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Martin Salm
Ansgar Wübker

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Technische Universität Dortmund, Department of Economic and Social Sciences
Vogelpothsweg 87, 44227 Dortmund, Germany

Universität Duisburg-Essen, Department of Economics
Universitätsstr. 12, 45117 Essen, Germany

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Martin Salm and Ansgar Wübker[1]

Do Higher Hospital Reimbursement Prices Improve Quality of Care?

Abstract

Does higher medical spending improve quality of care? We estimate the effect of changes in regulated reimbursement prices for hospitals on multiple dimensions of hospital quality, including mortality outcomes, surgical complications, process quality, and patient satisfaction. We exploit an exogenous variation in reimbursement prices between the years 2006 and 2010 based on a reform of hospital financing in Germany. We find that changes in reimbursement prices do not affect quality of care. This effect is precisely estimated, and we can rule out effect sizes that are large relative to the overall variation in quality indicators across hospitals.

JEL Classification: I11, H51, D22

Keywords: Health care expenditures; hospital care; quality of care

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1 Martin Salm, CentER, Tilburg University; Ansgar Wübker, Leibniz Science Campus Ruhr, RUB and RWI. *– The authors thank Mary Deely, Ellen Meara, and Raun van Ooijen for their valuable comments and suggestions as well as conference participants at the American Society of Health Economists in Los Angeles, the Netspar Workshop in Amsterdam and seminar participants at the Universities of Mainz, Mannheim, Munich, Trier, and Tilburg, Royal Holloway University London, and the Central Planning Bureau in the Hague. We thank Adam Pilny for making data on hospital mergers available to us. The financial support of the Fritz Thyssen Foundation is gratefully acknowledged.* *– All correspondence to: Ansgar Wübker, RWI, Hohenzollernstr. 1-3, 45128, Germany, e-mail: ansgar.wuebker@rwi-essen.de*

1. Introduction

What is the effect of higher medical spending on quality of care and medical outcomes? In light of high and increasing healthcare expenditures in countries across the world, this is an important question. However, the answer is far from obvious. On the one hand, we observe a positive correlation between higher healthcare expenditures and better health outcomes across countries and over time (Preston 1975, Chernew and Newhouse 2012). The rapid growth in healthcare expenditures over the past decades has coincided with a fast increase in life expectancy and a reduction in mortality from many causes, including cardiovascular diseases and cancer. On the other hand, if we compare different medical providers or regions within a country, then healthcare spending is often uncorrelated with quality of care and with health outcomes (Baicker and Chandra 2004, Yasaitis et al. 2009, and survey by Hussey et al. 2013). Possible explanations could be that marginal care is inefficient or that hospitals or regions with higher expenditures have patients with worse underlying health.

Several previous studies estimate the causal effect of medical spending on quality of care based on natural experiments such as changes in reimbursement prices for Medicare patients (Cutler 1995, Shen 2003, Wu and Shen 2014, Clemens and Gottlieb 2014), medical guidelines that give rise to discontinuities in spending (Almond et al. 2010), out-of-state hospital admissions (Doyle 2011), and ambulance referral patterns (Doyle et al. 2015). In our study we exploit a reform of hospital financing in Germany in order to examine the effect of a change in regulated reimbursement prices on quality of care. Compared to previous studies, our study has two main advantages: First, we look at a broader set of measures for hospital quality. Quality of hospital care is difficult to measure, and it has many dimensions which include patient health outcomes, process quality, and patient satisfaction (Donabedian 1966). Previous studies focus mostly on mortality, often for heart attack patients, as a measure for quality of care.[1] In our study, we examine the causal effect of medical spending on multiple dimensions of hospital quality, including mortality outcomes for different diagnoses, surgical complications, process quality, and patient satisfaction.

[1] Cutler (1995), Shen (2003), and Wu and Shen (2014) look at heart attack mortality outcomes, Clemens and Gottlieb look at overall mortality rates as well as numerous outcome variables other than quality of care. Almond et al. (2010) look at mortality and intensity of treatment for low-birthweight newborns. Doyle (2011) and Doyle et al. (2015) look at mortality rates for emergency hospital admissions. Studies examining not a causal effect, but the correlation between medical spending and quality of care have also used quality measures other than mortality (see survey by Hussey et al. 2013).

Second, the policy reform examined in our study proportionally shifted prices for (almost) all patients and types of hospital care, with some hospitals facing increasing prices and other hospitals facing decreasing prices. In contrast, previous studies examine changes in reimbursement prices that affect only a subset of patients such as Medicare beneficiaries. It is possible that medical providers compensate for lower reimbursement prices for Medicare patients by increasing revenues from other types of patients (He and Mellor 2012). This could explain the finding in some previous studies that changes in reimbursement prices do not affect quality of care.

Our empirical approach is based on changes in hospital specific base-rate factors (Basisfallwerte) in Germany between the years 2006-2010. Changes in base-rate factors shift the overall level of reimbursement prices for hospital admissions proportionally for (almost) all patients and types of care. In the year 2006, base-rate factors varied widely across hospitals based on historical costs. During the following years, base-rate factors gradually converged towards averages at the state level. Thus, base-rate factors increased for some hospitals, and they decreased for others. Base-rates at the 10^{th} percentile of initial prices increased by 10 percent in real terms between 2006 and 2010, while those at the 90^{th} percentile decreased by 8 percent. In our empirical approach, we leverage this variation in base-rate factors in order to estimate the effect of changes in base-rate factors between the years 2006 and 2010 on quality of care. We use a differences-in-differences estimation approach with the change in price as continuous treatment variable.

In our analysis, we examine a wide range of measures for hospital quality which are combined from various sources. Information on patient mortality for patients with different diagnoses, including heart attack and stroke patients, comes from claims-level data of a large health insurer for the years 2006-2010. Information on further health outcomes such as surgical complications with pacemaker implantations comes from the Federal Office for Quality in the Healthcare Sector (BQS) for the years 2006 and 2010. The BQS also provides information on process quality such as guideline conformity for various procedures. Detailed information on patient satisfaction with hospital care comes from a survey by Techniker Krankenkasse (TK), another large health insurer, conducted in the years from 2006 to 2010. We combine quality indicators with information on base-rate factors and further hospital characteristics included in the RWI hospital panel.

Our results indicate that changes in reimbursement prices do not affect quality of care. While the coefficient for one out of 17 quality indicators is significantly different from zero at the 5 percent level, the statistical significance disappears after adjusting the standard errors for multiple testing with a Bonferroni correction. We also show that our estimation coefficients are precisely estimated, and based on 95 percent confidence intervals of coefficients we can rule out effect sizes that are large relative to the overall variation in quality indicators across hospitals. Effect sizes also do not vary significantly by type of ownership, size of the hospital, or urban versus rural location after adjusting for multiple testing. Due to the lack of data availability we are not able to test whether the common trend assumption holds for periods before our study period. However, we show that our estimation results are essentially unchanged if we allow for time trends to vary with hospital characteristics such as ownership type, size of the hospital, and an urban vs. rural location. This suggests that our results cannot be attributed to different time trends in quality of care with respect to observed hospital characteristics, or to heterogeneous effects of the payment reform on different types of hospitals. Likewise, our estimation results are essentially unchanged if we exclude hospitals with a change in ownership type from our sample. We also find no evidence that the effect of price changes on quality of care is non-linear in prices. Furthermore, by examining changes in hospital quality over time we control for differences in the health of the local population between regions. We also control for changes in patient composition and case severity over time by using risk-adjusted outcome measures for mortality and surgical complications. Measures of process quality in our study are selected in such a way that they are not affected by case severity.

Our results are in line with results from previous studies that examine the effect of changes in regulated prices on quality of care. Cutler (1995), Shen (2003), and Wu and Shen (2014) also find no significant effect of price changes on mortality rates for heart attack patients, and Clemens and Gottlieb (2014) find no significant effect on overall mortality rates.[2] Yet, the results of our study are more general. We find no effect of price changes on quality of care not only for heart attack mortality rates, but also for a wide range of other quality indicators for patients with very different diagnoses and for multiple dimensions of quality.

In addition to the effect of price changes on quality of care, we also examine the effect of price changes on input factors for hospital care such as the quantity and quality of physicians and nurses. We find that a one percent increase in prices increases the number of nurses by 0.4 percent and the

[2] Cutler (1995) and Shen (2003) find an effect on the timing of mortality for heart attack patients, but no effect on 1-year mortality rates. Wu and Shen (2014) find no effect of price changes on mortality rates for heart attack patients in the short and medium run, but they do find that strong price reductions have a negative impact on heart attack survival rates in the long run. Clemens and Gottlieb (2014) find that price changes for outpatient care have no significant effect on all-cause mortality, hospitalizations, and the incidence of heart attacks.

number of physicians by 0.2 percent during our study period. Price changes do not affect the ratio of medical specialists to all physicians employed by the hospital.

Our study has important policy implications. First, we find that price changes do not lead to changes in quality of care. This finding suggests that pumping more money into the medical system by way of higher regulated reimbursement prices might not improve quality. Policymakers that aim to improve quality of care might consider other measures such as for example paying directly for quality improvements. Furthermore, our results suggest that an increase in hospital staff, especially in the number of nurses, does not lead to higher quality of care. The finding that hospitals can provide the same quality with fewer staff suggests that there might be room for improvements in efficiency. However, even if price changes do not affect quality of care in the short to medium run, quality of care could still be affected in the long run, for example if financially constrained hospitals slow down the adoption of new technologies (Acemoglu and Finkelstein 2008, Wu and Shen 2014).

