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#724

Imprint

Ruhr Economic Papers

Published by

RWI – Leibniz-Institut für Wirtschaftsforschung
Hohenzollernstr. 1-3, 45128 Essen, Germany

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Ruhr Economic Papers #724

Responsible Editor: Jochen Kluve

ISSN 1864-4872 (online) – ISBN 978-3-86788-844-8

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UNIVERSITÄT DUISBURG ESSEN

RUHR UNIVERSITÄT BOCHUM RUB

RWI

Bibliografische Informationen der Deutschen Nationalbibliothek

The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available on the Internet at http://dnb.dnb.de

RWI is funded by the Federal Government and the federal state of North Rhine-Westphalia.

http://dx.doi.org/10.4419/86788844
ISSN 1864-4872 (online)
ISBN 978-3-86788-844-8

Boris Augurzky, Christian Bünnings, and Ansgar Wübker[1]

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Abstract

In this study we investigate the relationship between nursing staffing levels and hospital quality in Germany. We use administrative data from almost all German hospitals from 2002 to 2013 and link it to mortality rates and patient satisfaction measures. To analyze the association between nursing staffing levels and hospital quality indicators empirically, we estimate linear regression models and control for a wide range of hospital and patient characteristics that might bias the results. In addition, we exploit the longitudinal structure of the data and rule out potential bias due to time-invariant unobserved heterogeneity. The estimation results indicate a positive relationship between nurse staffing levels and hospital quality for both subjective and objective quality measures. Increasing nurse staffing levels by 10 percent reduces the mortality rate by 0.05 percent and increases patient satisfaction by around 0.7 percent, on average. Although we find some of these relationships to be statistically significant, at least marginally, the absolute magnitudes of the estimated coefficients are rather small.

JEL Classification: C23, I11, I18

Keywords: Hospital quality; nurse staffing; patient satisfaction; mortality rate

December 2017

1 Boris Augurzky, RWI and UDE; Christian Bünnings, RWI and FOM; Ansgar Wübker, RWI, RUB and Leibniz Science Campus Ruhr. *– This research was part of a research project funded by the "Techniker Krankenkasse". The "Techniker Krankenkasse" had no role in the design of the study, in the collection and analysis of the data, in the interpretation of the results and in the preparation, review, or approval of the manuscript. The views expressed in this manuscript are those of the authors. The authors have no conflict of interest to report. The authors thank participants of the annual meeting of the EuHEA in Hamburg 2016. We are also grateful to Marcel Weigand (Weisse Liste) for providing us with data on patient satisfaction and Urban Janisch (Research Data Centres of the State Statistical Offices) for access to administrative data on German hospitals. Finally, we would like to thank Maryna Ivets and Astrid Schürmann for editing this work.* *– All correspondence to: Christian Bünnings, RWI, Hohenzollernstraße 1-3, 45128 Essen, Germany, e-mail: christian.buennings@rwi-essen.de*

1 Introduction

In most western health care systems, hospitals are under pressure to simultaneously control rising costs while improving care quality (e.g. Cook et al.; 2012) . Both challenges are particularly relevant to the public debate about nursing staffing levels. On the one hand, hospital nursing staff is an important cost factor for hospitals: increasing staffing levels increases costs.[1] On the other hand, sufficient nurse staffing is often linked to care quality. In a recent study Mark et al. (2013) argue that increasing nurse staffing might improve quality of care by enhancing surveillance of patients (e.g. patient observation, recognition of impending problems) and by reducing "missed nursing care" errors, leading to improvements in care quality. However, in their empirical investigation of California's minimum nursing staffing regulations, a widely known legislation which mandated minimum nurse-to-patient staffing ratios in acute care hospitals, they find mixed effects on quality.

