	-0.017	-0.013	-0.007	-0.002	0.012	-0.0004
	(0.054)	(0.044)	(0.045)	(0.042)	(0.04)	(0.038)
Emergency admit	0.04	0.005	0.025	0.026	0.022	0.02
	(0.036)	(0.028)	(0.029)	(0.027)	(0.026)	(0.025)
Transfer admit	0.438***	0.285***	0.072	0.039	0.077	0.103*
	(0.099)	(0.085)	(0.067)	(0.063)	(0.057)	(0.06)
Patients admitted at high volume hospitals	-0.307***	-0.195***	-0.198***	-0.205***	-0.205***	-0.188***
	(0.041)	(0.035)	(0.036)	(0.036)	(0.034)	(0.033)
Patients admitted at university hospitals	-0.024	-0.066	0.018	0.048	0.07	0.067
	(0.108)	(0.079)	(0.076)	(0.068)	(0.072)	(0.068)
Patients who received revascularization	-1.361***	-1.044***	-0.385***	-0.259***	-0.179***	-0.119***
	(0.043)	(0.039)	(0.036)	(0.034)	(0.032)	(0.031)
Hospital located in western Germany	-0.061	-0.053	-0.203***	-0.171***	-0.107**	-0.092*
	(0.055)	(0.048)	(0.055)	(0.052)	(0.05)	(0.047)

Notes. Competition calculated based on distance-weighted measures. Year fixed effects, age category indicators, Ontario acute myocardial infarction mortality prediction rules indices, male, nurse-per-bed, ownership type, patients residing in urban area , and distance between patient and hospital are included as controls in the regressions. Robust standard errors clustered at the hospital level are reported in parentheses. ***p < 0.01, **p < 0.05, * p < 0.1

Table 3.11 Logistic estimation-readmission results (all-cause)

Variables	7-day	30-Day	90-Day	180-Day	365-Day	730-Day
High competition area	0.128**	0.162***	0.200***	0.192***	0.191***	0.189***
	(0.068)	(0.052)	(0.052)	(0.055)	(0.059)	(0.054)
Low competition area	-0.017	-0.024	-0.014	-0.01	-0.013	-0.024
	(0.054)	(0.041)	(0.043)	(0.041)	(0.04)	(0.039)
Emergency admit	0.04	0.013	0.009	0.014	-0.003	-0.011
	(0.036)	(0.026)	(0.027)	(0.026)	(0.026)	(0.026)
Transfer admit	0.438***	0.327***	0.106*	0.069	0.086	0.125*
	(0.099)	(0.075)	(0.064)	(0.061)	(0.06)	(0.066)
Patients admitted at high volume hospitals	-0.307***	-0.195***	-0.191***	-0.198***	-0.201***	-0.191***
	(0.041)	(0.032)	(0.033)	(0.034)	(0.034)	(0.034)
Patients admitted at university hospitals	-0.024	-0.034	0.026	0.047	0.069	0.05
	(0.108)	(0.066)	(0.073)	(0.066)	(0.071)	(0.07)
Patients who received revascularization	-1.361***	-1.081***	-0.565***	-0.479***	-0.460***	-0.462***
	(0.043)	(0.035)	(0.034)	(0.032)	(0.032)	(0.034)
Hospital located in western Germany	-0.061	-0.029	-0.178***	-0.142***	-0.082*	-0.088*
	(0.055)	(0.044)	(0.051)	(0.049)	(0.048)	(0.047)

Notes. Competition calculated based on distance-weighted measures. Year fixed effects, age category indicators, Ontario acute myocardial infarction mortality prediction rules indices, male, nurse-per-bed, ownership type, patients residing in urban area , and distance between patient and hospital are included as controls in the regressions. Robust standard errors clustered at the hospital level are reported in parentheses. ***$p < 0.01$, **$p < 0.05$, * $p < 0.1$

Table 3.12 2SLS estimation mortality results

Variables	in hospital	30-day	90-day	180-day	365-day	730-day
High competition area	0.006**	0.005***	0.009***	0.009***	0.009***	0.015***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)
Low competition area	0.0003	0.002	0.003	0.003	0.004	0.006*
	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)	(0.004)
Emergency admit	0.008***	0.008***	0.007***	0.007***	0.007***	0.008***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)
Transfer admit	0.024***	0.025***	0.025***	0.025***	0.029***	0.035***
	(0.004)	(0.005)	(0.005)	(0.006)	(0.006)	(0.007)
Patients admitted at high volume hospitals	-0.016***	-0.018***	-0.018***	-0.021***	-0.024***	-0.030***
	(0.005)	(0.005)	(0.006)	(0.006)	(0.006)	(0.007)
Patients admitted at university hospitals	-0.001	-0.002	-0.002	-0.001	-0.002	-0.001
	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)
Patients who received revascularization	0.035	-0.018	-0.024	-0.023	-0.029	-0.018
	(0.027)	(0.030)	(0.033)	(0.035)	(0.038)	(0.041)
Hospital located in western Germany	-0.0001	0.0004	0.001	0.004	0.004	0.009**
	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)

Notes. Competition calculated based on HHI . Year fixed effects, age category indicators, Ontario acute myocardial infarction mortality prediction rules indices, male, nurse-per-bed, ownership type, patients residing in urban area and distance between patient and hospital are included as controls in the regressions. Robust standard errors are reported in parentheses. ***p < 0.01, **p < 0.05, * p < 0.1

Table 3.13 2SLS estimation readmission results (cardiac-related)

Variables	7-day	30-day	90-day	180-day	365-day	730-day
High competition area	0.007	0.014***	0.036***	0.035***	0.031***	0.023***
	(0.005)	(0.005)	(0.006)	(0.006)	(0.006)	(0.006)
Low competition area	0.002	-0.003	-0.001	0.001	-0.001	0.002
	(0.004)	(0.004)	(0.005)	(0.005)	(0.005)	(0.005)
Emergency admit	0.008**	0.004	0.008**	0.009**	0.008*	0.006
	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Transfer admit	0.053***	0.041***	0.012	0.005	0.013	0.018*
	(0.008)	(0.009)	(0.011)	(0.011)	(0.011)	(0.010)
Patients admitted at high	0.020**	0.025***	-0.009	-0.017	-0.018	-0.017
volume hospitals	(0.009)	(0.010)	(0.011)	(0.011)	(0.011)	(0.011)
Patients admitted at university	0.009	0.002	0.012	0.019	0.024	0.021
hospitals	(0.006)	(0.007)	(0.008)	(0.008)	(0.008)	(0.007)
Patients who received	-0.626***	-0.593***	-0.358***	-0.305***	-0.278***	-0.209***
revascularization	(0.057)	(0.063)	(0.074)	(0.076)	(0.076)	(0.072)
Hospital located in western	-0.015***	-0.015***	-0.051***	-0.045***	-0.030***	-0.023***
Germany	(0.005)	(0.005)	(0.006)	(0.006)	(0.006)	(0.006)

Notes. Competition calculated based on HHI . Year fixed effects, age category indicators, Ontario acute myocardial infarction mortality prediction rules indices, male, nurse-per-bed, ownership type, patients residing in urban area and distance between patient and hospital are included as controls in the regressions. Robust standard errors are reported in parentheses. ***p < 0.01, **p < 0.05, * p < 0.

Table 3.14 2SLS estimation readmission results (all-cause)

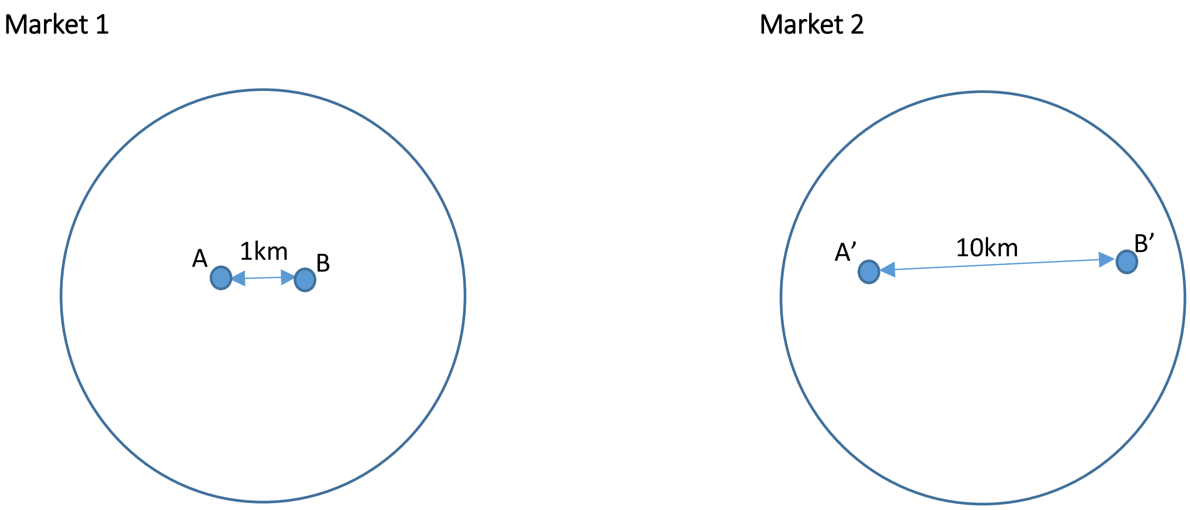
Variables	7-day	30-day	90-day	180-day	365-day	730-day
High competition area	0.007	0.021***	0.037***	0.035***	0.030***	0.025***
	(0.005)	(0.005)	(0.006)	(0.006)	(0.006)	(0.005)
Low competition area	0.002	0.000	0.003	0.005	0.006	0.010**
	(0.004)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Emergency admit	0.008**	0.005	0.004	0.005	0.001	-0.001
	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Transfer admit	0.053***	0.055***	0.021*	0.011	0.013	0.017*
	(0.008)	(0.009)	(0.011)	(0.011)	(0.010)	(0.010)
Patients admitted at high	0.020**	0.018*	-0.016	-0.017	-0.017	-0.014
volume hospitals	(0.009)	(0.010)	(0.011)	(0.011)	(0.011)	(0.010)
Patients admitted at university	0.009	0.005	0.014*	0.020**	0.024***	0.017**
hospitals	(0.006)	(0.007)	(0.008)	(0.008)	(0.007)	(0.007)
Patients who received	-0.626***	-0.598***	-0.358***	-0.341***	-0.301***	-0.239***
revascularization	(0.057)	(0.066)	(0.075)	(0.075)	(0.072)	(0.066)
Hospital located in western	-0.015***	-0.012***	-0.047***	-0.038***	-0.023***	-0.020***
Germany	(0.005)	(0.005)	(0.006)	(0.006)	(0.006)	(0.005)

Notes. Competition calculated based on HHI . Year fixed effects, age category indicators, Ontario acute myocardial infarction mortality prediction rules indices, male, nurse-per-bed, ownership type, patients residing in urban area and distance between patient and hospital are included as controls in the regressions. Robust standard errors are reported in parentheses. ***p < 0.01, **p < 0.05, * p < 0.1

3.6.1 Calculating Competition Measures

When using HHI, hospital markets are either defined using geographical boundaries or as the area within 15/20 km radius of a given hospital. Let us assume that there are two hospital markets, Market 1 and Market 2, with two hospitals and *n* patients are admitted to each hospital. In that case, both markets' HHI will be the same (HHI=5000), even though the level of competition hospital A faces is unlikely to be the same as the level of competition hospital A' faces because the distance is very important in hospital selection.