Our study continues as follows. Section 2 presents the institutional setting, and Section 3 describes the data. The empirical approach is described in Section 4, and estimation results are presented in Section 5. Section 6 concludes.

2. Institutional setting

The most important source of hospital financing in Germany are public and private health insurers which together pay for around 88.5 percent of all hospital expenditures (Simon 2010).[3] These payments cover most of hospitals' operating costs including physicians' salaries (for details of hospital financing in Germany see Quentin et al. 2010 and Simon 2010).[4]

The variation in reimbursement prices examined in our study is based on a reform of hospital financing which took place between the years 2004 and 2010. A more detailed description of this reform can be found in Salm and Wübker (2015), a previous study in which we use the same policy reform in order to examine the effect of price changes on volume of care. Generally, before 2004, hospital payment for operating costs was based on the historical cost structure of hospitals (see description by Busse and Riesberg 2004). Hence, hospitals with higher costs received higher

[3] The remaining 11.5 percent come from private households (2.3 percent), employers (3.4 percent), public accident insurance (1.2 percent) and the federal states (4.6 percent). These numbers are for the year 2007.
[4] In Germany there are no separate payments for hospital services and physician services. Typically, physicians are salaried employees of the hospital.

payment. In 2004, the DRG reform replaced the existing historically based hospital budgets by a prospective payment system.[5]

The aim of this reform was to enhance quality, transparency, and efficiency in the hospital sector. DRG-type hospital payment systems have been introduced in many countries since the early 1980s. A special feature of the German reform is that payment changes were introduced gradually. In 2004, hospitals were reimbursed according to DRGs, but prices were adjusted with hospital-specific base-rates in such a way that hospitals could still achieve their historical budgets. From 2005 onwards, hospital-specific base-rates were gradually adjusted towards average base-rates at the state level.

In the German DRG system, payment for a hospital admission is based on the following formula:[6]

$$payment_{ijt} = drg_{jt} * baserate_{it} \tag{1}$$

Payment is the product of two factors: drg_{jt} is the cost-weight factor for DRG *j* in year *t*, while $baserate_{it}$ refers to a hospital-specific base-rate factor for hospital *i* in year *t*. All discharged hospital patients are assigned to a DRG. Generally, this assignment rests on diagnoses but in some cases it rests also on procedures and patient characteristics such as age, sex, and birthweight (for newborns). The DRG system in Germany was based on the Australian DRG system and initially consisted of 664 DRGs. DRG cost-weight factors are identical for all hospitals in Germany. They are set at the national level jointly by representatives of hospitals and health insurers. Yearly adjustment of costs-weight factors is based on comprehensive patient-level cost data from a sample of hospitals. The cost-weight factors are standardized such that the average cost-weight factor is set to one. They are higher for cost-intensive DRGs such as bypass surgery in case of a heart attack, and they are lower than one for less cost-intensive DRGs such as a simple arm fracture.

Payment according to the formula described above applied to almost all patients and types of hospital care, with psychiatric treatment as the main exception during our study period. Payment

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[5] Before 2004, hospitals were paid according to a mixed system. For most admissions payment was based on hospital-specific and hospital-department-specific daily rates which depended on the costs of hospitals and their negotiation skills.

[6] This formula abstracts from adjustment factors for teaching hospitals, and some other special rules.

based on DRGs applies only to inpatient admissions.[7] The same formula applies to publicly and privately insured patients. Patient co-payments are small, and they do not depend on reimbursement prices for hospitals. Patients have to pay a fixed Euro 10 fee per night as a contribution towards room and board, and there are surcharges for additional services such as a single room and treatment by the hospital director.

Hospital-specific base-rates reflect historical hospital costs before the introduction of DRG payment. In the years after 2004, hospital-specific base-rates gradually converged toward state averages. Base-rates gradually decreased for hospitals with relatively high historical costs, i.e. with above-average base-rate factors. In contrast, base-rates gradually increased for hospitals with relatively low historical costs, i.e. below-average base-rates. This convergence process is illustrated in Figure 1. At the end of our study period, hospitals in the same state received the same base-rate. The convergence process placed substantial pressure on high-cost hospitals to reduce costs. To protect hospitals from extreme budget cuts, yearly cutbacks in total hospital budgets were limited, for example to at most 2.5 percent in the year 2008.

The distribution of hospital-specific base-rates, the empirical version of Figure 1, is shown in Figure 2. Our empirical approach is based on changes in hospital specific base-rate factors in Germany between the years 2006-2010.[8] The variation in base-rates was substantial. In 2006, the difference between the 10th percentile of base-rates and the 90th percentile of base-rates was about 25 percent. The convergence in base-rates implied substantial increases in across-the-board reimbursement prices for some hospitals and substantial reductions in across-the-board reimbursement prices for other hospitals. Base-rates at the 10th percentile of base-rate factors increased by 10 percent in real terms between 2006 and 2010, while those at the 90th percentile decreased by 8 percent.

[7] One of the traditional features of the German healthcare system is a strict separation of inpatient care and outpatient care. With some exceptions, hospitals are not allowed to provide outpatient care. Outpatient care is reimbursed by a different payment system.

[8] We do not exploit the price variation between 2004 and 2006 as our hospital quality measures are not available for the period before 2006. Base-rates are equalized at the state level already in the year 2009. Our end date is the year 2010 instead of 2009 since BQS quality indicators were collected biannually and are available only for 2010 and not for 2009.

3. Data

We use data from various sources. Outcome variables in our study are measures of hospital quality. We look at multiple dimensions of quality of care which include information on patient mortality, surgical complications, process quality, and patient satisfaction.

Information on patient mortality for several types of patients, including heart attack patients and stroke patients, comes from claims-level data of a large nationally operating health insurer, representing about 10 percent of the German population, for the years 2006-2010. The claims data cover the full sample of German hospitals. We look at mortality within 30 days after admission to the hospital. The standardized period ensures a fair assessment of all hospitals and makes sure that the measurement is not affected by differences in transfer rates or variations in length of stay (Krumholz and Normand 2008, Borzecki et al. 2010). The administrative claims-level data include patient characteristics such as age, sex, and secondary diagnoses given by ICD-10 codes. This information is used to adjust for different mortality risks of patients between hospitals (Fonarow et al. 2012). Specifically, we control for the Charlson Comorbidity Index (CCI).[9] We look at 30-day mortality rates for heart attack patients, stroke patients, and the general inpatient population. We use the International Classification of Diseases (ICD) version 10 to identify patients with heart attacks (I21, I22) and strokes (I63, I64).

Information on further health outcomes such as surgical complications with a pacemaker implantation comes from the Federal Office for Quality in the Healthcare Sector (BQS) for the years 2006 and 2010. The BQS has developed an external quality assurance system for German hospitals which was implemented parallel to the introduction of the DRG system in Germany in order to detect and prevent negative side effects of the DRG system. In the year 2006, BQS collected information on 180 indicators in 26 modules for different areas of hospital care (e.g. pacemaker implantation, kidney transplantation). In this study, we focus on a small subset of BQS indicators that have been selected by the BQS for mandatory public disclosure.[10] Selection criteria

[9] With help of the comorbidities of the patient we build the Charlson Comorbidity Index (CCI).The CCI consists of 17 comorbidities which are coded as binary variables. Afterwards, they are weighted and summed up to an index. (Charlson et al. 1987)

[10] By law, almost all hospitals had to collaborate with the data collection, and the indicators were used by the BQS for an internal benchmarking process. Within the benchmarking process hospitals got internal, nonpublic quality feedback by the BQS. In our study we look at the subset of BQS-indicators that have been selected for mandatory public disclosure. The BQS selection process was inspired by the Consensus Development Process for quality indicators conducted by the National Quality Forum (NQF) in the US (McGlynn 2003, Reiter et al. 2011).

for public disclosure include the category's relevance (e.g. importance of the quality indicator), scientific soundness (e.g. validity, reliability, and risk adjustment) and feasibility (e.g. understandability, data availability) (Reiter et al. 2011). Table 1 presents a more detailed description of the quality indicators in our data.[11] Among these indicators are health outcome indicators such as surgical complication rates with pacemaker implantation (e.g. infections) or with carotid reconstruction (e.g. stroke or death) as well as indicators for process quality of hospitals such as guideline conformity for various procedures.

Information on patient satisfaction with hospital care comes from a survey conducted by TK in the years 2006 to 2010. TK is another nationally operating large health insurer covering about 10 million participants. The survey covers different dimension of patient satisfaction such as general satisfaction with the hospital stay, as well as satisfaction with the medical result, medical treatment and nursing care, information and communication, and organization and services (see TK 2015, TK 2016 for the complete questionnaire). The survey started in 2006 and initially included around 200 hospitals, i.e. 10 percent of all hospitals in Germany.[12] In 2008 and 2010, the survey was extended to cover all hospitals, in which at least 250 TK-insured patients were treated. As a result, about 650 hospitals were involved. The survey was conducted anonymously (TK 2016 and Mennicken and Pilny 2014). The response rate in 2010 was 61.2 percent. Table 1 includes a description of the patient satisfaction indicators used in this paper. Figures A1a to A1d show the distribution of changes for all quality indicators between 2006 and 2010 (between 2008 and 2010 for satisfaction indicators). Generally, for the BQS result indicators (Figure A1a), the 30-day mortality indicators (Figure A1b) and the TK satisfaction indicators (Figure A1d), the mean is close to zero and the distribution is approximately symmetric showing that between 2006 (2008) and 2010 quality improvements are as common as a deterioration of quality. However, for BQS process indicators, average quality improved between 2006 and 2010.