In Germany, the relationship between hospital nursing staffing and quality of care is a significant concern for patients, health services researchers, policymakers, and health care decision makers. Concern about adequate nurse staffing in Germany rose after the introduction of a diagnoses related groups (DRG) payment system in 2004, which was implemented to make payment more transparent and to promote efficiency and competition. The German DRG payment system is similar to hospital payment systems in other countries, such as DRG payment for Medicare patients in the United States. These payment systems provide strong incentives for hospitals to keep costs low. It has been argued that hospitals are incentivized to reduce nursing staff in reaction to DRG-type payment systems, which can harm quality (see Augurzky et al.; 2016). In response to this increasing concern and to a worsening nursing shortage, recent law revisions in Germany (Krankenhausstrukturgesetz; 2015) have allocated considerable amounts of money to strengthen nursing staffing levels. Moreover, minimum nurse-to-patient staffing ratios will be introduced in German acute care hospitals starting in 2019 (Federal Ministry

[1] The overwhelming portion of hospital costs is personnel expenditures. In 2014, personnel expenditures accounted for 59.9% of hospital expenditures in Germany and nursing costs accounted for 30,4% of overall personnel expenditures (German Statistical Office; 2015)

of Health; 2017). These mandatory ratios will be similar to US minimum nurse staffing regulation in California.

Although a large body of literature investigates the relationship between nurse staffing levels and patient outcomes (for an overview see Kane et al.; 2007; Shekelle; 2013; Griffiths et al.; 2014), the results are still mixed and credible evidence for Germany is missing. While several studies observe a positive relationship between nurse staffing levels and mortality (e.g Aiken et al.; 2010, 2014; Arkin et al.; 2014) others find that higher staffing levels correlate with higher mortality rates (e.g. Kelly et al.; 2014; Talsma et al.; 2014). One drawback of many empirical studies in this field is their cross-sectional design which does not entirely allow the ruling out of unobservable factors that are correlated with both, the quality outcome and nurse staffing levels. In order to account for unobserved (time-invariant) confounders, recent contributions exploit longitudinal information and natural experiments. Using data from 422 hospitals from 1990 to 1995 Mark et al. (2004) observe a diminishing marginal effect of higher nurse staffing levels on reducing mortality, while other complications remain unaffected. Exploiting the introduction of California's minimum staffing regulation in January 2004 as a natural experiment, Cook et al. (2012) observe that improvements in hospitals nurse staffing levels do not lead to reduced failure in rescue rates (i.e. rates of death from complications that under normal circumstances might have been prevented). Again exploiting the introduction of California's minimum staffing legislation, Mark et al. (2013) find that failure-to-rescue rates decrease significantly more in some California hospitals than in hospitals from control states. On the other hand, they also observe more infections in some California hospitals than in the control hospitals, which might be the result of higher detection rates. In a recent study, Martsolf et al. (2016) extend the existing literature by examining the relationship between nurse staffing levels and subjective quality outcomes. Using a three year panel on patient experiences with care during their hospital stay, they find positive but small influences of higher nurse staffing levels on selected measures of patients' satisfaction.

Our study contributes to the existing literature on the relationship between nurse staffing levels and hospital quality in several ways. First, while existing studies analyze the role of nurse staffing levels and quality outcomes for specific national subsamples of

hospitals, this is the first study based on administrative data covering a long time period and nearly every German hospital. Second, while the majority of empirical studies focuses on the US context, this is one of the few studies outside the US and the first empirical investigation for Germany. Evidence from Germany might be of particular interest for other countries, as results can be interpreted in the context of a purely prospective payment system. Financing is based on a DRG-type payment system for almost all patients in Germany and patient co-payment is negligible. Moreover, weekly working time for nurses is relatively inflexible due to strict German labor law rules enhancing the reliability and validity of the main explanatory variable: the number of full-time equivalent nurses per 100 patients. Third, besides the mortality rate, which is a common and widely used quality measure, we build on the work of Martsolf et al. (2016) and extend the empirical evidence on the relationship between nurse staffing levels and subjective quality outcomes, i.e. patients satisfaction. Fourth, due to the comprehensive information in our data, our study is one of the first that explicitly controls for staffing levels of other occupational groups, such as physicians. Controlling for staffing levels of other occupational groups might be important (see Cook et al.; 2012) since they typically correlate with nurse staffing levels and may change significantly over time.