If hospital choice is responsive to quality, when the quality of hospital A decreases a little bit in Market 1, patients' likelihood of choosing hospital B over A will increase substantially. However, when the quality of hospital A' decreases a little bit in Market 2, because patients are sensitive to distance, patients' likelihood of choosing A' over B' will not change much. HHI does not consider the magnitude of the distance between hospitals as long as they are in the same market, and hence using distance-based measure allows us to measure competition more precisely than HHI.



While calculating the distance-weighted measure of competition, based on the family of weighting functions, we consider the following formula where x is the distance from the hospital's own location following Horwitz and Nichols (Horwitz, J., & Nichols, A. 2007).:

$$w(x;b) = \left(\frac{1}{1+bx^2}\right)^2$$

In the distance-weighted formula, cases are assumed to be distributed uniformly; hence, we pick the parameter b in the formula using the 75th percentile of the distance, which is 17km in our case:

$$\frac{\int_0^{17km} \left(\frac{1}{1+bx^2}\right)^2 dx}{\int_0^{\infty} \left(\frac{1}{1+bx^2} =\right)^2 dx} = 0.75$$

This weight function decays smoothly, doesn't put infinite weight on arbitrarily close points, and corresponds to the notion of 75% of the cases come from a 17 km around. The ratio of weight within 17km to the total weight is:

$$1 - \frac{1}{1+b(17)^2}$$

Furthermore, this will be 0.75 when b=0.01038.

Chapter 4

The Effect of Hospital Size on the Financial Performance

4.1 Introduction

Since the 1980s, the healthcare service industry in the United States has faced a wide range of policy interventions to tackle the rising healthcare costs. This increase in healthcare costs is mainly attributed to a combination of factors such as the aging of the population, technological advances, direct and indirect malpractice costs, high healthcare professionals' wages, and increased insurance coverage (Murthy and Okunade 2016, Schreck 2019). Many factors that increase the overall healthcare costs can undermine financial performance (Akinleye, McNutt et al. 2019), considering that being financially sound is crucial to secure the continuous delivery of healthcare services among hospitals (Ramamonjiarivelo, Weech-Maldonado et al. 2020). On the basis of available research evidence, different patient and hospital-level factors can affect financial performance. It is presumed that one of the potential sources of inefficiency is related to the hospital scale. On the one hand, the bigger hospital can make efficient use of available expertise, infrastructure, and equipment compared to the smaller hospital. On the other hand, due to the complexity of managing a hospital, it is presumed that a smaller hospital runs more smoothly than the larger one, making them more efficient. So, does it make economic sense that bigger hospitals have a better financial performance than the smaller ones?

One perspective on this idea is that larger hospitals can be associated with a higher cost-efficiency through the concept known as economies of scale. This concept suggests that larger hospitals are able to deliver care at a lower cost compared to smaller hospitals, as the fixed costs spread across a larger amount of care that is being delivered (Asbu, Masri, et al. 2020). It also implies that larger hospitals typically generate lower average costs and higher profits than smaller ones, as they are claimed to be more cost-efficient (Freeman, Savva et al. 2021).

Hospital size can be affected by the number of objects. Some literature focused on outlining the effect of hospital size, as a consequence of mergers and acquisitions (M&A), on the financial performance (Vogt and Town 2006, Gaynor and Town 2012). The merger can be beneficial as it is presumed to reduce costs, increase care coordination, eliminate inefficient duplication and enhance efficiency. This efficiency claim is made because larger hospitals seem to have higher cost savings since more cost allocation takes place in the larger hospitals (Gaynor 2018). In most cases, larger hospitals have more departments that share resources, thus also sharing the costs of these resources (Lambrecht 2004, Schmitt 2017). This makes larger hospitals more cost-efficient and is basically attributed to the economies of scale concept.

Despite the financial benefits that larger hospitals seem to have, according to this latter concept, the state of California has put a halt on expanding one hospital through M&A within the healthcare sector in 2015 and meanwhile, seek to expand and strengthen antitrust enforcement agencies in dealing with mergers they judge to be harmful (Diamond 2015, Gertler 2021). An argument for this halt and more supervision over this matter targeted the fact that it leads merging hospitals becoming consolidated and concentrated in the market. Having a more substantial market power leads to these hospitals demanding health insurers to pay more for medical care. Health economists even suggest that this could eventually lead these hospitals to drive up hospital prices, which can, in turn, may harm the quality of care. In addition, the burden of higher provider prices and/or lower quality falls on individuals (Krishnan 2001, Gaynor 2011, Gaynor 2018, Williams Jr, Reiter, et al. 2020, Gudiksen, Montague, et al. 2021). Thus, it seems that while larger hospitals might be more cost-efficient, they might also drive up the price for the consumers themselves. It suggested more than just one perspective on the relationship between hospital size and financial performance.

While there are many empirical pieces of research available regarding the economies of scale in a hospital context, research that primarily focuses on the relationship between hospital size and financial performance seems to be relatively sparse. Nevertheless, a limited number of such studies have supported both perspectives of the economies of scale concept. In addition, the research findings are mixed, which may occur due to a) different methodological approaches (parametric vs. non-parametric), b) different aggregation levels of analysis (hospital, department, units), c) case-mix adjustment (Leleu, Moises, et al. 2012). This study contributes to the literature by 1) providing insight into general acute hospitals' financial strength and potential problems using comprehensive financial performance measures. 2) tracking hospitals over five years, enabling us to consider longer-term financial viability. 3) it extends the use of DuPont analysis in hospitals' settings, where such analysis is lacking. DuPont analysis breaks return on equity into various components, namely: operating efficiency measured by profit margin, asset use efficiency measured by asset turnover, and financial leverage measured by equity multiplier; to gain detailed insight into financial performance. 4) our outcome variables contained only the operating items from the income statement and balance sheets (e.g., operating income, assets, and liabilities); because the nonoperating items per definition do not relate to the hospital's primary operating activities. Removing nonoperating items to assess financial performance allows us to focus on recurring operating items to project future cash flows (Linsmeier 2016).

This study uses data collected from general acute care hospitals in California state; because California has sought more oversight over the expansion of hospitals and provides a large proportion of small and large hospitals with different ownership types that have access to capital markets. Furthermore, there are two other benefits using data from hospitals in California for this study. The first benefit is that all hospitals in California are required to report their financial information annually, and the second one is that California allows others to access their hospitals' financial information. These benefits ensure that data on all general acute care hospitals in California will be incorporated in this study and give this study an edge in data collection.

The purpose of this study is to understand and explain the impact of the size of general acute hospitals in California on their financial performance. Seeing that big emphasis is being placed on hospitals' size and financial performance, it would be of great relevance to determine whether or not the financial performance can be influenced by hospital size.

Our paper is organized as follows: The following section provides the theoretical concept and summarises the related literature on the effect of hospital size on financial performance. The third section describes the material and methods used in this paper. The fourth section presents the results. The fifth section discusses the results, and the final section draws conclusions and sets out the policy implications of our findings.

4.2 Background

4.2.1 Theoretical Concept

There are several perspectives concerning the size of hospitals when it comes to their financial performance. This study will require a framework that can explain the link between hospital size and financial performance. The framework used in this study is the economies of scale. This theoretical concept has two competing perspectives: the economies of scale and the diseconomies of scale (Preyra and Pink 2006). The economies of scale suggest that the larger a hospital becomes, the lower the average production costs are per unit of care delivered. It also implies that larger hospitals have a higher cost efficiency, which in turn leads to an overall higher financial performance. In contrast to this perspective, the diseconomies of scale suggest that there are no efficiency gains to larger hospitals (Preyra and Pink 2006, Asbu, Masri et al. 2020, Freeman, Savva et al. 2021).

On the whole, this perspective suggests that there is an optimum output size for hospitals, in which the average production costs per unit of care delivered is the lowest possible. This optimum is known as the minimum efficient scale (MES) (Jehu-Appiah, Sekidde, et al. 2014). If a hospital decides to expand regardless of this optimum, each additional unit of care delivered increases the average production costs of these units, thus affecting the financial performance of this hospital (Canback, Samouel, et al. 2006). Figure 4.1 illustrates how this concept of economies of scale can be depicted in a graph. The first half of the U-shaped curve represents the economies of scale, as the average costs reduce while the total output increases. The second half of the graph represents the diseconomies of scale. The exact opposite can be noted here; the average costs rises as the output increases even more. The MES line can be found at the stationary point of the curve. This is the point where the economies of scale are exhausted, and the graph begins its curve in the opposite direction.

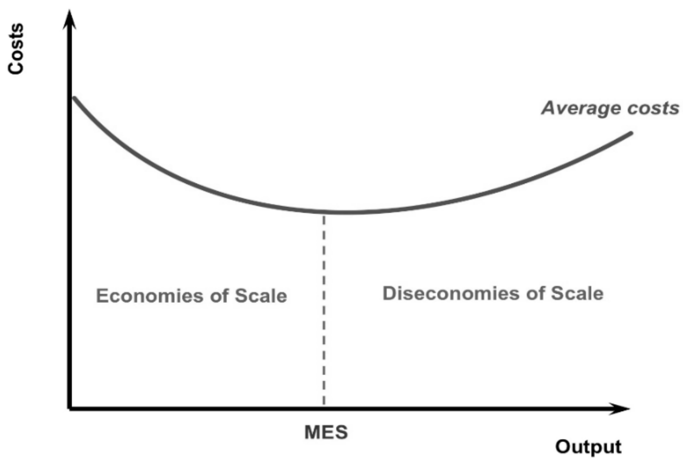


Figure 4.1 Economies of scale concept

This concept of economies of scale can have two very different views on the relationship between hospital size and financial performance. However, for this study, it would be essential to look at this theory from another perspective in order to interpret the results of this study more accurately. Essentially, the complete theory of economies of scale suggests that as output increases, the average costs for an organization decrease. However, once this output surpasses its optimum and continues to increase, this theory suggests that organizations will also witness an increase in the average costs. Since this study is going to focus on the financial performance rather than the costs of hospitals, it would be essential to look at this theory from a cost-efficiency perspective rather than the cost factor perspective.

This means that as the output increases prior to reaching its optimum, the cost efficiency of an organization also increases. Since the average costs decrease in this latter situation and output increases, this leads to more cost efficiency because more output is being generated for lesser costs. Essentially this is the definition of cost efficiency (Carey 2003). According to this theory, once the output surpasses this optimum, the average costs increase, which leads to the overall cost efficiency of an organization to decrease. What is noticeable in this situation is that the whole idea behind this theory has been flipped by focusing on cost efficiency rather than the cost itself. Even though it is the exact same theory and nothing has been modified besides its perspective, it is now represented differently. However, one implicit assumption must be made for this flip in theory to hold. This assumption is that the revenues per unit remain the same as the output increases. Figure 4.2 illustrates what this theory now looks like when depicted in a graph. As can be seen, this graph is the exact opposite of the graph given in Figure 4.1.