As additional outcome variables, we also look at input factors for quality of care. Our data on input factors is not as rich and detailed as our measures for quality of care, but we do have information on the number of medical staff. Specifically, we examine the effect of price changes on the number

[11] In our study we use all BQS indictors that have been selected for public disclosure and are available either in both the years 2006 and 2010 or both the years 2008 and 2010.
[12] As an exception, the question related to general satisfaction with the hospital was asked for all hospitals which admitted at least 250 TK-insured patients in 2006.

of physicians and nurses and the share of physicians who are medical specialists. This information is included in the RWI hospital panel (see Pilny 2014).

We combine quality indicators with information on base-rate factors provided by AOK, a group of health insurers, and with further hospital characteristics such as ownership type, or number of beds which are included in the RWI hospital panel. These data are merged with county-level regional indicators provided by the German Statistical Office. The main explanatory variable of interest is the percentage change in the base-rate factor (Basisfallwert) of a hospital between the years 2006 and 2010. Figure 3 shows the distribution of changes in base-rate factors between 2006 and 2010. Changes varied from substantial decreases to substantial increases in prices.

Table 2 shows descriptive statistics for all quality indicators, variables on quality inputs, and control variables. The sample sizes vary by quality indicator as not all hospitals perform all services or are included in the TK survey (see above). Moreover, we lose some hospitals as we do not have information on base-rates for each hospital (e.g. psychiatric hospitals are excluded from the DRG system and have no base-rate), and we cannot track all hospitals throughout the period from 2006 until 2010.[13] As described before, BQS process indicators improved considerably during our study period, while the other quality indicators did not change much between 2006 and 2010. The average number of physicians and nurses in hospitals, measured in full time equivalents, increased between 2006 and 2010. For the control variables the descriptive statistics refer to the sample for the outcome variable "Catheter dislocation in atrium". We chose this as the basis sample as most hospitals perform this treatment leading to a high sample size. During our study period the share of private hospitals increased from 11.7 to 14.4 percent, while the share of public hospitals decreased slightly from 48.3 to 46.0 percent. Regional indicators show a decline in the unemployment rate and an increasing average age of men and women between 2006 and 2010.

4. Empirical approach

Quality of hospital care has many determinants. On the one hand, quality depends on the quantity and quality of inputs such as physicians, nurses, and equipment and on the other hand on the quality production function which determines how efficiently these inputs are used. In our study, we

[13] E.g. for the general 30-day mortality rate, we lose i) 366 hospitals due to non-matching between different data sets, ii) 155 hospitals due to missing values for base-rates, and iii) 15 hospitals due to missing values for type of ownership.

examine how quality of hospital care is affected by changes in reimbursement prices. Higher reimbursement prices can allow hospitals to hire more and better qualified staff and to purchase more or better equipment. This can improve quality of care.

Our empirical approach follows the logic of a differences-in-differences estimation. However, instead of comparing changes in outcome variables between one treatment group and one control group, our main explanatory variable is a continuous variable, the change in reimbursement prices during the 2006-2010 period. We examine how quality indicators over this 4-year period change in response to changes in reimbursement prices. We apply linear regression models with hospital-specific fixed effects. Our baseline specification is shown below:

$$y_{it} = \Delta price_{i,2006-2010} I_{2010} \beta + I_{2010} \mu + X_{it}' \gamma + \alpha_i + \varepsilon_{it} \quad (2)$$

where y_{it} is an indicator for the quality of care for hospital $i \in (1...N)$ in year $t \in (2006, 2010)$.[14] $\Delta price_{i,2006-2010}$ is the change in the base-rate factor for hospital i between the years 2006 and 2010. I_{2010} is a binary indicator which takes the value one for the year 2010, and X_{it} includes regional demographic and economic characteristics. α_i captures time-invariant unobserved hospital characteristics, and ε_{it} is an error term. β, μ, and γ are parameters.

μ measures the time trend in quality between the years 2006 and 2010 if $\Delta price_{i,2006-2010}$ is zero. The hospital fixed effects α_i control for time-invariant differences in quality between hospitals. β is the main parameter of interest, and it measures the effect of changes in reimbursement prices on changes in quality of care.

Estimation coefficients for parameter β can be interpreted as causal effect if the strict exogeneity assumption below holds:

$$E(\varepsilon_{it} \mid \Delta price_{i,2006-2010}, I_{2010}, X_{it}) = 0 \quad (3)$$

Note that the equation above makes no assumptions about hospital-specific fixed effects α_i. Changes in prices $\Delta price_{i,2006-2010}$ can be correlated with time-invariant unobserved hospital characteristics α_i, as long as they are not also correlated with time-varying unobserved hospital

[14] For some quality indicators we include observations for the years 2008 and 2010 instead of 2006 and 2010.

characteristics ε_{it}. $\Delta price_{i,2006-2010}$ is related with historical costs, and it is possible that historical costs are correlated with quality of care. Further, $\Delta price_{i,2006-2010}$ is correlated with the average age in the region where the hospital is located.[15] However, this does not cause a bias in our estimation results as long as historical costs or regional characteristics are related only with the level of hospital quality and not also with changes in hospital quality during our study period.[16]

The assumption above is equivalent to a parallel trend assumption in a differences-in-differences estimation framework. In the absence of price changes underlying time trends in quality of care should be the same for hospitals with different values of $\Delta price_{i,2006-2010}$. A common test for the parallel trend assumption would be to examine how pre-trends in quality indicators in years before the start of the payment reform differed between hospitals with different values of $\Delta price_{i,2006-2010}$. Unfortunately, this approach is not feasible in our study since the quality indicators were not collected before 2006.[17] Instead, we can test whether estimation coefficients for β change if we control for possible time trends in quality with respect to observed hospital and regional characteristics. This test is based on the following linear regression equation:

$$y_{it} = \Delta price_{i,2006-2010} I_{2010} \beta + I_{2010} \mu + X_{it}' \gamma + I_{2010} X_{i2006}' \lambda + I_{2010} H_{i2006}' \kappa + \alpha_i + \varepsilon_{it} \qquad (4)$$

Where $t \in (2006, 2010)$, X_{i2006} are regional characteristics in the year 2006, and H_{i2006} are hospital characteristics in the year 2006. λ and κ are parameters.

Estimation of Equation (4) provides a test for two possible violations of the strict exogeneity assumption in Equation (3). A first possible violation of the strict exogeneity assumption could arise if underlying time trends in y_{it} are correlated with changes in prices $\Delta price_{i,2006-2010}$. For example, it is possible that time trends in hospital quality differ between large and small hospitals or between hospitals in regions with an old compared to a young population. In Equation (4) we control for time trends in quality with respect to observed hospital and regional characteristics such as for example the number of beds and the average age of men and women in the region where the

[15] This finding can be seen in Table A1 in the online Appendix in which we regress $\Delta price_{i,2006-2010}$ on hospital and regional characteristics in the year 2006.

[16] We later show in OLS estimation results that hospital quality is actually uncorrelated with $\Delta price_{i,2006-2010}$.

[17] TK satisfaction indicators for the sample of all hospitals are available only from the year 2008; BQS indicators were first collected in the year 2006; and the data to measure mortality reach back to the year 2005 only.

hospital is located. If the estimation coefficient for β in Equation (4) is essentially unchanged compared to the estimation coefficient for β in Equation (2) then we can conclude that our estimation results cannot be attributed to different underlying time trends in quality with respect to observed hospital and regional characteristics.

A second possible violation relates to the introduction of payment based on diagnosis related groups in Germany. In our study, we observe hospitals during a transition period shortly after the introduction of a new payment system, and it is possible that the reform of hospital payment had heterogeneous effects on different types of hospitals. If the estimation coefficient for β in Equation (4) is essentially unchanged compared to the estimation coefficient for β in Equation (2) then we can also conclude that our estimation results cannot be attributed to heterogeneous effects with respect to observed characteristics of the introduction of a new payment system.

A third possible violation of the strict exogeneity assumption relates to changes in ownership type. A change in ownership type could be linked to $\Delta price_{i,2006-2010}$, and a change in ownership can also affect quality of care. As a robustness check we exclude hospitals from our sample that were affected by a change in ownership type during the 2006-2010 period, and we examine whether this affects the estimation coefficient for β.

A fourth possible violation of the strict exogeneity assumption could be caused by non-linear effects of price changes on quality of care. For example, the effect of price increases and price decreases does not need to be symmetric. We can test for non-linear effects of price changes by comparing the changes in quality indicators over the 2006-2010 period for different ranges of $\Delta price_{i,2006-2010}$, and gauge whether these changes follow a linear pattern.

A further concern is that our results could be influenced by changes in patient composition or case severity. We address this concern by looking at quality variables that with the exception of variables for patient satisfaction are either risk adjusted or do not depend on case severity.