The remainder of the paper is organized as follows: Section 2 describes the data set used and the empirical methods applied in this study. Section 3 outlines the estimation results and in section 4 we discuss the results and give some concluding remarks.

2 Empirical Approach

2.1 Data Sources

For the empirical analysis we use administrative data from German hospital statistics from 2002-2013 (Research Data Centres of the State Statistical Offices; 2015).[2] These statistics are an annual census of all German hospitals and hospital admissions. It covers about 2000 hospitals and 18 million admissions each year and provides comprehensive hospital

[2]Due to the sensitivity of the data, all analyses were conducted via remote data processing.

and patient characteristics. This detailed information allows us to control for a range of potential confounding variables that might be simultaneously correlated with the level of nurse staffing and the quality indicators under consideration. We restrict our sample to general hospitals and exclude psychiatric or psychotherapeutic hospitals, day- or night-care clinics and military hospitals.

The data on patients' satisfaction is from the Patients' Experience Questionnaire (PEQ) for 2012 and 2013 (Weisse Liste; 2013). PEQ is a retrospective survey on patients' perceived hospital quality from members of two of the largest German sickness funds (Barmer and AOK) covering around 50 percent (approximately 33 million insurees in 2013) of all publicly insured individuals in Germany. The questionnaire includes 15 questions covering satisfaction with physicians and nurses as well as general topics like satisfaction with organization, management and service and the overall recommendation of the hospital. In order to receive a questionnaire, patients must be a member of one of the two sickness funds, hospitalized for at least two nights and be between 18 and 80 years old. Typically, patients receive the questionnaire by letter between two and eight weeks after discharge.

2.2 Key Variables

The independent variable of interest in all models is a measure of nurse staffing. Although the hospital statistics provide information on the number of registered nurses, licensed practical nurses and further nursing staff with or without qualification, the number of full-time equivalents (FTE) is only available for the total number of nurses and not separately for the three different nurse types. In the empirical analysis we measure a hospital's nurse staffing in terms of the total number of full-time equivalent (FTE) nurses per 100 patients and consequently cannot account for different skill mixes.

We use the mortality rate as an overall objective quality measure. The mortality rate or related measures like failure to rescue are widely used in empirical studies analyzing the relationship between nurse staffing levels and hospital quality (e.g. Mark et al.; 2004; Cook et al.; 2012; Mark et al.; 2013; Aiken et al.; 2014). The mortality rate can be calculated straightforwardly from administrative data and, even more importantly, it can be used to

compare results to those of previous studies. Based on the hospital statistics, we calculate the mortality rate as the number of patients who died during their hospital stay over the total number of patients.

Subjective quality of care is accessed through four different measures originating from PEQ. Among other things, former patients rate their satisfaction with nursing care in four areas: consideration of needs/concerns, bedside manner, information provision, and overall satisfaction with nursing care.[3] Participants rate their satisfaction on a scale from 1 (not satisfied at all) to 6 (completely satisfied).[4] Based on these individual-level ratings, we calculate average ratings for each hospital-year observation.

2.3 Control Variables

As mentioned, German hospital statistics comprise a wide range of hospital and patient characteristics. This breadth of information mitigates concerns about biased estimates of the key independent variable due to omitted variables. Hospital characteristics are captured by binary indicators for hospital ownership (public, non-profit, private, university) and a set of seven indicators representing hospital size based on the number of beds (1-49, 50-99, 100-149, 150-199, 200-299, 300-499, 500+ beds).

In contrast to most existing studies, we are also able to control for staffing levels of other occupational groups. Specifically, we include staffing levels of physicians, medical-technical services (e.g. medical-technical assistants, physiotherapists, masseurs) and functional services (e.g. operating room assistants, anesthesia assistants, endoscopy assistants). Again, staffing levels are expressed in terms of FTE per 100 patients. Including these additional occupations might be important, because their staffing levels are likely correlated with nurse staffing levels and hospital quality. Hence, omitting these variables would result in biased estimates.