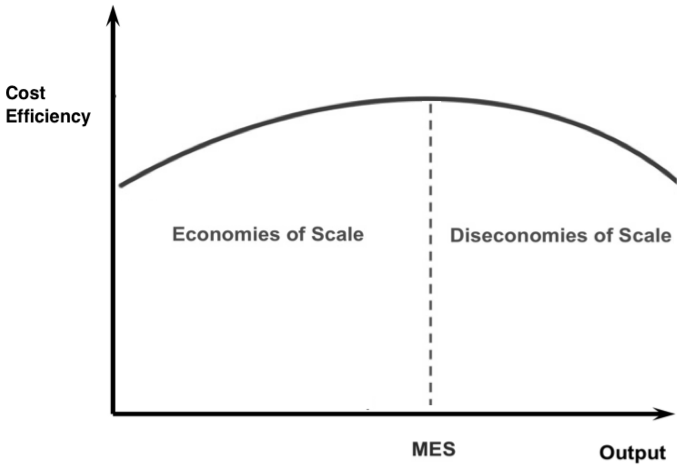


Figure 4.2 Economies of scale with cost efficiency

Essentially the graph has been flipped to get a better idea about the theory as well as to apply this theory to the findings of this study without any confusion. This study focuses on the financial performance rather than the costs of hospitals, which is why using this perspective, has a better fit within this study. By using this concept as the theoretical framework, this study will be able to explain the findings of the empirical data. It would further answer which of the two theoretical perspectives might play a role within a hospital setting in the relationship between hospital size and financial performance.

In the process of healthcare production, a hospital enjoys several advantages or experiences several disadvantages as a result of economies and diseconomies of scale, respectively. Both of these perspectives can be caused by internal and external forces. The internal forces are related to the actions a firm has taken, which only impact the same firm (Canback, Samouel et al. 2006). M&A is one of the examples in which internal economies of scale play a substantial role. Only the firms directly involved in the M&A will experience the benefits and advantages that are suggested to occur according to the concept of economies of scale. Cost efficiency is the primary notion behind this concept; however, it is not only achieved by a better spread of the fixed costs, as mentioned before. More factors play a role in cost efficiencies in larger organizations or organizations that intend on expanding. In the example of an M&A, two organizations can combine their resources that can then eventually lead to higher outputs, without any additional production costs (Lambrecht 2004). Rather than decreasing existing costs, higher outputs are achieved without increasing these existing costs. This is also known as pooling the resources, in which organizations share their individual resources amongst each other, intending to achieve better results (Best, Sandıkçı et al. 2015). In a large organization, such as a large hospital, pooling the resources can occur, for example, between the different departments/units.

Internal diseconomies of scale occur when the financial benefits do not occur in larger or expanded organizations. In this situation, every extra output created decreases the cost efficiency for these organizations. This is the exact opposite of the economies of scale concept in which, rather than experiencing continued increasing cost efficiency per increase in a unit, organizations see a decrease in cost efficiency when output is increased (Canback, Samouel et al. 2006, Giancotti, Guglielmo et al. 2017). This decrease in cost efficiency can be explained from a managerial inefficiency perspective. This perspective suggests that inefficiencies arise as organizations grow, and these inefficiencies will lead to higher average costs in the long run, which in turn diminishes the cost-efficiency. It can be an example of the principal-agent problem (Canback, Samouel et al. 2006, Vaubel 2006). As a firm grows, more tasks are delegated to managers from the owners themselves. However, this is where the principal-agent problem arises, in that the managers receiving the new tasks are not as committed to the firm as the owners are. This can potentially lead to more problems down the road in most cases. Moral hazard is one of these problems that can occur and relates to the managers who received these delegated tasks but only perform a part of these tasks that align with their own interests (Müller and Turner 2005, Vaubel 2006).

Another problem that can occur is adverse selection. Since managers are more concentrated on the work floor and possess some decision-making authority to a certain extent, it remains uncertain whether managers make the right choices with the right intentions that benefit the organization as a whole (Müller and Turner 2005). Under most circumstances, a rational manager would use this authority to primarily meet his or her self-interested goals, even if the outcome has adverse effects for the organization, such as higher average costs. From the managerial perspective, the decrease in cost efficiency that occurs in larger or expanded organizations is attributed to problems that arise in the organization's management.

External forces can also cause economies and diseconomies of scale. These forces are related to the actions that directly influence a specific industry, which probably impacts every organization within that industry (Canback, Samouel et al. 2006). An example of both external economies and diseconomies of scale is policy changes by the government. Depending on the content of the policy changes, it could change the dynamic of a whole industry. Policy changes within an industry that enhance collaboration amongst different organizations can be seen as positive and relates to the economies of scale notion. By encouraging collaboration, organizations will then be able to merge or even use the concept of pooling the resources easier than before in order to decrease their average costs and increase their cost-efficiency. However, policy changes that negatively affect an industry, for example, higher import duties amongst different countries, which then affects the financial benefits of expanding organizations, can be related to the diseconomies of scale (Canback, Samouel et al. 2006). By distinguishing the difference between internal and external forces, this study will be able to gain more insights as to the factors that may directly play a role when it comes to the economies and diseconomies of scale within a hospital setting. Depending on the outcomes of this study, these factors will be further discussed in the discussion section.

4.2.2 Related Literature

Several theoretical and empirical studies have also contributed to discussing how hospital size affects financial performance, albeit with mixed findings. The empirical studies yielded inconclusive results depending on the a) policy intervention, b) different methodological approaches (parametric vs. non-parametric),c) different aggregation levels of analysis (e.g., hospital, department, units), d)case-mix adjustment, and e) the specific measures of size and financial performance used (Leleu, Moises et al. 2012). Plus, a limited amount of such studies have supported both perspectives of the economies of scale concept.

For instance, Giancotti et al. (Giancotti, Guglielmo et al. 2017) performed a systematic literature review on the efficiency and optimal size of hospitals. They summarise 105 studies published between 1969 and 2014. They found that the size of organizations affects their efficiency and supports the economies of scale in hospitals with 200 to 300 beds, and they expected that diseconomies of scale occur in hospitals that accommodate less than 200 beds or more than 600 beds.

Carey et al. (Carey, Burgess Jr et al. 2015) compare general and single-specialty hospitals with respect to economies of scale and scope. They found evidence of strong scale economies for both types of hospitals. However, for the sample of general hospitals, scale economies become exhausted fairly rapidly for medium-sized facilities. Asmild et al. (Asmild, Hollingsworth et al. 2013) highlight environmental factors and find that Smaller hospitals in the less (densely) populated regions and larger hospitals in more urban areas were efficient.

Some literature found scale economies at higher bed levels. For example, Kristensen et al. (Kristensen, Olsen et al. 2012) focused on the potential advantages of hospital size in Denmark prior to the radical restructuring plan. They concluded that larger hospitals have more financial benefits than smaller hospitals, as they are able to deliver the same amount of care to healthcare consumers at a lower cost. This decrease in cost is attributed to the divisibility of large amounts of specialized staff and fixed costs found in hospitals. Preyra & Pink (Preyra and Pink 2006) support the notion of diseconomies of scale as they found that larger hospitals tend to have poor financial performances compared to average-sized hospitals. They argue that this is caused due to the tendency of larger hospitals having an excess of resources, which do not end up being consumed. According to them, larger hospitals tend to overestimate overall productivity, leading to these excesses of resources.

Another study conducted by Younis et al.(Younis, Younies et al. 2006) focused on the factors that influence the profitability of hospitals in the United States. They conclude that hospital size is one of the factors that contribute to the increase of hospital profitability. However, this relationship seems to be non-linear, suggesting that smaller hospitals have the highest profitability. They also argue that having a monopoly within the hospital setting diminishes profitability. This study supports the notion of diseconomies of scale.

Weaver & Deolalikar(Weaver and Deolalikar 2004) argue that diseconomies of scale in a hospital setting can be caused by the fact that managing large hospitals is quite a challenge, considering that these are very complex organizations with a significant amount of patient flow. From this perspective, one might even consider managing a smaller hospital as a more feasible task in which fewer things can go wrong with the financial performance. Despite this, the findings of their study support the economies of scale perspective, suggesting that larger hospitals have better financial outcomes than smaller hospitals.

It is apparent that these various empirical studies each have their perspective on the topic of the matter. In addition, they illustrate that there is no conclusive answer as to which of the perspectives of the economies of scale may play a role in a hospital setting. Thus, there is yet no conclusive answer about the effect of hospitals' size on their financial performance. Generally, the current study expands our understanding of the relationship between hospital size and financial performance and provides detailed insight into hospital financial performance using DuPont analysis components. DuPont analysis and its usefulness in predicting future profitability have received less attention in healthcare industries as a heavily regulated setting compared with financial service industries.

4.3 Methods

4.3.1 Data

To examine our study questions, several datasets supplied by the Office of Statewide Health Planning and Development (OSHPD) in California were merged from 2015 to 2019. The OSHPD database provides information on organizational structure, utilization, hospital annual financial disclosure, and staffing information. The unit of analysis for the study was the hospital. The sample consists of all medical/surgical acute care hospitals operating in California between 2015 and 2019, resulting in a sample size of 1519 hospital-year observations for an average of 304 hospitals per year. Specialty, children and psychiatric hospitals, and observations in which all the independent/dependent variables were missing are not included in our sample (651 hospital-year).

4.3.2 Variable

We assessed various financial performance measures as the dependent variables that captured different aspects of the hospital's financial viability. The dependent variables for this analysis include the return on equity (ROE), operating revenue, and costs. Given that the payer mixes, for example, Medicare or MediCal (i.e., Medicare in California State) revenue and costs, including inpatient and outpatient activities, we use adjusted patient days[1] to account for inpatient and outpatient services for operating revenue and cost.

We use ROE in order to take into account the impact on profit from the degree of leverage provided by the capital structure of the hospital. DuPont analysis is used, which is a classical tool for assessing the determinants of financial performance of firms. It is based on financial ratios comparing revenues with costs (margin ratio), revenue with assets (turnover ratio), and debt with assets (leverage ratio) (Saus–Sala, Elisabet etal. 2021). Prior literature suggests that unique industry characteristics provide useful information for the persistence of changes in DuPont components and hence their usefulness for predicting future profitability (Chang, Chichernea et al. 2014). Table 4.1 presents definitions for each of the variables for this analysis.

Given that the independent variable is hospitals' size based on the number of beds, nonoperating items do not necessarily relate to profit consistently from hospital to hospital because, by definition, they do not relate to the primary operating activities of the hospital. Removing nonoperating items to assess financial performance allows us to focus on recurring operating items to project future cash flows (Linsmeier 2016).

We control for the hospital structural factors (including ownership status, teaching status, hospital system membership and rural location, health service area, and the average age of the plant, and hospital's age), operational factors (including case mix index, payer mix percentage, occupancy rate, the average length of stay), environmental factor (including Herfindahl-Hirschman index), staffing factor (including hospital staffing intensity, and nurse staffing ratio), plus investment and in_hospital mortality and percentage of outpatients to inpatient revenue.