In our study, we examine the effect of price changes on multiple quality indicators. This can have consequences for statistical inference, and it requires adjustments to how statistical significance is assessed. Therefore, we use the Bonferroni method to compute p-values that account for multiple testing.

5. Results

Correlation between initial prices and quality indicators

Table 3 reports estimation results for the impact of base-rate factors on multiple dimensions of hospital quality. Column 1 presents OLS estimation results for the year 2006. The results show that there is no significant correlation between base rate factors and quality of care. None of the 17 coefficients for quality measures is significantly different from zero at the 5-percent level. Since base-rate factors in the year 2006 mostly reflect historical costs of a hospital these results suggest that hospitals with higher costs do not deliver higher quality of care on any of the dimensions included in our study. While OLS estimation results cannot be interpreted as causal effect of higher reimbursement prices on quality of care, it is remarkable that quality of care is essentially uncorrelated with the level of reimbursement, especially since the variation in reimbursement prices is substantial (as seen in Figure 3), and it applies to essentially all patients and types of care.

Baseline results

Column 2 presents estimation results for our baseline specification (Equation 2). Out of the 17 coefficients for quality measures only the coefficient for perioperative complications (such as death or stroke) due to carotid reconstruction is significant at the 5 percent level. A one percent increase in prices causes a decrease in perioperative complications due to carotid reconstruction by 0.0014 percentage points.

However, with multiple outcome variables, criteria to assess statistical significance need to be adjusted. With 17 independent outcome variables and a 5-percent significance level, the chance of observing at least one significant coefficient is 58 percent, even if all parameters are actually zero. To control for multiple testing, we apply a Bonferroni correction which modifies the critical p-value to α/N, where α stands for the significance level and N for the number of outcome variables. In our case, with N=17 outcome variables and a significance level of $\alpha = 0.05$, we only reject a null hypothesis that an estimation coefficient is zero if the conventional p-value is less than 0.0029. Thus, after applying a Bonferroni correction, all our baseline estimation coefficients in Column 2 of Table 3 are statistically insignificant at any conventional significance level.

In case of insignificant estimation results, the question arises whether the insignificant results are due to a small effect size or due to an imprecise estimation. In order to address this question we standardize all quality indicators. The standardized quality indicators all have a mean of zero and a standard deviation of one. Thus, it becomes possible to evaluate the size of estimation coefficients in relation to the overall variation of the quality measures in our sample. Figure 4 shows the standardized estimation coefficients of quality measures and their 95-percent confidence intervals. From Figure 4 it becomes obvious that a one percent increase in base-rate factors has i) a rather small impact on all quality indicators and ii) that the effect is quite precisely measured. For all quality measures a one percent increase in base-rate factors causes a change in quality that is smaller in absolute value than 0.02 standard deviations of the corresponding quality measure. Based on 95-percent confidence intervals we can for all quality measures exclude effect sizes that are larger in absolute value than 0.04 standard deviations. For a change in the overall level of reimbursement prices of 3.6 percent (a standard deviation of the price change in our study) we can thus rule out effect sizes of more than 0.14 standard deviation for perioperative complications due to carotid reconstruction, the variable with the largest effect size. Correspondingly, the upper bounds on effect sizes for the other quality measures are even smaller.

Robustness checks

Our estimation results are robust to alternative specifications. Column 3 of Table 3 shows estimation results for a fixed-effects model without covariates. The estimation results are very similar to the baseline specification in column 2. The specifications shown in columns 4 and 5 of Table 3 provide tests for possible violation of the exogeneity assumption which have been discussed in Section 4. Column 4 shows estimation results for a fixed-effects model that allows for time trends in quality with respect to observed hospital and regional characteristics as specified in Equation (4). Specifically, we control for heterogeneous time trends in quality with respect to hospital characteristics such as ownership type and the size of the hospital measured by the number of beds, and with respect to regional characteristics such as urban vs. rural location, average age of men and women in the region, and the local unemployment rate. Including such time trends leaves the estimation results essentially unchanged compared to the baseline specification. This finding suggests that our results cannot be attributed to different underlying time trends in quality for hospitals with different observed characteristics or to heterogeneous effects of the payment reform. Column 5 shows estimation results for a sample which excludes hospitals that change type of ownership during our study period.[18] Again, the results are very similar to the baseline specification. Thus, our results can also not be attributed to changes in ownership type.

Next, we examine whether the effect of price changes on quality of care is nonlinear in price changes. For example, it is possible that quality of care responds stronger to price increases than to price decreases, or vice versa. For this purpose, we divide our sample in 20 equal bins according to the change in price. For each bin we compute the average change in the quality measure. Figure 5 shows the relationship between price changes and changes in quality of care. If quality responds stronger to price increases than to price decreases then we would expect a convex pattern in Figure 5. If quality responds stronger to price decreases than to price increases then we would expect a concave pattern. Figure 5 shows that the relationship between price changes and changes in quality of care closely follows a linear pattern for heart attack mortality. Corresponding figures for other quality measures also follow a linear pattern.[19] Thus, we find no evidence for asymmetric effects of price increases and price decreases.

Heterogeneous effects

Furthermore, we look at heterogeneous effects, and we examine the effect of price changes on quality of care separately for hospitals with different observed characteristics. In Table 4 we show estimation results separately by type of ownership (public, not-for-profit, and private), urban vs. rural location, and hospital size (number of beds above and below average). Higher reimbursement prices have a significant effect at the conventional 5-percent level on fewer perioperative complications due to carotid reconstruction and higher guideline conformity with respect to the safety margin in case of mastectomy for public hospitals. Higher prices have also a significant effect on fewer surgical complications with pacemaker implementations for not-for-profit hospitals, lower overall mortality for rural hospitals, and more guideline conformity with respect to hormone receptor analysis in case of breast surgery for hospitals with a small number of beds. However, after adjusting for multiple testing with a Bonferroni correction, none of the estimation coefficients is significantly different from zero. Thus, we don’t find evidence for a significant effect of reimbursement prices on quality of care for any subgroup of hospitals.

[18] The number of excluded hospitals varies by sample. With regard to the sample for the outcome variable “Catheter dislocation in atrium” these are 180 hospitals.
[19] Patterns for other quality indicators are shown in Figures A2a, A2b, A2c in the Online Appendix.

Mechanisms

There are two possible explanations for our findings: either hospitals can provide the same quality of care with fewer inputs, or the changes in prices do not (immediately) translate into a change in inputs. In the following, we examine which of these two explanations is most relevant in our setting. For this purpose, we look at the effect of price changes on the number and quality of physicians and nurses. The number and quality of medical staff is arguably the most important determinant of quality of hospital care, and salaries of physicians and nurses also account for a large share of hospital budgets.

Table 5 shows that a one percent increase in prices increases the number of nurses by around 0.4 percent and the number of physicians by around 0.2 percent over our study period. Thus, price changes have an impact on staffing levels, especially for nurses. Yet, staffing levels increase less than proportionally with prices. Therefore, price changes are not completely absorbed by changes in staffing levels, and there is also room for other mechanisms. For example, price changes can also be absorbed by changes in investments, salaries, or profits, or the effects of price changes on hospital budgets can be partially offset by changes in volume of care (Salm and Wübker 2015).

The results in Table 5 together with our results on quality of care suggest that hospitals can provide the same quality of care with fewer staff. Remarkably, increases in the number of nurses do also not coincide with higher satisfaction with nursing care and medical results in the TK survey. Our findings fit well with results by Augurzky et al. (2017) showing that nursing staffing levels in German hospitals are not related with quality of care. However, there are also studies who do find a relationship between quality of hospital care and staffing levels (Griffith et al. 2014).

In addition to the effect of price changes on the quantity of staff, we also look at the effect on quality of staff. As a rough measure for the quality of physicians we look at the share of medical specialists among all physicians. We do not find a significant effect of price changes on the share of medical specialists among physicians. One possible explanation for this finding is that hospitals cannot easily substitute more senior physicians by junior physicians who have not yet completed their specialization.

6. Conclusions

In this study, we examine the effect of changes in regulated reimbursement prices on quality of hospital care in Germany. Our empirical approach is based on a reform of hospital financing which increased regulated prices for some hospitals and decreased regulated prices for other hospitals. This setting allows us to apply a differences-in-differences estimation with the change in price as continuous treatment variable. Our estimation results suggest that reimbursement prices have no significant effects on quality of care. Our estimation coefficients are precisely estimated, and based on 95-percent confidence intervals, we can rule out effect sizes that are large relative to the overall variation in the quality indicators in our data.

A main contribution of this study is that we take into account multiple dimensions of quality of care. We collected quality indicators from multiple sources. Our quality indicators cover the most commonly discussed dimensions of quality of care, including health outcomes, process quality, and patient satisfaction. Furthermore, we look at variation in regulated prices that affected essentially all patients and types of care.

We can exclude alternative explanations for our results. Our results cannot be explained by different time trends in quality of care according to observed hospital characteristics such as ownership type, size of the hospital, or whether the hospital is located in an urban or rural area. Our results can also not be explained by changes in ownership type or by changes in patient composition. Our variables for all health outcomes, including mortality and surgical complications, have been adjusted for case mix. In additional analysis, we find that a one percent increase in prices increases the number of physicians by around 0.2 percent and the number of nurses by around 0.4 percent during our study period.