[3]The concrete questions are: Have your wishes and concerns been taken into account by the nursing staff? How would you assess nurses' bedside manner? Have you been adequately informed by the nursing staff? How do you rate the quality of nursing care in your hospital?

[4]The original scale is 1 (completely satisfied) to 6 (not satisfied at all). We use the reversed scale, so that a positive coefficient estimate indicates higher satisfaction with the respective category.

Finally, we include measures reflecting the patient mix, which is of particular importance since hospitals with more complex cases are likely to have higher staffing levels and worse quality outcomes, for instance in terms of mortality rates. Ideally, one would incorporate the hospital-specific case mix, because it is widely used in the literature to capture differences in patient composition between hospitals. Due to data restrictions, however, we cannot directly control for the case mix. To circumvent this problem and to still capture patient composition, we use a set of variables representing the patient mix. These are the share of female patients, the share of cases with surgery, and the average patient age. In addition, we use the distribution of cases according to the 22 chapters of the German version of the international classification of diseases (ICD-GM). Specifically, for each hospital and year we calculate the proportion of cases for each of the 22 chapters.

2.4 Estimation

In order to estimate the relationship between nurse staffing levels and the outcome variables of interest of hospital i at time t, we assume the following linear population model:

$$y_{it} = \beta_1 nurse_{it} + \beta_2 staff_{it} + \beta_3 hospital_{it} + \beta_4 patient_{it} + \alpha_i + \gamma_t + \varepsilon_{it}$$

Y refers to the respective quality outcome, *nurse* represents the nurse staffing level in FTE per 100 patients, $staff$ includes staffing levels of other occupational groups in FTE per 100, *hospital* is a vector of hospital characteristics and *patient* includes patient characteristics. The parameter of interest in all specifications is β_1.

In addition to the various control variables, we exploit the longitudinal nature of our data and include a separate intercept for each hospital (α_i). These hospital fixed effects cover a range of potential time-invariant confounding variables, such as the general work environment, cooperation between nurses and physicians, location and specialization of the hospital, and to some extent, the structural composition of patients.

Finally, we control for potential calendar time effects by a full set of binary indicators for calendar years (γ_t) to net out time effects that are invariant across hospitals for a given

point in time. These time effects capture, for instance, medical and technical innovations, changes in the composition of the population or prevalence rates of specific diseases.

Identifying the effect of nurse staffing levels on hospitals quality requires that, conditional on all covariates, nurse staffing levels are uncorrelated with the regression error term (ε_{it}). This, however, is a crucial assumption, since we ultimately cannot rule out that other unobserved time-varying factors confound our estimation results. Therefore, the empirical results presented in this study should be interpreted rather carefully and should be considered as suggestive and not conclusive.

3 Results

3.1 Descriptive Results

Table 1 presents descriptive summary statistics of the two estimation samples. The first two columns refer to the specification where the mortality rate is the dependent variable (sample I), whereas the last two columns relate to specifications that use subjective quality measures as outcome variables (sample II). The latter comprises information from 2012 and 2013 and is a sub-sample of the former.

Considering the quality measures of interest, table 1 shows that 2.2 percent of all patients in our sample died during their hospital stay. The subjective quality measures indicate a fairly high level of patient satisfaction. The average satisfaction is lowest in the subcategory "appropriate information by nurses" with 4.997 of a maximum of 6. The highest satisfaction can be observed in the subcategory "bedside manner" with an average of 5.275 of a maximum of 6. Overall satisfaction with nursing care reaches an average rating of 5.060.