[1] Adjusted patient days=total inpatient days+(inpatient days*(outpatient revenue/inpatient revenue)

Table 4.1 Listing and definition of all variables used for this analysis

	variable	definition
Dependent variables		
DuPont analysis	Operating margin	Net from Operations divided by total operating revenue
	Operating asset turnover	Total operating revenue divided by the operating assets(i.e., the sum of total current assets plus net property, plant, and equipment)
	Leverage ratio	Operating assets divided by equity
Operating revenue per adjusted patient days		Total operating revenue divided by adjusted patient days
Operating costs per adjusted patient days		Total operating expense divided by adjusted patient days
Independent variable		
Hospital size		Total number of licensed bed
Control variables		
investment		The physical objects or rights provide future economic benefit to its owner or any cost benefiting a future period.
Occupancy rate		The inpatients days, divided by the product of the total number of beds and 365 days.
The average length of stay		The approximate average period of hospitalization (exclusive of long-term care) for formally admitted inpatients who were discharged during the reporting period.
Non-profit hospitals		Includes hospitals operated by a church, non-profit corporation, or non-profit other
For-profit hospitals		Included hospitals operated by an investor-individual,investor-partnership, or investor corporation
Teaching status		University hospitals
Rural status		Hospitals located in the rural area
Health service area (HSA)		The HSA geographic area, consisting of one or more contiguous counties, is designated by the federal department of health and human services for health planning on a regional basis. The 14 HSAs in California are: 1) Northern California, 2) Golden Empire, 3) North Bay, 4) West Bay, 5) East Bay, 6) North San Joaquin, 7) Santa Clara, 8) Mid-Coast, 9) Central, 10) Santa Barbara/Ventura, 11) Los Angeles County, 12) Inland Counties, 13) Orange County and 14) San Diego/Imperial.
Market competition		Measured using the Her_ndahl-Hirschman Index (HHI)
In_hospital mortality		Number of patients who die in the hospital
System affiliation		Hospitals that are part of a system
Hospital staffing intensity		The number of FTE, per 1000 adjusted patient days.
Nurse staffing ratio		The ratio of FTE nurses divided by total inpatient days multiplied by 100.
Case Mix Index (CMI)		The measure of patients" severity level; represents the average DRG relative weight for each given hospital. The CMI is obtained by summing DRG weights for all Medicare discharges and dividing by the number of discharges.
The average age of the plant		Accumulated depreciation divided by depreciation expense
Medicare coverage		Includes patients covered by Medicare
Medi-cal coverage		Includes patients covered by medi_cal (i.e., Medicaid program in the California state)
Private coverage		Includes patients covered by private plans
Uninsured coverage		Includes patients covered by no insurance/plan

4.3.3 Analysis

Descriptive analyses (means and standard deviations) were performed to determine the organisational and market characteristics of our sample of hospitals.

The first model is a classical DuPont Analysis model that measures how a firm's performance is affected the most common measure of financial performance, return on equity, into three very relevant standard financial ratios: operating profit margin (OPM), return on operating asset (ROA), and leverage, which showed Profitability, Asset Usage Efficiency and Capital Structure, respectively (Saus–Sala, Farreras–

$$ROE_{it} = \beta_0 + \beta_1 OPM_{it} + \beta_2 ROA_{it} + \beta_3 Leverage_{it} + \varepsilon_{it} \quad (1)$$

Noguer et al. 2021). Model (1) aimed to show which variable is the most dominantly determinant on a firm's financial performance in general acute hospitals in California.

Given the continuous nature of dependent variables, the data were modeled using linear regressions withyear fixed effect clustered at the hospital level. The year fixed effects were used to adjust for time trends, which may affect all hospitals' financial performance.

Separate linear regression models were used for each of the five dependent variables for a total of 5 regression models to find the relationship between the size and financial performance. To test the non-linear relationship between size and financial performance, the quadratic term (i.e., bed-squared) is also included as another model specification. X denotes all other control/confounding variables in the models.

$$OPM_{\ it} = \beta_0 + \beta_1 size_{it} + \beta_2 size^2{}_{it} + \beta_3 X_{it} + \varepsilon_{it} \quad (2)$$
$$ROA_{it} = \gamma_0 + \gamma_1 size_{it} + \gamma_2 size^2{}_{it} + \gamma_3 X_{it} + \varepsilon_{it} \quad (3)$$
$$Leverage_{it} = \alpha_0 + \alpha_1 size_{it} + \alpha_2 size^2{}_{it} + \alpha_3 X_{it} + \varepsilon_{it} \quad (4)$$
$$operating\ revenue_{it} = \partial_0 + \partial_1 size_{it} + \partial_2 size^2{}_{it} + \partial_3 X_{it} + \varepsilon_{it} \quad (5)$$
$$operating\ cost_{it} = \mathrm{C}_0 + \mathrm{C}_1 size_{it} + \mathrm{C}_2 size^2{}_{it} + \mathrm{C}_3 X_{it} + \varepsilon_{it} \quad (6)$$

To test the robustness of our findings, we performed several sensitivity analyses. A sensitivity analysis conducted among teaching and nonteaching hospitals separately revealed similar results to those of the full sample. We also categorize hospitals based on the number of beds to small (11-120 beds), medium (120-350 beds), and large (more than 350 beds), and rerun the regression using the medium-sized hospital as a reference category. All analyses were conducted in SAS version 9.4 and STATA version 17.

4.4 Results

Table 4.2[2] gives a better illustration of the data used in this study using mean and standard deviation. The descriptive analysis is provided for each of the different sizes of the hospital as well as all three combined. Based on table 4.2, the mean number of beds was 236. 60% of the hospital in our sample were non-profit, 24% profit, and the rest 16% were governmental hospitals. The mean number of full-time equivalent (FTE) staff per 1000 adjusted patient days was 15.5. The high share of hospitals in our sample were system affiliated (69%).

Table 4.2 Descriptive analysis of study variables by size (i.e., small, medium, large)

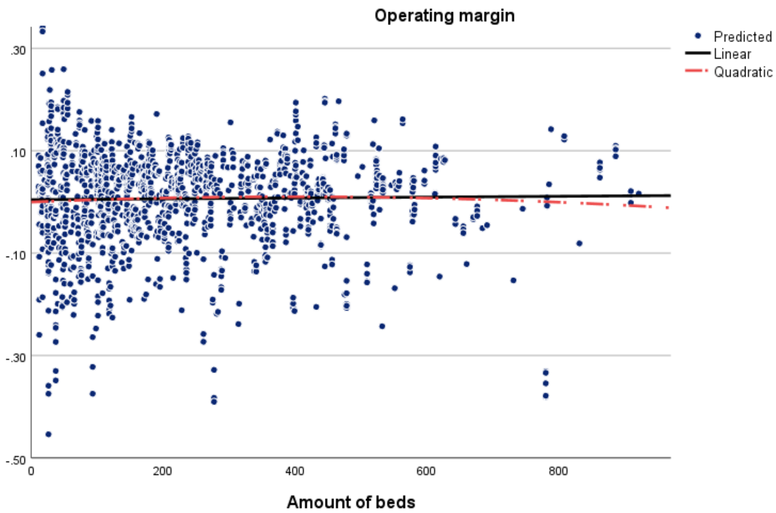
Size	Small		medium		large		All (100%)	
variables	mean	SD	mean	SD	mean	SD	mean	SD
Operating margin	-0.005	0.25	0.003	0.17	0.01	0.16	0.004	0.20
ROA	1.86	1.31	1.43	0.78	1.23	0.56	1.52	0.98
Leverage ratio	1.62	35.63	8.85	191.88	1.06	6.83	4.48	125.30
Operating revenue per adjusted patient days	3358.28	3026.00	3831.56	9183.65	4357.72	1867.96	3804.12	6245.32
Operating costs per adjusted patient days	3332.15	2790.06	4163.13	19537.63	4202.22	1735.38	3893.90	12710.96
Hospital size	67.02	33.44	216.36	61.11	487.93	128.23	235.90	175.35
Investment (on a scale of 1:1.000.000)	7.41	53.29	21.23	65.79	101.99	292.26	36.67	158.47
Occupancy rate	49.37	21.06	55.16	14.78	59.43	13.45	54.38	17.15
The average length of stay	7.79	10.86	4.72	3.46	4.99	1.20	5.75	6.68
Non-profit	0.48	0.50	0.62	0.49	0.71	0.46	0.60	0.49
For-profit	0.29	0.45	0.27	0.44	0.12	0.33	0.24	0.43
government	0.23	0.42	0.12	0.32	0.17	0.38	0.16	0.37
Teaching status	0.00	0.00	0.04	0.20	0.33	0.47	0.10	0.30
Rural status	0.45	0.50	0.08	0.27	0.00	0.00	0.17	0.38
System affiliation	0.58	0.49	0.73	0.44	0.75	0.44	0.69	0.46
HHI	0.07	0.03	0.06	0.03	0.06	0.03	0.06	0.03
Hospital staffing intensity	14.82	10.85	15.59	43.14	16.47	6.16	15.55	28.63
Nurse staffing ratio	1.21	0.96	0.92	1.14	0.95	0.30	1.02	0.95
Case Mix Index	1.41	0.63	1.38	0.25	1.52	0.30	1.43	0.42
Outpatient revenue over inpatient revenue	0.50	0.25	0.37	0.13	0.35	0.09	0.41	0.19
The average age of plant	12.65	14.67	11.62	9.14	13.25	8.68	12.37	11.21
Hospital age	46.58	19.98	50.04	19.59	57.11	16.62	50.68	19.43
Medicare coverage	0.47	0.19	0.39	0.14	0.34	0.12	0.40	0.16
Medi-Cal coverage	0.28	0.17	0.31	0.20	0.34	0.19	0.31	0.19
Private coverage	0.19	0.13	0.25	0.17	0.27	0.16	0.23	0.16
Uninsured coverage	0.02	0.04	0.02	0.04	0.02	0.02	0.02	0.04
Other coverage	0.03	0.07	0.02	0.03	0.03	0.03	0.03	0.05

[2] In the appendix table 4.6 provides mean estimation and table 4.7 provide descriptive analysis by ownership types as further analyses.

Comparing the different sizes of the hospitals shows that, on average, the OPM is higher in larger hospitals than the smaller ones; on the contrary, ROA is higher in smaller hospitals than the larger ones. Medium-sized hospitals represent by far the highest average leverage ratio measured using the equity multiplier (i.e., 8.85), and larger hospitals showed, on average, the lowest leverage ratio (1.06). The operating revenue and cost per adjusted patient day are, on average, the highest in large hospitals.

Larger hospitals are, on average older hospitals, and slightly over 100 million dollars have been invested in those hospitals. Large hospitals have the highest FTE staff per adjusted patient days. As many as 71% of the non-profit hospitals are categorized as large hospitals, while the most significant proportion of for-profit and government hospitals are categorized as small hospitals. On average, 17% of all hospitals are located in rural areas. Of those hospitals, the highest percentage is categorized as small hospitals. Small hospitals, on average, have a higher FTE registered nurses ratio, and they earn as much as 50% of their revenue providing outpatient services.

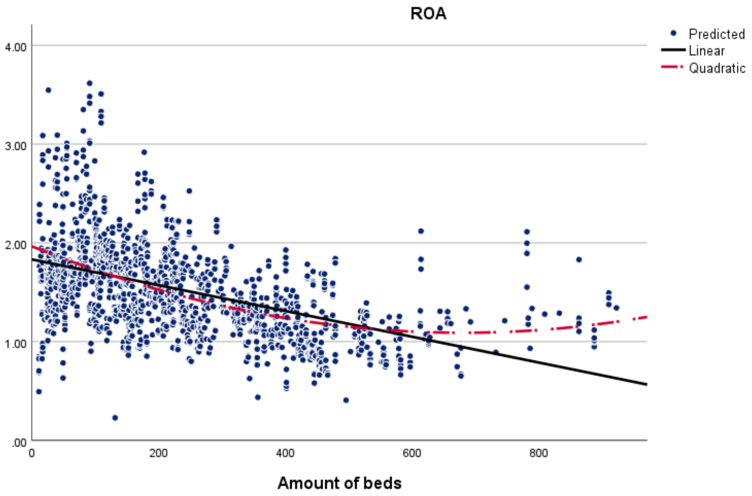
Figures 4.3 to 4.7 illustrate the scatterplots of all predicted financial performance indicators against the hospital size, considering all confounding variables. The black line indicates the linear relationship between the variables, and the red line indicates a non-linear relationship. The model summary and parameter estimates of each variable are presented below its scatterplot. We also calculate the stationary points of non-linear lines. These stationary points are where the curves bend in the opposite direction. The graphs (i.e., Figure 4.3 to Figure 4.5) imply the relationship between hospital size and financial performance based on DuPont analysis.