Our findings relate directly to the current debate on health policy in Germany. One of the plans of the new government in their proposed coalition agreement is to take financing for nursing staff in hospitals out of the DRG system, and instead pay hospitals directly for nursing staff based on actual costs. This measure is combined with minimum requirements for the number of nursing staff in hospitals. The aim of these combined measures is to increase the number of nursing staff. Yet, in light of our results it is doubtful whether an increase in nursing staff will improve quality of care.

While we show that price changes do not affect quality of care over a 4-year period, we cannot rule out effects over longer time horizons, for example if lower reimbursement prices delay the adaption of new technologies. Whether or not there is a long-run effect of changes in reimbursement prices on quality of care is an interesting topic for future research.

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Table 1: Indicators of Quality

Quality Indicator	Description
Results indicators (BQS)	
Catheter dislocation in atrium	Percentage share of patients admitted for pacemaker implementation to a hospital in a year with catheter dislocation in atrium. Dislocation of pacemakers is a complication that is related to technical problems of pacemaker implementation.
Carotid reconstruction perioperative stroke or death	Percentage share of patients admitted for carotid reconstruction to a hospital in a year with perioperative stroke or death. Carotid reconstruction is an intervention to widen narrowed arteries in order to enhance the blood flow in the body and to avoid severe health shocks like strokes.
Surgical Complication with pacemaker implantation	Percentage share of patients admitted for pacemaker implantation to a hospital in a year with perioperative surgical complication. The range of potential complications ranges from infections to death.
Results indicators (Mortality 30 days)	
General hospital mortality rate	Percentage share of patients who die within 30 days of being admitted to a hospital in a year.
Mortality rate stroke	Percentage share of patients with principal diagnosis of stroke who die within 30 days of being admitted to a hospital in a year. Ischemic stroke diagnostic codes: ICD-10: I63-I64.
Mortality rate AMI	Percentage share of patients with principal diagnosis of acute myocardial infarction (AMI) who die within 30 days of being admitted to a hospital in a year. AMI diagnostic codes: ICD-10: I21, I22
Procedure indicators	
Antibiotic prophylaxis in case of hysterectomy	Percentage share of women admitted for hysterectomy to a hospital in a year who get antibiotic prophylaxis. A hysterectomy is a surgical intervention to remove a woman's uterus. Antibiotic prophylaxis is important to avoid severe surgery complications like infections.
Indication of safety margin in case of mastectomy	Percentage share of women admitted for mastectomy to a hospital in a year with an indication of safety margin. A mastectomy is the medical term for the surgical removal of one or both breasts, completely or partially. It is often executed to treat breast cancer. Adequate surgical margins in breast-conserving surgery are an important predictor of local recurrence cancer rates.
Thrombosis prophylaxis in case of hysterectomy	Percentage share of women admitted for hysterectomy to a hospital in a year with thrombosis prophylaxis. A hysterectomy is a surgical intervention to remove a woman's uterus. Thrombosis is a potentially severe complication obstructing the blood flow through the circulatory system.
Hormone receptor analysis (breast surgery)	Percentage share of patients admitted for breast surgery to a hospital in a year with hormone receptor analysis. Knowing the hormone receptor status of a breast cancer is an important information that can guide treatment decisions.
Guideline conform indication for bradycardic dysrhythmias	Percentage share of patients admitted for pacemaker implementation to a hospital in a year that got a guideline conform indication for bradycardic dysrhythmias. A heartbeat that is too slow is called bradycardia. It will not pump blood through the body efficiently leading to symptoms like fatigue or dizziness. Pacemakers can speed up the heart rhythm.

Indication of asymptomatic carotid stenosis	Percentage share of operated patients with asymptomatic carotid stenosis with indication for operation (i.e. degree of stenosis > 60 %) being admitted to a hospital in a specified year. Carotid stenosis restricts the optimal blood flow due to narrowed vessels or arteries. Patients with asymptomatic carotid stenosis are at high risk of myocardial infarction and at moderate risk of stroke. There is a tradeoff between the risk of surgery and the risk of no surgery in case of carotid stenosis and patients should be operated if the degree of stenosis is > 60 %.
Satisfaction indicators	
Satisfaction with medical results	Satisfaction with medical results on a scale from 0 to 100 for patients admitted to a hospital in a year. The indicator is based on 3 equally weighted questions on satisfaction with medical results, e.g. "How satisfied have you been with medical results of the hospital" with the response options: 1) very satisfied, 2) somewhat satisfied, 3) somewhat unsatisfied, 4) very unsatisfied (compare TK 2015).
Satisfaction with medical treatment and nursing care	Satisfaction with medical treatment and nursing care on a scale from 0 to 100 for patients admitted to a hospital in a year. The indicator is based on 5 equally weighted statements on satisfaction with medical treatment and nursing care, e.g. "I am completely convinced by the medical performance of the doctors." with the response options: 1) totally agree, 2) somewhat agree, 3) somewhat disagree, 4) completely disagree, 5) cannot assess (compare TK 2015).
Satisfaction with information and communication	Satisfaction with information and communication on a scale from 0 to 100 for patients admitted to a hospital in a year. The indicator is based on 8 equally weighted statements on satisfaction with information and communications, e.g. "I have been informed very well about the surgery" with the response options: 1) totally agree, 2) somewhat agree, 3) somewhat disagree, 4) completely disagree, 5) cannot assess (compare TK 2015).
Satisfaction with organization and services	Satisfaction with information and communication on a scale from 0 to 100 for patients admitted to a hospital in a year. The indicator is based on 7 equally weighted questions on satisfaction with organization and services, e.g. "How satisfied are you with following issues? … housekeeping … meals … entertainment program" with the response options: 1) very satisfied, 2) somewhat satisfied, 3) somewhat unsatisfied, 4) very unsatisfied (compare TK 2015).
General satisfaction	General satisfaction on a scale from 0 to 100 for patients admitted to a hospital in a year. The indicator is based on 5 equally weighted questions on general satisfaction, e.g. "If you consider all aspects of your hospital stay (e.g. assistance, information, organization, accommodation) how satisfied are you with the hospital in general?" with the response options: 1) very satisfied, 2) somewhat satisfied, 3) somewhat unsatisfied, 4) very unsatisfied (compare TK 2015).

Table 2: Descriptive statistics

	Year 2006		Year 2010	
	Mean	Standard dev.	Mean	Standard dev.
Result indicators (BQS)				
Catheter dislocation in atrium (N = 741)	0.002	0.004	0.002	0.003
Carotid reconstruction perioperative stroke or death (N = 334)	0.031	0.090	0.025	0.053
Surgical Complication with pacemaker implantation (N = 735)	0.013	0.027	0.011	0.020
Result indicators (Mortality 30 days)				
General hospital mortality rate (N=1228)	0.036	0.026	0.035	0.029
Mortality rate stroke (N = 819)	0.135	0.162	0.143	0.177
Mortality rate ami (N = 784)	0.181	0.210	0.156	0.183
Procedure indicators				
Antibiotic prophylaxis in case of hysterectomy (N = 668)	0.893	0.192	0.968	0.081
Indication of safety margin in case of mastectomy (N = 572)	0.824	0.234	0.928	0.179
Thrombosis prophylaxis in case of hystectomy[2] (N = 741)	0.979	0.098	0.991	0.028
Hormone receptor analysis (breast surgery) (N = 650)	0.947	0.141	0.978	0.113
Guideline conformity for bradycardic dysrhythmias (N = 669)	0.875	0.154	0.965	0.046
Indication of asymptomatic carotid stenosis (N = 343)	0.890	0.184	0.949	0.083
Satisfaction indicators				
Satisfaction with medical result[1] (N = 481)	0.781	0.030	0.779	0.030
Satisfaction with medical treatment and nursing care[1] (N = 481)	0.765	0.038	0.769	0.038
Satisfaction with information and communication[1] (N = 481)	0.781	0.036	0.774	0.036
Satisfaction with organization and services[1] (N = 481)	0.725	0.047	0.730	0.045
General satisfaction (N = 477)	0.793	0.051	0.799	0.051
Quantity of hospital inputs				
# Physicians (N = 1129)	77.621	117.552	86.880	130.621
# Nurses (N = 1190)	207.801	248.330	218.980	256.570
Quality of hospital inputs				
Ratio specialists/physicians (N = 1234)	0.561	0.135	0.561	0.119
Control variables				
Public hospitals (N = 741)	0.483	0.500	0.460	0.498
Not-for-profit hospitals (N = 741)	0.399	0.490	0.395	0.489
Private hospitals (N = 741)	0.117	0.322	0.144	0.352
Unemployment rate (N = 741)	10.974	4.454	7.885	3.256
Average age men (N = 741)	40.815	1.201	41.960	1.385
Average age women (N = 741)	43.768	1.650	44.659	1.792
Rural (N = 741)	0.192	0.254	0.192	0.245
Number of beds (N = 741)	413.965	338.80	419.299	361.938

Notes: Descriptive statistics refer to sample in baseline specification (Table 3, column 2). [1] Indicators are available for the years 2008 and 2010 [2] Indicator is available for the years 2006 and 2008. For the control variables the descriptive statistics refer to the sample in the baseline specification for the outcome variable "Catheter dislocation in atrium" (row 2).