With respect to staffing levels, nursing staff represents the largest occupational group within a hospital with on average 2.2 FTE per 100 patients. The second largest group is physicians with 1.1 FTE per 100 patients. Staffing levels are lowest for medical-technical services and functional services with 0.8 FTE per 100 patients. It is noticeable that average staffing levels are considerably smaller (around one third) in sample II, which covers the

subjective quality measures. The main reason is the steady – and still ongoing – increase in the number of cases since the introduction of the DRG payment system in Germany in 2004.[5]

Around 75 percent of the observations refer to hospitals that are either non-profit or public, two percent are university hospitals and the remaining are private hospitals. These shares are quantitatively similar in both samples. The observations are well distributed by size, with around one third of the observations with 149 beds and less, one third between 150 and 300 beds, and one third with more than 300 beds. Again, the distribution is very similar in both samples with a slight over-representation of larger hospitals in the smaller sample II.

The average patient age is 55.7 years (57.7 years in sample II) and 55 percent are females. One third of patients who were admitted underwent a surgery. The distribution of the ICD main diagnoses is similar in both samples. The top three ICD chapters are diseases of the circulatory system (16.3%/16.0%), diseases of the musculoskeletal system and connective tissue (12.6%/13.5%) and injury, poisoning and certain other consequences of external causes (10.1%/10.0%).

Overall the observations are well distributed over time. In sample I, the share of observations ranges from 8.7 percent in 2002 to 7.9 percent in 2013. The slight decrease over time is the result of an ongoing concentration process in the German hospital market. In sample II, the observations are almost equally distributed over both years (2012: 51%, 2013: 49%).

[5]The number of hospital admissions has increased by around 16% from 2004 to 2016 (German Statistical Office; 2016).

Table 1: Descriptive Statistics

	Sample I		Sample II	
	Mean	SD	Mean	SD
Quality measures				
Mortality rate	0.0224	0.0219		
Consideration of needs and concerns			5.0913	0.2369
Bedside manner			5.2752	0.2170
Appropriate information			4.9974	0.2476
Overall satisfaction with nursing care			5.0599	0.2403
Staffing levels (FTE/100 patients)				
Nurse	2.2195	11.5143	1.7085	1.5789
Physician	1.0558	7.8019	0.6737	0.4843
Medical-technical services	0.8261	5.7902	0.6577	0.8259
Functional services	0.7704	9.2445	0.4949	0.6006
Hospital characteristics				
Public	Base group			
Non-profit	0.3930	0.4884	0.4012	0.4902
Private	0.2538	0.4352	0.2493	0.4327
University	0.0207	0.1423	0.0255	0.1575
1-49 beds	Base group			
50-99 beds	0.1177	0.3222	0.1139	0.3178
100-149 beds	0.1406	0.3476	0.1398	0.3468
150-199 beds	0.1156	0.3197	0.1127	0.3163
200-299 beds	0.1719	0.3773	0.1778	0.3824
300-499 beds	0.1903	0.3926	0.2141	0.4103
500+ beds	0.1480	0.3551	0.1838	0.3874
Patient characteristics				
Female patients	0.5489	0.1039	0.5373	0.0774
Patients' age	55.7701	10.3179	57.7209	8.7417
Patients with surgery	0.3521	0.2727	0.2945	0.2123
A00-B99	0.0256	0.0405	0.0287	0.0189
C00-D48	0.0833	0.1100	0.0790	0.0954
D50-D90	0.0063	0.0049	0.0068	0.0047
E00-E90	0.0309	0.0614	0.0294	0.0571
F00-F99	0.0431	0.1026	0.0394	0.0842
G00-G99	0.0507	0.1117	0.0499	0.1133
H00-H59	0.0150	0.0821	0.0109	0.0563
H60-H95	0.0067	0.0230	0.0059	0.0085
I00-I99	0.1625	0.1596	0.1603	0.1492
J00-J99	0.0617	0.0664	0.0651	0.0673
K00-K93	0.0999	0.0909	0.0975	0.0650
L00-L99	0.0169	0.0571	0.0176	0.0603
M00-M99	0.1264	0.1955	0.1346	0.1913
N00-N99	0.0470	0.0527	0.0472	0.0477
O00-O99	0.0401	0.0488	0.0391	0.0461
P00-P96	0.0057	0.0116	0.0062	0.0101
Q00-Q99	0.0068	0.0310	0.0041	0.0120
R00-R99	0.0380	0.0331	0.0474	0.0291
S00-T98	0.1007	0.0700	0.1040	0.0659
V01-Y84	Base group			
Z00-Z99	0.0328	0.0890	0.0269	0.0336
U00-U99	0.0000	0.0002	0.0000	0.0000
Time period	2002-2013		2012-2013	
Observations	19742		2475	
Hospitals	1994		1278	