	Model summary			Equation
Equation	R_square	F	Sig.	
Linear	0.000	0.354	0.552	$-0.004 + 8.29e - 06x$
Quadratic	0.001	0.859	0.424	$-0.0001 + 5.25e - 05x - 6.61e - 08x^2$ $max = 794\ beds$

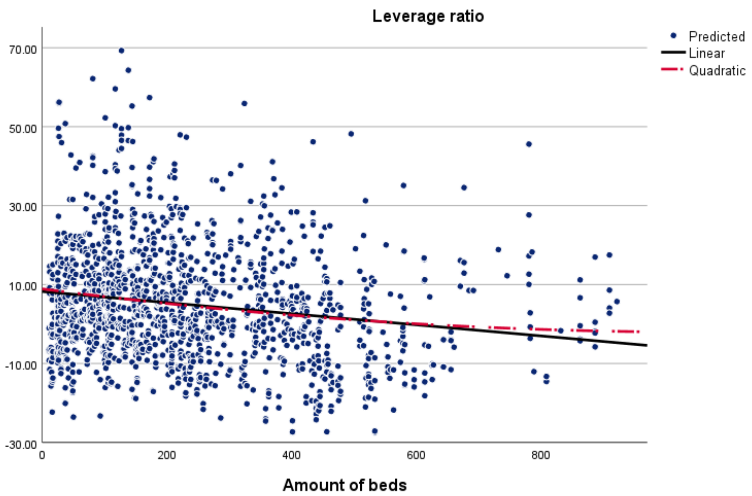
Figure 4.3 Scatterplot predicted OPM over the number of beds

According to Figure 4.3, the relationship between hospital size and predicted OPM is positive; however, the model summary showed that both linear and non-linear effects of hospital size on predicted OPM are not significant.



	Model summary			Equation
Equation	R_square	F	Sig.	
Linear	0.225	441.4	0.000	$1.83 - 0.01x$
Quadratic	0.254	258.35	0.000	$1.97 - 0.002x + 1.89e - 06x^2$ $min = 1058\ beds$

Figure 4.4 Scatterplot predicted ROA over the number of beds

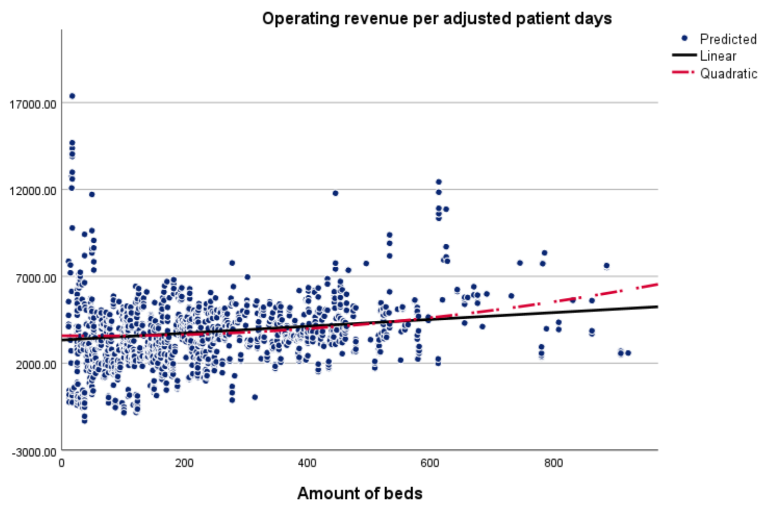


	Model summary			Equation
Equation	R_square	F	Sig.	
Linear	0.030	46.70	0.000	$8.25 - 0.014x$
Quadratic	0.031	24.01	0.000	$8.91 - 0.020x + 9.51e - 06x^2$ $min = 2105\ beds$

Figure 4.5 Scatterplot predicted leverage ratio over the number of beds

Figures 4.4 and 4.5 indicate a negative relationship between hospital size and financial performance based on ROA and leverage ratio. Both linear and non-linear effects of hospital size on ROA and leverage ratio were significant.

The relationship between the hospital size and financial performance based on operating revenue and cost per adjusted patient days is also presented in the same way as the previous indicators mentioned above. The model summary showed that both linear and non-linear effects of the hospital size on predicted operating revenue and costs are significant and non-significant, respectively. Yet, what is noticeable in Figures 4.6 and 4.7 is the marginally negative association between variables. The curve minimum in Figure 4.6 is equal to 140 beds, while the curve minimum in Figure 4.7 is equal to 307 beds. In other words, this indicates that as the amount of beds increases to 140 and 307, the operating revenue and cost per adjusted patient days, respectively, tend to decrease marginally. After the curve minimum, as the amount of beds increases, the operating revenue and cost per adjusted patient days also marginally increase.



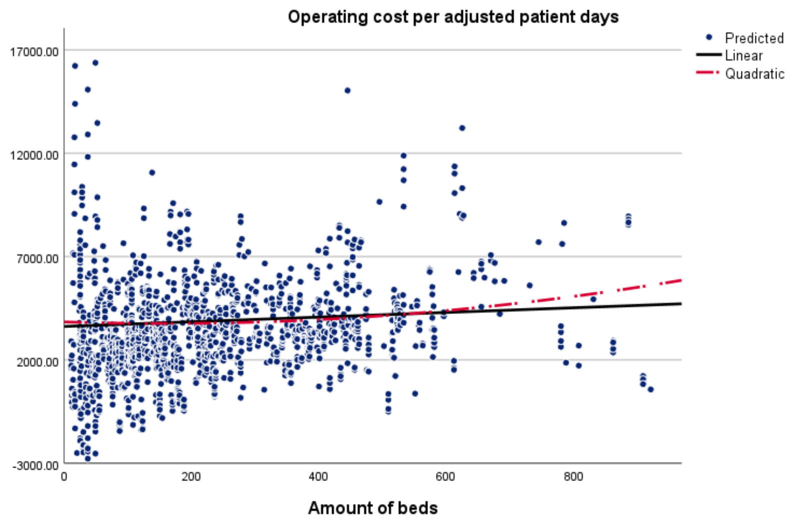
	Model summary			Equation
Equation	R_square	F	Sig.	
Linear	0.003	5.10	0.024	$3336.83 + 1.97x$
Quadratic	0.004	3.06	0.047	$3586.13 - 0.421x + 0.0036x^2$ $min = 140\ beds$

Figure 4.6 Scatterplot predicted operating revenue per adjusted patient days over the number of beds

Table 4.3 shows the result of the classical DuPont analysis[3]. It is found that all components of DuPont Analysis, Profitability, Efficiency, and Leverage variables are statistically significant to explain ROE in this

[3] Figure 4.8 in the appendex provide information on the Mean_DuPont components and ROE over year

model. When the profitability ratio is investigated, there is a positive and significant relationship between OPM and the hospital's financial performance. 1 Unit increase in OPM also increases ROE by 1.283 units. OPM is the most powerful determinant of financial performance among all other independent variables performed in the model. Efficiency measured by ROA has a positive and statistically significant relationship with ROE. A one Unit increase in asset utilization efficiency for Californian hospitals also increases financial performance by 0.33. Lastly, regression model results show that debt usage positively affects financial performance in hospitals. The relationship between debt usage and hospitals' financial performance is statistically significant.



	Model summary			Equation
Equation	R_square	F	Sig.	
Linear	0.000	0.39	0.533	$3621.82 + 1.12x$
Quadratic	0.000	0.28	0.751	$3841.41 - 0.981x + 0.0032x^2$ $min = 307\ beds$

Figure 4.7 Scatterplot predicted operating cost per adjusted patient days over the number of beds

Table 4.3 Classical DuPont analysis Results

	ROE	
variables	Coef.	Robust Std. Err.
Operating margin	1.282	0.480
Turnover on asset	0.325	0.124
Leverage ratio	0.070	0.002
n	1526	
R^2	86.08%	

Table 4.4 summarises the regression results on the effect of hospital size on the DuPont analysis components. Concerning its profitability component, there is a marginally positive, insignificant relationship between the hospital size and OPM. Adding the quadratic term into the previous model slightly improved the model fit, but the relationship between hospital size and the OPM remained insignificant.

Table 4.4 Regression results of hospital size and DuPont analysis components

Variables	Operating margin		operating assets turnover		Leverage ratio	
model	I	II	I	II	I	II
Hospital size	4.97E-05	1.13E-04	-0.001***	-0.003***	-0.026	-0.094
	(5.81E-05)	(1.29E-04)	(3.195E-04)	(0.001)	(0.025)	(0.087)
Hospital size^2		-8.49E-08		2.87E-06***		9.210E-05
		(1.81E-07)		(9.40E-07)		(8.370E-05)
Investment	2.49E-06	2.17E-06	4.140E-04***	4.249E-04***	0.009	0.009
	(2.53E-05)	(2.55E-05)	(1.474E-04)	(1.443E-04)	(0.009)	(0.009)
Occupancy rate	0.002***	0.002***	-0.003	-0.003	-0.026	-0.012
	(0.001)	(0.001)	(0.003)	(0.003)	(0.075)	(0.073)
Average LOS	-0.001	-0.001	0.004	0.002	-0.019	-0.094
	(0.002)	(0.002)	(0.014)	(0.014)	(0.276)	(0.325)
Non-profit	0.058**	0.059**	0.372***	0.354***	-1.059	-1.645
	(0.026)	(0.027)	(0.124)	(0.125)	(2.405)	(2.628)
For-profit	0.117***	0.119***	0.731***	0.675***	8.326	6.529
	(0.031)	(0.032)	(0.161)	(0.164)	(9.026)	(7.560)
Average age of plant	-0.002	-0.002	0.001	0.002	-0.252	-0.237
	(0.001)	(0.001)	(0.004)	(0.004)	(0.200)	(0.187)
Hospital staffing intensity	-0.001*	-0.001*	0.003	0.004	-0.071	-0.052
	(0.001)	(0.001)	(0.005)	(0.005)	(0.072)	(0.060)
Nurse staffing ratio	0.018	0.019	-0.157	-0.183	-0.186	-0.997
	(0.025)	(0.025)	(0.155)	(0.157)	(1.866)	(1.710)
CMI	0.141***	0.140***	-0.111	-0.079	-6.139	-5.090
	(0.047)	(0.046)	(0.282)	(0.280)	(7.092)	(6.427)
system	0.025	0.025	-0.150	-0.147	4.548	4.636
	(0.019)	(0.019)	(0.098)	(0.098)	(5.355)	(5.429)
n	1519	1519	1519	1519	1519	1519
R^2	27.12%	27.15%	24.04%	25.14%	1.3%	1.37%

Note: the age category indicators, teaching status of hospital, hospital located in the rural rea, hospital age, the payer category (including Medicare, medical, private, and uninsured), HHI, and the percentage of outpatients' revenue over inpatient revenue are included as controls in the regressions. Robust standard errors are clustered at the hospital level reported in parentheses. ***p < 0.01, **p < 0.05, * p < 0.1

The findings also showed that for-profit hospitals have a significantly higher OPM than other ownership types. It also shows that the higher occupancy rate and the admission of more severe cases result in a higher OPM and their relationship was significant. Concerning the efficiency component in DuPont analysis, there is a marginally negative and significant relationship between hospital size and ROA. Incorporating the quadratic term into the model slightly improved the model fit and was significantly associated with the ROA. It is evident from the results that for-profit hospitals showed a significantly higher ROA compared to other ownership types. In addition, as expected per definition, there was a significant positive relationship between investment and ROA. Concerning the financial leverage components in DuPont analysis, there is an insignificant marginally negative relationship between hospital size and leverage ratio using equity multiplier. Adding the quadratic term into the model hardly improved the model fit; hence the results remained unchanged.