Table 3: Effects of price changes on quality indicators

	Treatment variable: Δprice (2006-2010)				
	OLS[4] (1)	FE (2)	FE Without covariates (3)	FE With add. Trends (4)	FE No change of owner type (5)
Results indicators (BQS)					
Catheter dislocation in atrium (N = 741)	-0.003	0.001	0.001	0.001	0.003
	(0.002)	(0.003)	(0.002)	(0.003)	(0.003)
Carotid reconstruction perioperative stroke or death (N = 334)	0.104*	-0.140**	-0.153**	-0.158*	-0.160*
	(0.059)	(0.069)	(0.067)	(0.081)	(0.083)
Surgical Complication with pacemaker implantation (N = 735)	0.015	-0.029	-0.027	-0.028	-0.038*
	(0.014)	(0.017)	(0.016)	(0.019)	(0.021)
Results indicators (Mortality 30 days)					
General hospital mortality rate³ (N=1228)	-0.012	0.001	0.011	0.0003	0.002
	(0.014)	(0.004)	(0.008)	(0.004)	(0.004)
Mortality rate stroke³ (N = 819)	0.034	0.016	-0.005	0.012	0.044
	(0.054)	(0.068)	(0.073)	(0.067)	(0.073)
Mortality rate ami³ (N = 784)	-0.195*	-0.039	-0.102	-0.083	0.061
	(0.111)	(0.123)	(0.138)	(0.130)	(0.152)
Procedure indicators					
Antibiotic prophylaxis in case of hysterectomy (N = 668)	-0.256	0.139	0.174	0.129	0.185
	(0.213)	(0.121)	(0.122)	(0.125)	(0.135)
Indication of safety margin in case of mastectomy (N = 572)	0.036	0.281	0.235	0.304	0.374
	(0.082)	(0.184)	(0.180)	(0.183)	(0.212)
Thrombosis prophylaxis in case of hysterectomy² (N = 741)	-0.006	.0167	0.012	0.009	-0.018
	(0.140)	(.059)	(0.059)	(0.061)	(0.032)
Hormone receptor analysis (breast surgery) (N = 650)	-0.000	0.221*	0.195	0.208	0.303
	(0.145)	(0.130)	(0.125)	(0.136)	(0.151)
Guideline conformity for bradycardic dysrhythmias (N = 669)	-0.099	0.148	0.137	0.158	0.052
	(0.091)	(0.104)	(0.101)	(0.103)	(0.112)
Indication of asymptomatic carotid stenosis (N = 438)	0.0173	-0.090	-0.070	-0.139	-0.038
	(0.175)	(0.160)	(0.155)	(0.178)	(0.167)
Satisfaction indicators					
Satisfaction with medical result¹ (N = 481)	0.026	0.004	0.004	0.003	0.005
	(0.026)	(0.040)	(0.039)	(0.043)	(0.020)
Satisfaction with medical treatment and nursing care¹ (N = 481)	0.038	0.029	0.019	0.031	-0.011
	(0.030)	(0.036)	(0.034)	(0.037)	(0.018)
Satisfaction with information and communication¹ (N = 481)	0.038	0.024	0.017	0.010	-0.005
	(0.026)	(0.032)	(0.031)	(0.033)	(0.016)
Satisfaction with organization and services¹ (N = 481)	0.034	0.050	0.058*	0.035	0.010
	(0.039)	(0.036)	(0.035)	(0.039)	(0.018)
General satisfaction (N = 477)	0.049	-0.013	-0.183	-0.019	-0.012
	(0.038)	(0.017)	(0.018)	(0.019)	(0.019)
Control variables	Yes	Yes	No	Yes	Yes

Notes: Estimations in column (2) are based on Equation (1). Parentheses show robust standard errors, clustered at hospital level. Control variables on county level include unemployment rate, average age of men, average age of women, and a binary indicator whether it is rural area. Control variables on hospital level include binary indicators for different ownership types (public, private and non-for profit, and the number of hospital beds. [1] Estimation for the years 2008 and 2010. ² Estimation for the years 2006 and 2008. ³ These models are based on individual level sickness fund data and include the following individual level control variables: age dummies (below 30 years, 5 year age bins for age >30 and age < 90 and above 90 years), gender, dummies for Charlson comorbidities and the Charlson Comorbidity Index (CCI) (Charlson et al., 1987). The CCI consists of 17 comorbidities which are coded as binary variables. Afterwards, they are weighted and summed up to an index. In the AMI-mortality-model, a dummy for ST-elevated myocardial infarction is included (STEMI, diagnosis codes I21.0–I21.2). In the general-mortality-model dummies for 2-digit-ICD 10 codes are included.[4] The OLS-specification refers to the year 2006. * significant at 10%; ** significant at 5%; *** significant at 1%

Table 4: Heterogeneous effects of price changes on quality indicators

	Δprice (2006-2010)* Hospital ownership			Δprice (2006-2010)* Rural		Δprice (2006-2010)* Hospital size	
	Public	Non-Profit	Profit	Rural	Urban	Many beds	Few beds
Results indicators (BQS)							
Catheter dislocation in atrium (N = 741)	-0.002 (0.004)	0.005 (0.005)	-0.002 (0.003)	0.003 (0.002)	-0.001(0.005)	-0.000 (0.003)	0.002 (0.004)
Carotid reconstruction perioperative stroke or death (N = 334)	-0.323** (0.152)	-0.023 (0.118)	0.015 (0.048)	-0.071 (0.093)	-0.220 (0.109)	-0.150 (0.080)	-0.103 (0.131)
Surgical Complication with pacemaker implantation (N = 735)	0.007 (0.022)	-0.049 (0.030)	-0.070 (0.049)	-0.028 (0.024)	-0.030 (0.025)	-0.042 (0.019)	-0.002 (0.038)
Result indicators (Mortality 30 days)							
General hospital mortality rate³ (N = 1178)	-0.002 (0.007)	-0.003 (0.006)	0.0004 (0.005)	-0012**(0.005)	0.008 (0.005)	-0.002 (0.005)	-0.001 (0.005)
Mortality rate stroke³ (N = 812)	-0.004 (0.108)	-0.064 (0.106)	0.023 (0.105)	-0.178 (0.117)	0.067 (0.072)	-0.105 (0.095)	0.057 (0.084)
Mortality rate ami³ (N = 782)	0.022 (0.161)	-0.057 (0.135)	0.249 (0.271)	0.069 (0.126)	0.009 (0.166)	0.016 (0.129)	0.076 (0.196)
Procedure indicators							
Antibiotic prophylaxis in case of hysterectomy (N = 668)	0.276 (0.220)	0.049 (0.162)	-0.052 (0.164)	0.019 (0.133)	0.273 (0.211)	0.126 (0.151)	0.162 (0.219)
Indication of safety margin in case of mastectomy (N = 572)	0.519** (0.247)	0.047 (0.259)	0.293 (0.542)	0.192 (0.234)	0.419 (0.276)	0.191 (0.204)	0.518 (0.416)
Thrombosis prophylaxis in case of hysterectomy² (N = 741)	-0.058 (0.050)	0.106 (0.138)	-0.028 (0.066)	-0.050 (0.045)	0.084 (0.110)	0.049 (0.094)	-0.029 (0.043)
Hormone receptor analysis (breast surgery) (N = 650)	0.211 (0.206)	0.145 (0.162)	0.425 (0.305)	0.176 (0.139)	0.276 (0.217)	0.068 (0.139)	0.592 (0.264)
Guideline conformity for bradycardic dysrhythmias (N = 669)	0.249* (0.134)	0.305* (0.172)	-0.380 (0.252)	0.013 (0.090)	0.287 (0.180)	0.169 (0.120)	0.102 (0.185)
Indication of asymptomatic carotid stenosis (N = 438)	-0.009 (0.231)	-0.206 (0.288)	-0.130 (0.362)	-0.264 (0.199)	0.141(0.256)	-0.139 (0.186)	0.114 (0.247)
Satisfaction indicators							
Satisfaction with medical result¹ (N = 481)	0.026 (0.055)	-0.003 (0.039)	-0.083 (0.074)	0.015 (0.043)	-0.033 (0.050)	-0.013 (0.017)	-0.016 (0.057)
Satisfaction with medical treatment and nursing care¹ (N = 481)	0.049 (0.045)	02.018 (0.036)	0.023 (0.082)	0.039 (0.037)	-0.005 (0.046)	-0.004 (0.036)	0.048 (0.123)
Satisfaction with information and communication¹ (N = 481)	0.025 (0.041)	0.025 (0.034)	-0.005 (0.075)	0.033 (0.034)	-0.008 (0.046)	0.028 (0.035)	0.036 (0.086)
Satisfaction with organization and services¹ (N = 481)	0.042 (0.045)	0.055 (0.037)	0.034 (0.084)	0.056 (0.038)	0.029 (0.049)	0.015 (0.034)	0.074 (0.058)
General satisfaction (N = 477)	-0.037 (0.030)	0.001 (0.024)	-0.002 (0.048)	0.000 (0.019)	-0.064*(0.035)	0.045 (0.036)	0.075 (0.085)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes

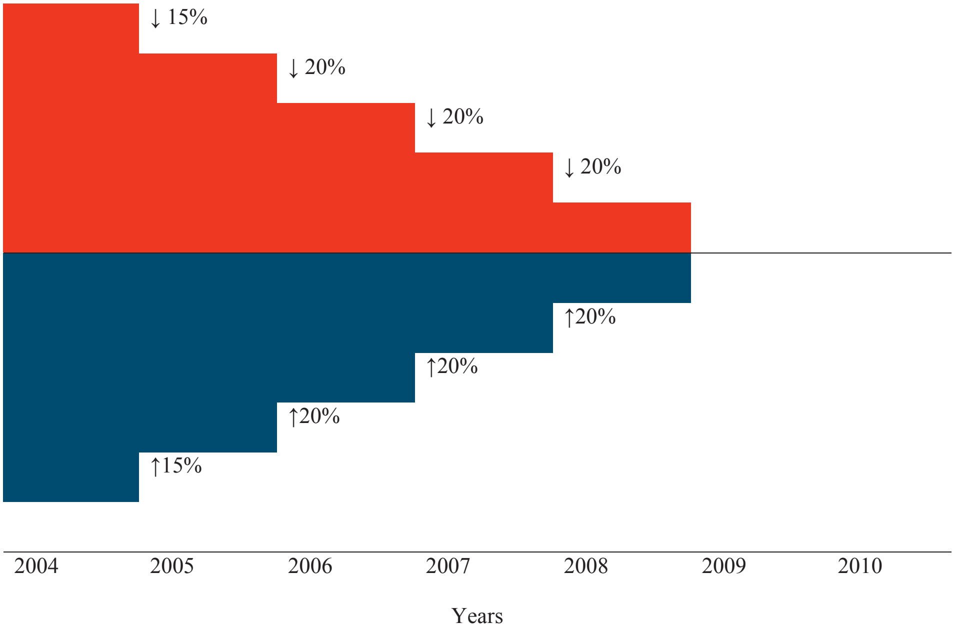
Notes: Estimations are based on Equation (1), extended by interaction term for Δprice (2006-2010) and hospital ownership (columns 1-3), market concentration (columns 4-5) and hospital size (columns 6-7). The sample includes observations for the years 2006 and 2010. Δ price (2006-2010) is defined as log(price 2010) – log(price 2006). Control variables on county level include unemployment rate, average age of men, average age of women, and a binary indicator whether it is rural area. Control variables on hospital level include binary indicators for different ownership types (public, private and non-for profit, and the number of hospital beds. ¹ Estimation for the years 2008 and 2010. ² Estimation for the years 2006 and 2008. ³ These models are based on individual level sickness fund data and include following individual level control variables: age dummies (below 30 years, 5 year age bins for age >30 and age < 90 and above 90 years), gender, dummies for Charlson comorbidities and the Charlson Comorbidity Index (CCI) (Charlson et al., 1987). The CCI consists of 17 comorbidities which are coded as binary variables. Afterwards, they are weighted and summed up to an index. In the AMI-model, a dummy for ST-elevated myocardial infarction is included (STEMI, diagnosis codes I21.0–I21.2). In the general-mortality-model dummies for 2-digit-ICD 10 codes are included. Regional indicators include average age of men, average age of women, and unemployment rate. Parentheses show robust standard errors. * significant at 10%; ** significant at 5%; *** significant at 1%

Table 5: Effects of price changes on quantity and quality of hospital staff

	Treatment variable: Δprice (2006-2010)				
	OLS[1]	FE	FE Without covariates	FE With add. Trends	FE No change of owner type
	(1)	(2)	(3)	(4)	(5)
Quantity of hospital inputs					
# Physicians	0.073	0.206***	0.206***	0.231***	0.224***
	(0.230)	(0.074)	(0.077)	(0.075)	(0.080)
# Nurses	-0.380	0.420***	0.445***	0.431***	0.338***
	(0.262)	(0.119)	(0.120)	(0.123)	(0.122)
Quality of hospital Inputs					
Ratio specialists/physicians	-0.029	-0.061	-0.071	-0.058	-0.052
	(0.045)	(0.057)	(0.057)	(0.059)	(0.064)
Control variables	Yes	Yes	No	Yes	Yes

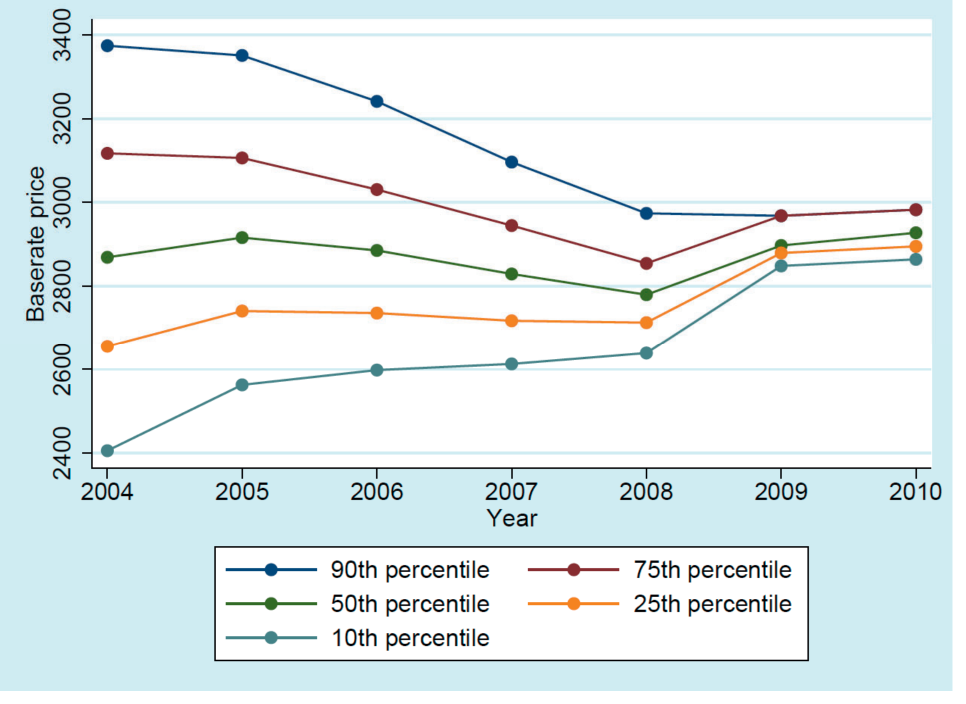
Notes: Estimations in column (2) are based on Equation (1). Parentheses show robust standard errors, clustered at hospital level. Control variables on county level include unemployment rate, average age of men, average age of women, and a binary indicator whether it is rural area. Control variables on hospital level include binary indicators for different ownership types (public, private and non-for profit, and the number of hospital beds. [1] The OLS-specification refers to the year 2006. * significant at 10%; ** significant at 5%; *** significant at 1%

Figure 1: Convergence of base-rate factors



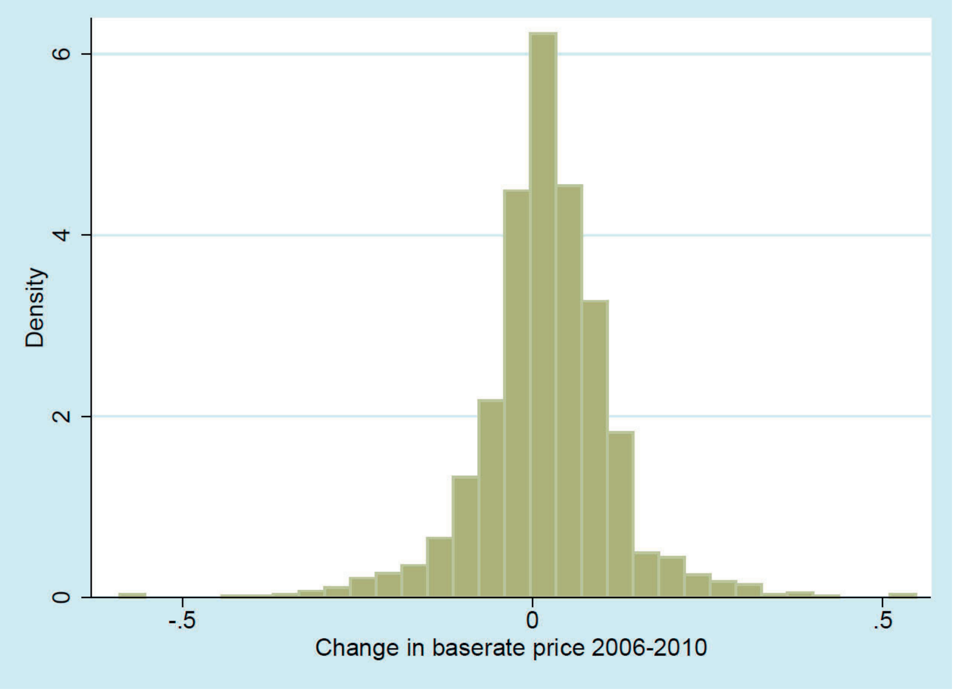
Note: This figure shows the reduction of initial differences in base-rate factors between the years 2004 and 2010.