Notes: Own calculations based on data from the hospital statistics (Research Data Centres of the State Statistical Offices; 2015) and from PEQ (Weisse Liste; 2013).

3.2 Estimation Results

Table 2 presents the estimated coefficients on the four occupational groups in the main specification, i.e. including hospital fixed effects. We estimate five different models, one for each of the five quality measures. With respect to the mortality rate, we observe a negative and statistically significant coefficient estimate of nurse staffing levels. Higher staffing levels correlate with lower mortality rates. Although statistically significant at the five percent level, the estimated coefficient can be considered as rather small. More precisely, the point estimate suggests that increasing nurse staffing levels by 10 percent of its sample mean ($= 0.222 = 0.1 \times 2.22$) decreases the mortality rate on average by 0.00001 ($= -0.000048 \times 0.222$) percentage points. To put this into perspective, the average mortality rate in the sample amounts to 2.24 percent. Hence, a 10 percent increase in nurse staffing levels, which would be a change of considerable magnitude, translates into a reduction of the mortality rate by 0.05 percent ($= {}^{-0.000048 \times 0.222}/_{0.0224}$) evaluated at its mean. The coefficient estimates of the other occupational groups are neither statistically nor economically significant.

Considering the results of the subjective quality outcomes, we observe a very similar picture as compared to the mortality rate. The estimated coefficients of nurse staffing levels exhibit the intuitive sign and are marginally significant ($p < 0.1$) in three out of four specifications. Yet, the absolute sizes of the coefficient estimates imply a relationship that is rather small. Increasing nurse staffing levels by 10 percent is, for instance, related to an average increase in the satisfaction with appropriate information by nurses of 0.034 ($= (0.1 \times 1.709) \times 0.2014$) points. Relating this to the sample mean of 4.997 reveals that a 10 percent increase in nurse staffing levels increases patients' satisfaction on average by 0.7 percent ($= {}^{0.034}/_{4.997}$). Although the effect size is roughly 14 times larger as compared to the corresponding effect on the mortality rate, it remains small given the substantial increase in nurse staffing levels of 10 percent. Again, the estimated coefficients on the other occupational groups are both statistically and economically insignificant, and most of them are substantially smaller than those obtained for nurse staffing levels.

Table 2: Estimation Results – Longitudinal

	Mortality rate	Needs & concerns	Bedside manner	Information	Overall quality
Nurses	−0.000048**	0.1693	0.1626*	0.2014*	0.1895*
	(0.000023)	(0.1101)	(0.0933)	(0.1153)	(0.1044)
Physicians	−0.000045	−0.0395	0.1960	0.0374	0.0637
	(0.000042)	(0.2067)	(0.1733)	(0.2044)	(0.1973)
Medical-Technical Service	0.000023	−0.1541	−0.1570	−0.1072	−0.1220
	(0.000026)	(0.1471)	(0.1364)	(0.1507)	(0.1265)
Functional Service	−0.000022	0.0822	0.0994	0.0923	0.0705
	(0.000034)	(0.1603)	(0.1769)	(0.1962)	(0.1765)
Observations	19,742	2475	2475	2475	2475
Hospitals	1994	1278	1278	1278	1278
Mean of dependent variable	0.0224	5.091	5.275	4.997	5.060

Notes: Own calculations based on data from the hospital statistics (Research Data Centres of the State Statistical Offices; 2015) and from PEQ (Weisse Liste; 2013). The table shows the estimated coefficients on the occupational groups for five different quality outcomes. Standard errors, clustered at the hospital level, in parentheses, *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