The relationship between hospital size and operating revenue per adjusted patient days was positive and insignificant; similar results have been seen when incorporating the quadratic term into the model. The relationship between hospital size and operating costs per adjusted patient days was marginally negative and significant (see Table 4.5). We provide the elaboration on the study finding in the following section.

Table 4.5 Regression results of hospital size and operating revenue, and cost per adjusted patient's days

Variables	Operating revenue per adjusted patient days		Operating cost per adjusted patient days	
model	I	II	I	II
Hospital size	0.90	2.91	0.72	5.07**
	(0.56)	(1.99)	(0.66)	(2.30)
Hospital size^2		-2.74E-03		-0.01**
		(2.26E-03)		(0.003)
Investment	1.18***	1.18***	0.32	0.33
	(0.28)	(0.28)	(0.31)	(0.30)
Occupancy rate	10.72*	10.14*	23.02***	21.76***
	(5.75)	(5.42)	(6.02)	(5.81)
Average LOS	-2.31	-0.06	29.62	34.46*
	(17.87)	(18.69)	(20.19)	(20.39)
Non-profit	503.14***	514.80***	391.52	416.69
	(175.29)	(176.43)	(284.17)	(283.73)
For-profit	371.57*	410.25*	645.02*	728.48**
	(221.50)	(220.59)	(334.69)	(331.13)
Average age of Plant	-7.60*	-8.14*	1.44	0.29
	(4.18)	(4.27)	(4.88)	(4.71)
Hospital staffing intensity	184.34***	183.43***	467.69***	465.74***
	(13.34)	(13.76)	(13.75)	(13.63)
Nurse staffing ratio	884.16**	919.65**	-736.88**	-660.31*
	(428.34)	(446.83)	(350.94)	(355.78)
CMI	-235.79	-278.12	-1536.50***	-1627.83***
	(479.09)	(487.04)	(542.21)	(529.10)
System	343.90**	339.23**	503.50**	493.42**
	(144.63)	(143.49)	(199.55)	(198.98)
n	1519	1519	1519	1519
R^2	95.72%	95.75%	98.43 %	98.46 %

Note: the age category indicators, teaching status of hospital, hospital located in the rural rea, hospital age, the payer category (including Medicare, medical, private, and uninsured), and HHI are included as controls in the regressions. Robust standard errors are clustered at hospital level reported in parentheses. ***p < 0.01, **p < 0.05, * p < 0.1

4.5 Discussion

In this study, we conducted linear and quadratic regression analysis regarding the effect of hospital size on financial performance in California State. Given that hospital financial challenges in the United States continued to be a top concern of hospital CEOs, this study reveals important and new relevant insight into the relationship between hospital size and financial performance using comprehensive financial performance measures. We explore the link between hospital size and financial performance using the concept of economies of scale. Therefore, besides operating revenue and cost per adjusted patient days, we used the DuPont analysis, which is used to break ROE into its three components, including profitability, efficiency, and leverage ratios, to gain new insight into financial performance.

In summary, we find highly mixed evidence of the association between hospitals' size and financial performance. There are no significant results concerning OPM and leverage ratio. However, there is a significant marginal negative non-linear relationship between hospital size and ROA. ROA is an indicator of how well a hospital utilizes its assets in terms of profitability. As can be seen in Figure 4.4, as the hospital size increases, ROA decreases. This is the core definition of the diseconomies of scale perspective, which may not be very likely to be experienced by hospitals in the very beginning. We can partly justify this result when we look at the components of ROA. ROA accounts for the hospitals' debts and liabilities, as well. So we can suppose that hospitals at first take on more debts. By taking on debt, a hospital increases its assets thanks to the cash that comes in so that the denominator of ROA calculation is high because the assets are high. ROA therefore falls. Another explanation for marginally negative ROA is the higher mean leverage ratio in small and medium-sized hospitals. In other words, It can justify that the assets are mostly funded with debt than equity.

Overall, our results on the impact of size on operating revenue and costs per adjusted patient days suggest that increasing the size of the hospital on average is associated with increased operating revenue as well as operating costs. Findings from the regression analysis suggest a marginally insignificant negative relationship between hospital size and operating revenue. The relationship between hospital size and operating cost is also marginally negative but significant. It is possible that hospitals need to break even before they can generate more revenue and thus increase their financial performance. Figures 4.6 and 4.7 indicate this to a certain extent. The curve minimum of 140 beds occurs when the operating revenue seems to be equal to the operating cost. The operating costs, on the other hand still decreasing to the curve minimum of 307. This makes sense because, within the hospital sector, the initial costs are very high. Equipment, medicines, and even staff can be expensive within the sector (Kihiu, Maranga et al. 2012). However, when the curve shows the marginally positive relationship following the curve minimum of 140 beds, it can be said that economies of scale play the role. In this situation, an increase in the number of beds lead to an increase in the overall financial performance measured by operating revenue and operating costs until the curve minimum of 307. The increase in revenue per operating patients days in this study from larger hospitals may be explained by the hospital's ability to increase inpatient admission and treat more acute patients, which may be the result of higher occupancy rate, higher hospital intensity, or nurse to patient ratio [35]. The increased cost per adjusted patient days in this study from the bigger hospital may be explained by the mix of very severe patients with more comorbidities. Hence the cost of their care increases.

Following the curve minimum 307, we can still presume that the economies of scale play the role while the OPM is marginally positive up to the maximum point of 794 beds (see Figure 4.3). There is a possibility that hospitals that reached the optimum of 794 beds will experience diseconomies of scale. However, those elaborations are somewhat speculative, while the association between size and OPM and size and operating revenue is insignificant. It seems that our results are consistent with the theory of economies of scale. This theory suggests that organizations first experience economies of scale. After reaching its full potential with this notion, organizations tend to experience the diseconomies of scale.

In summary, an increase in bed amounts after 140 beds leads to an increase in the total financial performance. Thus it is safe to say that based on our results, economies of scale can be experienced and play a substantial role in general acute hospitals in California. However, if hospitals grow (i.e., to the optimal 794 beds), the inefficiencies arise due to diseconomies of scale, and it is consistent with the principal-agent problem as well. To a certain extent, our findings are consistent with the findings of Kristensen et al. (Kristensen, Olsen et al. 2012). They focused on the economies of scale and scope in the Danish hospital sector prior to the restructuring plan in 2007. Their results suggested that the Danish hospital potentially gains from scale economies in terms of beds obtained from consolidation. Contrary to our findings, Wever & Deolalikar(Weaver and Deolalikar 2004) estimated the economies of scale and scope in Vietnamese hospitals. They found that Economies of scale and scope depended on the hospital's category in addition to the number of beds and volume of output. They found that larger hospitals had constant return to scale, whereas smaller hospitals faced modest to large diseconomies of scale.

Several internal and external factors can influence the economies of scale perspective within the hospital setting. Recent trends in California hospitals suggested that outsourcing in those hospitals become increasingly common as health system administrators seek to enhance profitability and efficiency while maintaining outcome quality (Berry, Letchuman et al. 2021). This outsourcing can be seen as a type of internal economies of scale, as hospitals are not forced to do this. However, the hospitals that choose this option may have some financial benefits. These benefits lead to, for example, lower overhead costs and more significant (cost) efficiencies (Raeissi, Sokhanvar et al. 2018).

Furthermore, external economies of scale can play a role through the OSHPD. Since it is required for hospitals in California to report their financial data to the OSHPD annually, this data can then be further analyzed and used by other hospitals as an indicator or reference in order to achieve better results. This is also known as input sharing, where specific data on organizations within the same industry are openly available. In addition, input sharing also leads to increased productivity as well as the efficiency of healthcare services (Krzeczewski, Bartłomiej 2019).

Our study has some strengths. First, we use a publicly available dataset to derive robust estimates and track hospitals over five years, enabling us, in turn, to consider longer-term financial viability. Second, in this study, we focused on DuPont analysis which has gotten a little attention in the healthcare setting. Finally, we accounted for omitted variable bias by controlling for a large set of variables to have a better estimate of the association between hospital size on financial performance. There are also limitations to this study, each of which offers an avenue for further research. One limitation is that the results can only investigate the effect in general hospitals within California and cannot necessarily be generalized to other types of care (e.g., children's hospital, psychiatric hospital) and/or a larger population. Even though the state of California is seen as the laboratory of healthcare within the United States, it remains uncertain whether these findings also relate to hospitals in other States. The generalizability of this study cannot be based simply on speculation. Although our study provides a fertile ground for future research in this matter, for any future studies, it might be better to conduct a similar study on a broader scale.

4.6 Conclusion

In closing, it can be said that larger hospitals tend to have better financial performance than smaller ones within the hospital sector in California. As the US trend in M&A has been on the rise following the passage of the affordable care act (Channick 2014); based on the results of this study, it is also safe to say that hospitals within this state that are considering expansion or merging with other hospitals have a higher chance of achieving better financial performances. It can be mainly attributed to the economies of scale perspective, which takes place after 140 beds in this study. However, when it comes to the diseconomies o scale perspective, this latter may seem to be influenced in a very large hospital (i.e., 794 beds). This study aims to clear out the hospital size and financial performance link. While this study might not be able to tackle the rising healthcare costs entirely, it can be fruitful to be considered by hospital managers, owners, and even policymakers in California in adjusting their organization in such a way that can potentially benefit their financial performance.

4.7 Appendix

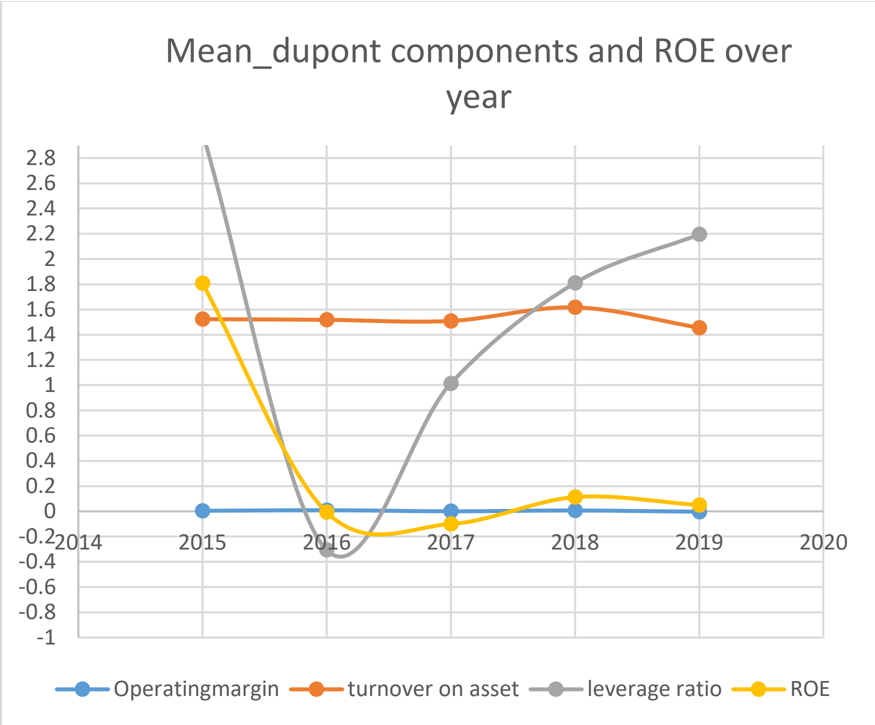


Figure 4.8 Mean_DuPont components and ROE over year

Table 4. 6 Mean estimation (n=1498, S.E. adjusted for 320 clusters in hospital Id)

variables	mean	Robust S.E.	(95% conf. Interval)	
Dependent variables				
Operating margin	0.01	0.01	-0.01	0.02
ROA	1.53	0.05	1.44	1.62
Leverage ratio	4.89	3.25	-1.50	11.28
Operating revenue per adjusted patient days	3872.05	347.42	3188.52	4555.58
Operating costs per adjusted patient days	3790.03	193.68	3408.98	4171.07
Independent variable				
Hospital size	233.67	10.20	213.60	253.74
small	0.34	0.03	0.28	0.39
medium	0.41	0.03	0.36	0.47
large	0.25	0.02	0.20	0.30
Control variables				
Non-profit ownership	0.57	0.03	0.50	0.61
For-profit ownership	0.26	0.03	0.21	0.31
Government ownership	0.18	0.02	0.14	0.23
Investment (on a scale 1:1.000.000)	39.28	8.80	21.99	56.58
Occupancy rate	55.09	0.95	53.22	56.96
HHI	0.06	0.002	0.06	0.07
Average length of stay	5.93	0.37	5.19	6.66
Teaching status	0.09	0.02	0.05	0.12
Rural status	0.19	0.02	0.15	0.24
System affiliation	0.67	0.03	0.62	0.72
Hospital staffing intensity	15.53	0.83	13.90	17.15
Nurse staffing ratio	1.02	0.04	0.94	1.10
Case Mix Index	1.42	0.02	1.38	1.47
Hospital age	52.60	1.03	50.58	54.63
Average age of facility	12.32	0.47	11.40	13.24
Medicare coverage	0.41	0.01	0.39	0.43
Medi-Cal coverage	0.33	0.01	0.31	0.35
Private coverage	0.21	0.01	0.19	0.22
Uninsured coverage	0.02	0.002	0.02	0.03
Other coverage	0.03	0.002	0.03	0.04

Table 4.7 Descriptive analysis of selected variables by ownership type

Ownership type	**Non-profit (60%)**		**For-profit (24%)**		**Government (16%)**		**All (100%)**	
variables	mean	SD	mean	SD	mean	SD	mean	SD
Operating margin	0.01	0.18	0.05	0.17	-0.09	0.26	0.004	0.20
ROA	1.37	0.64	1.97	1.31	1.35	1.10	1.52	0.98
Leverage ratio	1.45	8.14	12.46	244.80	2.28	7.42	4.48	125.30
Operating revenue per adjusted patient days	4521.5	8034.3	2962.1	20157	2806	2511.2	3804.1	6245.3
Operating costs per adjusted patient days	4671.9	16856.9	2890.3	2154.5	2942.5	2480.5	3894	12711
Hospital size	263.30	181.96	181.71	119.48	214.79	196.90	235.90	175.35
Investment (on a scale of 1:1.000.000)	38.16	189.28	33.60	109.21	35.72	73.21	36.67	158.47
Occupancy rate	53.07	16.35	56.32	18.29	56.36	17.88	54.38	17.15
The average length of stay	4.5	3.20	9.22	11.71	5.27	3.60	5.75	6.68
Teaching status	0.12	0.32	0	0	0.17	0.38	0.10	0.30
Rural status	0.15	0.35	0.05	0.22	0.46	0.50	0.17	0.38
System affiliation	0.77	0.42	0.82	0.38	0.19	0.40	0.69	0.46
Hospital staffing intensity	17.06	37.33	13.27	8.67	14.20	10.57	15.55	28.63
Nurse staffing ratio	1.11	1.13	0.80	0.35	1.02	0.78	1.02	0.95
Case Mix Index	1.41	0.29	1.61	0.67	1.21	0.20	1.43	0.42
Outpatient revenue over inpatient revenue	0.43	0.16	0.27	0.17	0.53	0.19	0.41	0.19
The average age of plant	12.01	8.38	9.25	7.80	17.96	18.60	12.37	11.21
Medicare coverage	0.41	0.14	0.42	0.18	0.38	0.19	0.41	0.16
Medi-Cal coverage	0.27	0.17	0.35	0.20	0.41	0.20	0.31	0.19
Private coverage	0.29	0.16	0.17	0.12	0.14	0.10	0.23	0.16
Uninsured coverage	0.02	0.02	0.02	0.05	0.02	0.04	0.02	0.04
Other coverage	0.02	0.03	0.03	0.07	0.04	0.04	0.03	0.05

Chapter 5

General Conclusion and Outlook

This dissertation provides important new insights on key challenges in measuring cost and analyzing hospital performance based on both quality of care and financial performance.

Based on a systematic literature review, chapter 2 analyzes the association between cost/price and quality of care in a hospital setting. Our findings highlighted that price and cost relate to hospital quality of care in various ways. In addition, several critical design characteristics may alter the association between cost/price and quality of care. Among them, condition and specific resource utilization turn out to be more important. Although our results suggest that there is no general relationship between cost/price and quality of care, accounting for endogeneity, the evidence suggests that a positive relationship exists. Aiming to study the association between cost/price and quality of care, researchers should consider the provided design characteristics that may alter the association between cost/price and quality of care in their future studies. Policy makers should also be prudent with the measures used to reduce hospital costs to avoid endangering the quality of care, especially in resource-sensitive settings.

Chapter 3 analyzes the effects of competition on the quality of care. This study focuses on AMI admissions in Germany. Our finding highlighted that competition and its effects on outcomes depend on each country's regulatory regime, including factors such as the regulation of competition, regulation of the quality of care, and the price regime. Our results show that the level of competition does not affect the quality of care as long as the quality of care measure is not very high. This finding can be partly explained by the limited effect of quality differential on hospital choice (Marshall, Shekelle et al. 2000); when quality is not a very important factor in a patient's hospital choice decision, hospitals are unlikely to exert efforts to improve quality in order to attract patients. However, patients admitted to hospitals in high competition areas are more likely to die or be readmitted than patients admitted to hospitals in low competition areas. Therefore, if policies promoting competition in health care are continued or strengthened in Germany, it would be advisable for policymakers to monitor the quality of care more closely and to consider mechanisms for sanctioning hospitals that deviate substantially from quality benchmarks.

Chapter 4 investigate the link between hospital size and financial performance. Based on existing evidence, we presumed that one of the potential sources of inefficiency is related to the hospital scale. It is presumed that larger hospitals can be associated with greater cost-efficiency through economies of scale. We use DuPont analysis to measure financial performance. The findings suggest that larger hospitals tend to have better financial performance than smaller ones within the hospital sector in California, and It is mainly attributed to economies of scale. Hospital managers/owners and policymakers should consider the findings when making decisions about, e.g., scales and/or mergers.

Despite the variety of different research methods and data sets used to study hospital performance, this dissertation also identifies important gaps in research that future studies should address. In chapter 2, we observed some differences in the associations between surgical and medical conditions. Future work could explain the reason for these differences. Additionally, we focus on several critical design characteristics that may alter the association between cost/price and the quality of care; however, some other characteristics, such as market characteristics (e.g., competition), might be able to explain some differences in the cost/price-quality relationship. In chapter 3, we partly address the latter in chapter 2 (analyzing the competition-quality link), and our results may call into question policies that stimulate competition in health care in Germany. However, the desirability of such policies requires a complete welfare analysis, which can be addressed by future studies. The analysis in chapter 4 relies on observational design, accounting for many patients and hospital factors in California. It is suggested that future studies should be conducted on a broader scale and in other types of care (e.g., children's hospitals, psychiatric hospitals) and/or using non-parametric methodological design or policy interventions to draw causal inferences.

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Appendices

A.1 Statement of Personal Contribution Pursuant to §6 (4) PromO

		Personal contribution		
RESEARCH PROJECT	CO-AUTHORS	CONCEPTION/DESIGN	EXECUTION	REPORTING
A Systematic Review of the Association Between Hospital Cost/Price And the Quality of Care (Chapter 2)	Vera Winter Jonas Schreyögg	• Defined research question • Conceptualized research design (systematic review)after consultations with co-authors • Developed screening algorithm and data extraction sheet	• Performed literature screening (title&abstract screening and full-paper screening) • Conducted data extraction from included literature review • Aggregated results from the systematic review • Discussed results • Derived policy recommendations	• Prepare manuscript • Collected feedback from all co-authors and revised manuscript • Presented study at Research in Progress Workshop (2018), Rotterdam, EuHEA (2018) conference, Maastricht, doctoral seminar in Ratzeburg (2018)
The Effect of Hospital Competition on Health Outcomes: Evidence from AMI Admissions in Germany (Chapter 3)	Esra Eren Bayindir Udo Schneider Jonas Schreyögg	• Defined research question • Developed research design (2SLS regression)based on three combined datasets (quality reports, TK claims data, and the INKAR dataset)	• Conducted literature review • Prepared and merged two datasets • Conducted data analyses • Gather additional data for further robustness checks and data analyses • Discussed results • Derived policy recommendations	• Prepare manuscript • Collected feedback from all co-authors and revised manuscript • Presented at HCHE center day in Hamburg (2020)

Personal Contribution				
Research Project	Co-Authors	Conception/Design	Execution	Reporting
The Effect Of Hospital Size on The Financial Performance (Chapter 4)	Jonas Schreyögg	• Defined research questions • Developed research design based on OSHPD datasets from California State	• Conducted literature review • Prepared and merged different datasets • Conducted data analyses • Discussed results • Derived policy recommendations	• Prepare manuscript • Collected feedback from all co-authors and revised manuscript

A.2 Short Summary of Studies Pursuant to §6 (6) PromO

Short Summary in the English Language

Study 1 (Chapter 2)

Limited empirical evidence exists regarding the effect of price changes on hospital behavior and, ultimately, the quality of care. Additionally, an overview of the results of prior literature is lacking. This study aims to provide a synthesis of existing research concerning the relationship between hospital cost/price and the quality of care. Searches for literature related to the effect of hospital cost and price on the quality of care, including studies published between 1990 and March 2019, were carried out using four electronic databases. In total, 47 studies were identified, and the data were extracted and summarized in different tables to identify the patterns of the relationships between hospital costs/prices and the quality of care. The study findings are highly heterogeneous. The proportion of studies detecting a significant positive association between price/cost and the quality of care is higher when a) price/reimbursement is used (instead of cost); b) process measures are used (instead of outcome measures); c) the focus is on acute myocardial infarction, congestive heart failure, and stroke patients (instead of patients with other clinical conditions or all patients); and d) the methodological approach used to address confounding is more sophisticated. Our results suggest that there is no general relationship between cost/price and the quality of care. However, the relationship seems to depend on the condition and specific resource utilization. Policy makers should be prudent with the measures used to reduce hospital costs to avoid endangering the quality of care, especially in resource-sensitive settings.

Study 2 (Chapter 3)

Countries increasingly rely on competition among hospitals to improve health outcomes. There is, however, limited empirical evidence on the effect of competition on health outcomes in the German hospital market. This study examines the effect of hospital competition on quality of care, which we assess using health outcomes, focusing on acute myocardial infarction (AMI) treatment in Germany. We employed three datasets in our analysis: 63,439 patient records with AMI as primary diagnosis from 2015-19 from a large statutory health insurer; hospital characteristics from hospital quality reports; and geographical characteristics of hospitals and patients from the INKAR database. We assessed the quality of care in terms of in-hospital and post-hospitalization mortality, and cardiac-related readmission. We applied ordinary least squares, logistic, and 2-stage least squares regression models to investigate the association between competition and health outcomes. We found that high competition was associated with lower quality of care in terms of mortality and readmissions whereas quality of care at medium and low competition markets did not differ significantly. Patients treated in high competition markets were 8.04% and 10.2% more likely to die within 30 days or 2 years of admission, and 13.33% and 4.8% more likely to be readmitted within 7 days or 2 years of discharge, respectively, than patients treated in low competition markets. Hospital competition does not lead to better health outcomes for AMI patients in Germany. Therefore, additional measures, such as sanctions for deviations from quality benchmarks, should be considered to achieve quality improvement.