To benchmark the previous results and to get an indication whether the lack of statistical significance is due to limited within-hospital variation, we now ignore the longitudinal design of the data and re-estimate all models based on pooled cross-sections, i.e. without hospital fixed effects. The results of this exercise are shown in Table 3. As can be seen, the absolute size of the coefficient estimates of nurse staffing levels is considerably smaller and no longer statistically significant. Moreover, the point estimate in four out of five models carries the counterintuitive sign, suggesting that higher nurse staffing levels are related to lower quality. This, however, is a common finding in the existing literature, particularly in cross-section analyses (e.g. Kelly et al.; 2014; Talsma et al.; 2014; Horwitz et al.; 2015). One explanation for this counterintuitive finding might be that hospitals with higher nurse staffing levels are those hospitals that also have more severe cases on average. The latter might be reflected in average lower quality outcomes, too. Hence, results from cross-sectional analyses without an exogenous source of variation in nurse staffing levels and non-adequate risk adjustment should be interpreted with caution.

Table 3: Estimation Results – Cross-sectional

	Mortality rate	Needs & concerns	Bedside manner	Information	Overall quality
Nurses	0.000052	−0.0202	0.0038	−0.015	−0.0082
	(0.000033)	(0.0174)	(0.0116)	(0.0121)	(0.0097)
Physicians	−0.000057	−0.0725**	−0.0366	−0.0548**	−0.0632***
	(0.000047)	(0.0303)	(0.0237)	(0.0240)	(0.0237)
Medical-Technical Service	−0.000038	0.0508	0.0020	0.0258	0.0089
	(0.000039)	(0.0337)	(0.0265)	(0.0243)	(0.0252)
Functional Service	0.00003	0.0291*	0.0160	0.0222*	0.0328***
	(0.000028)	(0.0166)	(0.0109)	(0.0118)	(0.0119)
Observations	19,742	2475	2475	2475	2475
Hospitals	1994	1278	1278	1278	1278
Mean of dependent variable	0.0224	5.091	5.275	4.997	5.060

Notes: Own calculations based on data from the hospital statistics (Research Data Centres of the State Statistical Offices; 2015) and from PEQ (Weisse Liste; 2013). The table shows the estimated coefficients on the occupational groups for five different quality outcomes. Standard errors, clustered at the hospital level, in parentheses, *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

4 Discussion

As one of the first studies outside the US, this study analyzes the role between nurse staffing levels and objective as well as subjective quality outcomes of hospitals. Exploiting longitudinal data for nearly every hospital in Germany, we find that nurse staffing levels are (marginally) significantly related to both objective and subjective quality measures. Specifically, higher nurse staffing levels are related to lower mortality rates and higher perceived quality by patients. Yet, the effect size can be considered as rather small. Interestingly, we observe neither a statistically nor an economically significant relationship between the quality measures and other occupational groups, such as physicians. Using a cross-sectional design, it turns out that ignoring the longitudinal nature of the data may lead to counterintuitive results and potentially incorrect conclusions with respect to the relationship between nurse staffing levels and hospital quality.

How do the empirical results of the present study fit into the existing literature? With respect to the relationship between nurse staffing levels and hospital mortality rates, previous studies provide a large range of estimates. Harless and Mark (2010), for instance, estimate that an increase of one FTE registered nurse per 1000 inpatient days correlates with a 4.3 percent decrease in the mortality rate. A somewhat smaller effect is provided