Study 3 (Chapter 4)

The healthcare service industry in the United States has faced a wide range of policy interventions to tackle the rising healthcare costs and improve financial performance. On this basis, There have been debates whether it is financially beneficial to invest in larger hospitals rather than smaller hospitals. This study discusses the impact of hospital size on the financial performances within the Californian hospital sector. The first purpose of this study is to get a better understanding of this relationship and to clarify the debate on this relationship. The second purpose of this study is to illustrate whether this relationship can be explained by the economies of scale and diseconomies of scale perspectives. To examine our study questions, several datasets supplied by the Office of Statewide Health Planning and Development in the California state were merged from 2015 to 2019. We explore the link between hospital size and financial performance using the concept of economies of scale. Therefore, besides operating revenue and cost per adjusted patient days, we used the DuPont analysis, which is used to break ROE into its three components, including profitability, efficiency, and leverage ratios, to gain new insight into financial performance. The results suggest that larger hospitals tend to have better financial performance than smaller ones within the hospital sector in California. As the US trend in M&A has been on the rise following the passage of the affordable care act, it is safe to say that hospitals within this state that are considering expansion or merging with other hospitals have a higher chance of achieving better financial performances. It can be mainly attributed to the economies of scale perspective, which takes place after 140 beds. However, when it comes to the diseconomies o scale perspective, this latter may seem to be influenced in a very large hospital (i.e., 794 beds). While this study might not be able to tackle the rising healthcare costs entirely, it can be fruitful to be considered by hospital managers, owners, and even policymakers in California in adjusting their organization in such a way that can potentially benefit their financial performance.

A.2 Kurzzusammenfassung der Studien gemäß §6 (6) PromO

Kurzzusammenfassung in deutscher Sprache

Studie 1 (Kapitel 2)

Es gibt nur begrenzte empirische Belege für die Auswirkungen von Preisänderungen auf das Verhalten von Krankenhäusern und damit auf die Qualität der Versorgung. Außerdem fehlt ein Überblick über die Ergebnisse der bisherigen Literatur. Ziel dieser Studie ist es, eine Synthese der vorhandenen Forschungsergebnisse über die Beziehung zwischen Krankenhauskosten/Preisen und der Qualität der Versorgung zu erstellen. In vier elektronischen Datenbanken wurde nach Literatur zu den Auswirkungen von Krankenhauskosten und -preisen auf die Qualität der Versorgung gesucht, einschließlich Studien, die zwischen 1990 und März 2019 veröffentlicht wurden. Insgesamt wurden 47 Studien identifiziert, deren Daten extrahiert und in verschiedenen Tabellen zusammengefasst wurden, um Muster in den Beziehungen zwischen Krankenhauskosten/-preisen und der Qualität der Versorgung zu identifizieren. Die Ergebnisse der Studien sind sehr heterogen. Der Anteil der Studien, in denen ein signifikant positiver Zusammenhang zwischen Preisen/Kosten und der Qualität der Versorgung festgestellt wurde, ist höher, wenn a) Preise/Erstattungen (anstelle von Kosten) verwendet werden; b) Prozessmaße (anstelle von Ergebnismaßen) verwendet werden; c) der Schwerpunkt auf Patienten mit akutem Myokardinfarkt, Herzinsuffizienz und Schlaganfall liegt (anstelle von Patienten mit anderen klinischen Zuständen oder allen Patienten); und d) Störfaktoren mittels einer ausgereifteren Methodik begegnet werden. Unsere Ergebnisse deuten darauf hin, dass es keine allgemeine Beziehung zwischen Kosten/Preis und der Qualität der Versorgung gibt. Die Beziehung scheint jedoch von der Erkrankung und der spezifischen Ressourcennutzung abzuhängen. Die politischen Entscheidungsträger sollten mit den Maßnahmen zur Senkung der Krankenhauskosten vorsichtig umgehen, um die Qualität der Versorgung nicht zu gefährden, insbesondere in ressourcenintensiven Einrichtungen.

Studie 2 (Kapitel 3)

Länder verlassen sich zunehmend auf den Wettbewerb zwischen Krankenhäusern, umgesundheitliche Zielgrößen zu verbessern. Es gibt jedoch nur wenige empirische Belege für die Auswirkungen des Wettbewerbs auf gesundheitliche Zielgrößen für den deutschen Krankenhausmarkt. Diese Studie untersucht die Auswirkungen des Krankenhauswettbewerbs auf die Qualität der Versorgung, die wir anhand von Gesundheitsergebnissen bewerten, wobei wir uns auf die Behandlung des akuten Myokardinfarkts (AMI) in Deutschland konzentrieren. Für unsere Analyse haben wir drei Datensätze verwendet: Routinedaten von 63.439 Patienten mit AMI als Hauptdiagnose aus den Jahren 2015-19 von einer großen gesetzlichen Krankenkasse, Krankenhausmerkmale aus Krankenhausqualitätsberichten sowie geografische Merkmale von Krankenhäusern und Patienten aus der INKAR-Datenbank. Wir bewerteten die Qualität der Versorgung im Hinblick auf die Sterblichkeit im Krankenhaus und nach dem Krankenhausaufenthalt, sowie die kardial bedingte Wiederaufnahme. Zur Untersuchung des Zusammenhangs zwischen Wettbewerb und gesundheitlichen Zielgrößen wurden OLS Regressionen, sowie logistische Regressionen und Hürdenmodelle geschätzt. Es zeigte sich, dass ein hoher Wettbewerb mit einer niedrigeren Versorgungsqualität in Bezug auf Sterblichkeit und Wiederaufnahmen verbunden war, während sich die Versorgungsqualität in Märkten mit mittlerem und niedrigem Wettbewerb nicht wesentlich unterschied. Patienten, die in Märkten mit hohem Wettbewerb behandelt wurden, hatten eine um 8,04 % bzw. 10,2 % höhere Wahrscheinlichkeit, innerhalb von 30 Tagen bzw. 2 Jahren nach der Aufnahme zu sterben, und eine um 13,33 % bzw. 4,8 % höhere Wahrscheinlichkeit, innerhalb von 7 Tagen bzw. 2 Jahren nach der Entlassung wieder aufgenommen zu werden, als Patienten, die in Märkten mit niedrigem Wettbewerb behandelt wurden. Der Krankenhauswettbewerb führt in Deutschland nicht zu besseren Gesundheitsergebnissen für AMI-Patienten. Daher sollten zusätzliche Maßnahmen, wie z. B. Sanktionen für Abweichungen von Qualitätsmaßstäben, in Betracht gezogen werden, um eine Qualitätsverbesserung zu erreichen.

Studie 3 (Kapitel 4)

Das Gesundheitswesen in den Vereinigten Staaten ist mit einer Vielzahl politischer Maßnahmen konfrontiert, um die steigenden Gesundheitskosten einzudämmen und die finanzielle Leistungsfähigkeit zu verbessern. Auf dieser Grundlage wurde diskutiert, ob es finanziell vorteilhafter ist, in größere Krankenhäuser zu investieren als in kleinere Krankenhäuser. In dieser Studie werden die Auswirkungen der Krankenhausgröße auf die finanzielle Leistungsfähigkeit des kalifornischen Krankenhaussektors erörtert. Das erste Ziel dieser Studie ist es, ein besseres Verständnis dieser Beziehung zu erlangen und die Debatte über diese Beziehung zu klären. Das zweite Ziel dieser Studie ist es, zu zeigen, ob diese Beziehung durch die Perspektive der Größenvorteile und Größennachteile erklärt werden kann. Zur Untersuchung unserer Studienfragen wurden mehrere vom Office of Statewide Health Planning and Development im Bundesstaat Kalifornien bereitgestellte Datensätze von 2015 bis 2019 zusammengeführt. Wir untersuchen den Zusammenhang zwischen Krankenhausgröße und finanzieller Leistungsfähigkeit anhand des Konzepts der Skalenerträge. Daher haben wir neben den Betriebseinnahmen und den Kosten pro bereinigten Patiententagen die DuPont-Analyse verwendet, mit der die Eigenkapitalrendite in ihre drei Komponenten, einschließlich Rentabilität, Effizienz und Verschuldungsgrad, zerlegt wird, um neue Erkenntnisse über die finanzielle Leistungsfähigkeit zu gewinnen. Die Ergebnisse deuten darauf hin, dass größere Krankenhäuser im kalifornischen Krankenhaussektor tendenziell eine bessere finanzielle Leistungsfähigkeit aufweisen als kleinere Krankenhäuser. Da der Trend zu Fusionen und Übernahmen in den USA nach der Verabschiedung des "Affordable Care Act" zugenommen hat, kann man mit Sicherheit sagen, dass Krankenhäuser in diesem Bundesstaat, die eine Expansion oder einen Zusammenschluss mit anderen Krankenhäusern in Erwägung ziehen, eine höhere Wahrscheinlichkeit haben, bessere finanzielle Ergebnisse zu erzielen. Dies ist vor allem auf die Größenvorteile zurückzuführen, die sich ab 140 Betten ergeben. Was jedoch die Skaleneffekte betrifft, so scheinen diese in einem sehr großen Krankenhaus (d. h. 794 Betten) beeinflusst zu werden. Auch wenn diese Studie nicht in der Lage ist, die steigenden Gesundheitskosten vollständig zu bewältigen, kann sie für Krankenhausmanager, Eigentümer und sogar politische Entscheidungsträger in Kalifornien bei der Anpassung ihrer Organisation in einer Weise von Nutzen sein, die sich möglicherweise positiv auf ihre finanzielle Leistungsfähigkeit auswirkt.

A.3 List of Publications to §6 (6) PromO

Journal Article	Publication Status
Jamalabadi, S., Winter, V. & Schreyögg, J. A Systematic Review of the Association Between Hospital Cost/price and the Quality of Care. Appl Health Econ Health Policy 18, 625–639 (2020). https://doi.org/10.1007/s40258-020-00577-6	Published in *Applied Health Economics and Health Policy*
Jamalabadi, S., Bayindir, E.E. , Schneider, U & Schreyögg, J. The Effect of Hospital Competition on Health Outcomes: Evidence from AMI Admissions in Germany. (2022)	Will be shortly submitted to the *European Journal of health economics*
Jamalabadi, S. & Schreyögg, J. The Effect of Hospital Size on the Financial Performance. (2022)	Will be shortly submitted to *Health service research*

Affidavit

I, Sara Jamalabadi, hereby declare in lieu of an oath that I have written the dissertation entitled

Measuring cost and analyzing hospital performance

Autonomously- and if in cooperation with other scientists as described in the attached statement according to §6 Abs. 4 of doctoral regulations of Faculty of Business Administration dated July 9, 2014- and that I did not use any other aids than those I indicated herein. The parts are taken literally or by sense from other works than mine are marked as such. I assure that I did not take advantage of any commercial doctoral consultation, nor was my work accepted or judged insufficient in an earlier doctoral procedure at home or abroad.

Hamburg, March 29,2022 *Sara Jamalabadi*