by Mark et al. (2004). The latter estimate that the mortality rate decreases by 1.5 percent when the registered nurse staffing level increases by one FTE per 1000 inpatient days. Our estimates suggest that mortality decreases by 0.2 percent ($= {}^{-0.000048}/_{0.0224}$) if nurse staffing levels increase by one FTE per 100 patients.[6] To put this into perspective, the average length of stay in Germany in 2013 was 7.5 days. Hence, one FTE per 100 patients translates on average into one FTE per 750 inpatient days, which makes the estimates at least roughly comparable. Thus, our estimated change in the mortality rate is considerably smaller than the above mentioned estimates. One possible explanation for the difference in the estimated changes might be the definition of nurse staffing levels. While Harless and Mark (2010) and Mark et al. (2004) use the number of registered nurses, our measure of nurse staffing levels also includes further nursing staff with or without qualification. Assuming that less educated nursing staff improves hospitals' quality on average less than better educated nursing staff, i.e. registered nurses, this would result in a smaller estimated coefficient of nurse staffing levels.

There is little existing literature that considers the relationships between subjective quality measures (such as patient satisfaction) and nurse staffing levels. Using cross-sectional data from the Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS), Jha et al. (2008) observe a significant positive relationship between nurse staffing levels and patient satisfaction. The differences between hospitals in the lowest and those in the highest quartile of the nurse staffing level distribution range between 0.9 and 4.2 percentage points (on a scale from 0 to 100). Martsolf et al. (2016), using three years of the same survey and controlling for unobserved time-invariant confounders, find that an increase of one FTE per 1000 inpatient days is associated with an increase in average patient satisfaction of 0.6 to 1.3 percent (evaluated at the respective mean). Yet, most of the coefficient estimates are no longer statistically significant once hospital fixed effects are included. Our results suggest that an increase of one FTE per 100 patients is associ-

[6] It is important to note, that an increase of one FTE per 100 patients constitutes a substantial increase in nurse staffing level by roughly 45 percent evaluated at its mean ($0.45 = {}^{1}/_{2.22}$).

ated with an increase in average patient satisfaction of 3.1 to 4.0 percent (evaluated at the mean).[7] However, these relationships are only marginally significant.

This study has several limitations. First, the lack of quasi-experimental data prevents us from drawing causal inference. Although we try to mitigate concerns about confounding factors by using a large set of hospital and patient characteristics as well as netting out unobservable hospital characteristics that are time-invariant, we cannot rule out the possibility that unobserved time-variant factors influence our estimation results. Second, our analysis is based on hospital level data. It is conceivable that even within the same hospital, staffing levels and quality outcomes differ significantly across different units. Detailed information on staffing levels and quality measures is not available on a unit-level, at least not for Germany. Third, the transition between nurses and other occupational groups like medical-technical service is often smooth; e.g. there might be complementarities and overlap in nursing inputs and other inputs between these groups. In addition, these transitions are not the same for different hospitals, making it empirically challenging to disentangle the relationships between different staffing levels and the hospital quality. We try to mitigate this problem by controlling for staffing levels of other occupational groups. Fourth, we are not able to account for differences in the skill mix distribution of nurses within a hospital. As long as one can assume skill mixes to be constant over time, these would be part of the hospital fixed effects and would not cause a problem. This, however, is likely not the case, especially since our analysis is based on a long time series.

Taken together, we find the expected positive relationship between nurse staffing levels and hospital quality for both subjective and objective measures. The absolute size of the estimated coefficients, however, indicates that considerable quality improvements can only be achieved if staffing levels substantially increase. Since the absolute amount of staffing levels is only one determinant in the complex construct of hospital quality, the results suggest that emphasis should not be strictly on nurse staffing levels, but also on

[7] As the HCPHS measures are different from our measures, a comparison of results is limited. However, considering that one FTE per 100 patients translates into one FTE per 750 inpatient days (see below) and assuming comparable indicators, we find slightly higher effects compared to Martsolf et al. (2016) and effects that are in the range of Jha et al. (2008). Again, in our opinion these are still rather small effects as an increase of one FTE per 100 patients is a huge staff increase of around 60 percent ($0.58 = 1/1.71$).

other soft factors. Examples of such soft factors might be the collaboration between different occupational groups within a hospital, e.g. between nurses and physicians, or the general working environment. The challenge in analyzing such soft factors is, however, acquiring corresponding data.

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