Figure 2: Convergence of base-rate factors (empirical evidence)



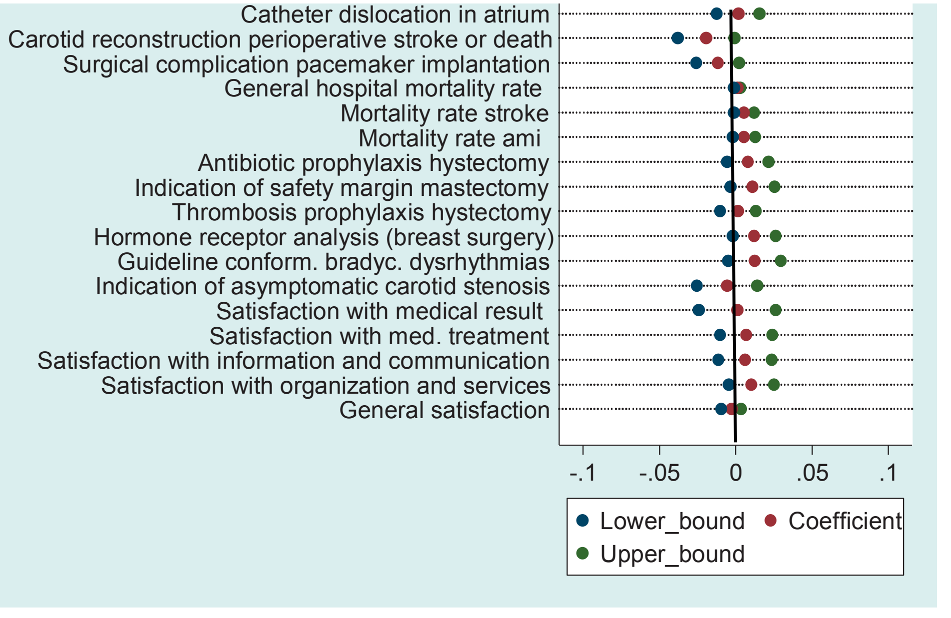
Notes: This figure shows the empirical distribution of hospital-specific base-rate factors for quantiles of prices and the reduction of initial differences in base-rate factors between 2004 and 2010.

Figure 3: Distribution of price changes between 2006 and 2010



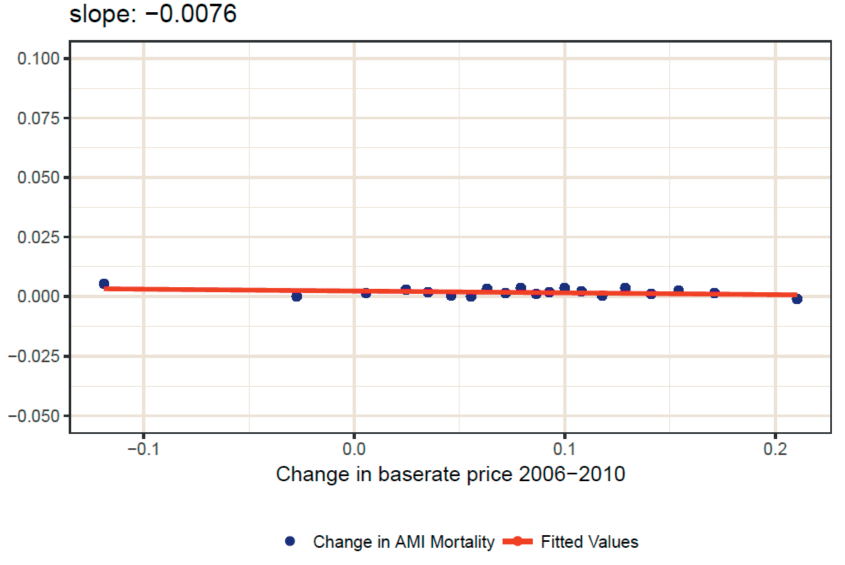
Notes: This figure shows the distribution of Δ price (2006-2010). Δ price (2006-2010) is defined as log(price 2010) – log(price 2006).

Figure 4: Effects of price changes on quality indicators – Quantitative importance



Notes: This Figure shows estimation results based on Equation (1). The outcome variables have been rescaled to have a mean of zero and a standard deviation of one. Each row shows an estimation coefficient and 95 percent confidence interval for a different outcome variable. Sample sizes and control variables are identical to those in Table 2, column 2.

Figure 5: Non-linear effects of price changes on AMI mortality



Notes: We group the sample of hospitals into 20 bins of equal size ("ventiles") according to their total change in base-rate factors over 2006-2010. The x-axis displays the mean of price changes for hospitals in each ventile. The y-axis shows, for each ventile, the average difference in the log of AMI mortality rates between 2006 and 2010. We estimate a trend line from OLS regression using the 20 data points shown in the graph.

Online Appendix

Table A1: Determinants of price changes

	Price change 2006-2010	
	Coefficient	Standard error
Large number of beds in 2006[1]	-0.005	0.006
Public ownership in 2006	0.003	0.010
Not-for-profit ownership in 2006	0.018	0.010
Unemployment rate in 2006	-0.000	0.001
Average age men in 2006	-0.017**	0.008
Average age women in 2006	0.010	0.007
Rural in 2006	0.018	0.011
N (hospitals)	1529	

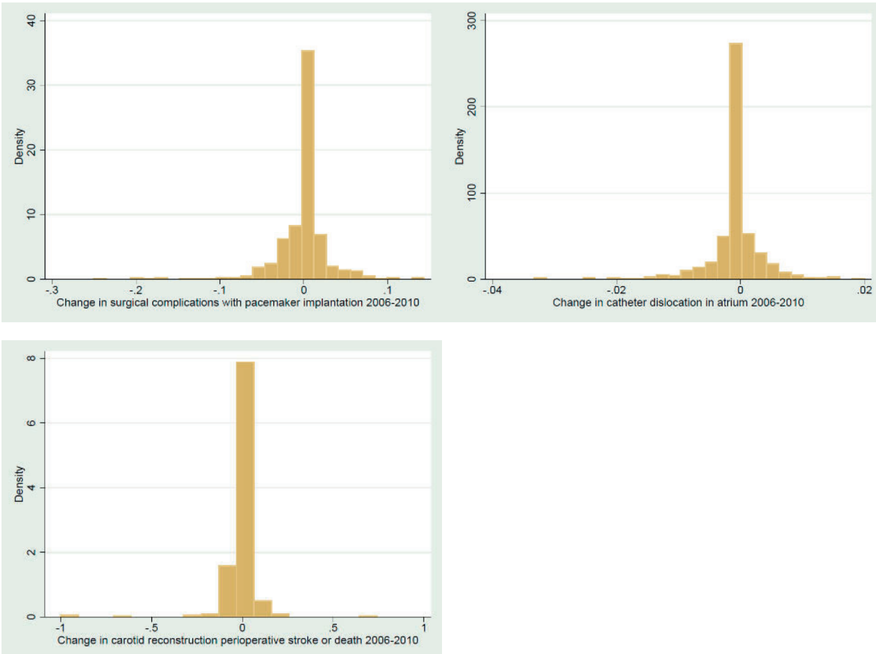
Notes: 1) Large number of beds in 2006 is defined as 1, if the number of beds in 2006 is larger than the median of 176 beds, else 0. The table shows OLS estimation coefficients. Parentheses show robust standard errors. * significant at 10%; ** significant at 5%; *** significant at 1%

Table A2: Effects of price changes on quality indicators – Quantitative importance

	Treatment variable: Δprice (2006-2010)			
	FE Stand. outcome (1)	FE CI Lower Bound (2)	FE CI Upper Bound (3)	FE Standard error (4)
Results indicators (BQS)				
Catheter dislocation in atrium (N = 741)	0.170	-1.221	1.562	0.709
Carotid reconstruction perioperative stroke or death (N = 334)	-1.932**	-3.805	-0.058	0.954
Surgical Complication with pacemaker implantation (N = 735)	-1.169	-2.569	0.230	0.713
Results indicators (Mortality 30 days)				
General hospital mortality rate (N = 1228)[3]	0.233	-0.649	1.115	0.450
Mortality rate stroke (N = 819)[3]	0.616	-0.689	1.921	0.666
Mortality rate AMI (N = 784)[3]	-0.358	-1.708	0.99	0.689
Procedure indicators				
Antibiotic prophylaxis in case of hysterectomy (N = 668)	0.802	-0.569	2.174	0.699
Indication of safety margin in case of mastectomy (N = 572)	1.124	-0.320	2.568	0.736
Thrombosis prophylaxis in case of hysterectomy² (N = 741)	0.166	-0.996	1.322	0.593
Hormone receptor analysis (breast surgery) (N = 650)	1.225	-0.195	2.644	0.723
Guideline conformity for bradycardic dysrhythmias (N = 669)	1.250	-0.474	2.974	0.879
Indication of asymptomatic carotid stenosis (N = 438)	-0.565	-2.536	1.407	1.004
Satisfaction indicators				
Satisfaction with medical result[1] (N = 481)	0.114	-2.424	2.652	1.293
Satisfaction with medical treatment and nursing care[1] (N = 481)	0.710	-1.012	2.433	0.878
Satisfaction with information and communication[1] (N = 481)	0.645	-1.103	2.392	0.890
Satisfaction with organization and services[1] (N = 481)	1.028	-0.463	2.519	0.760
General satisfaction (N = 477)	-0.266	-0.917	0.385	0.331
Control variables	Yes	Yes	No	Yes

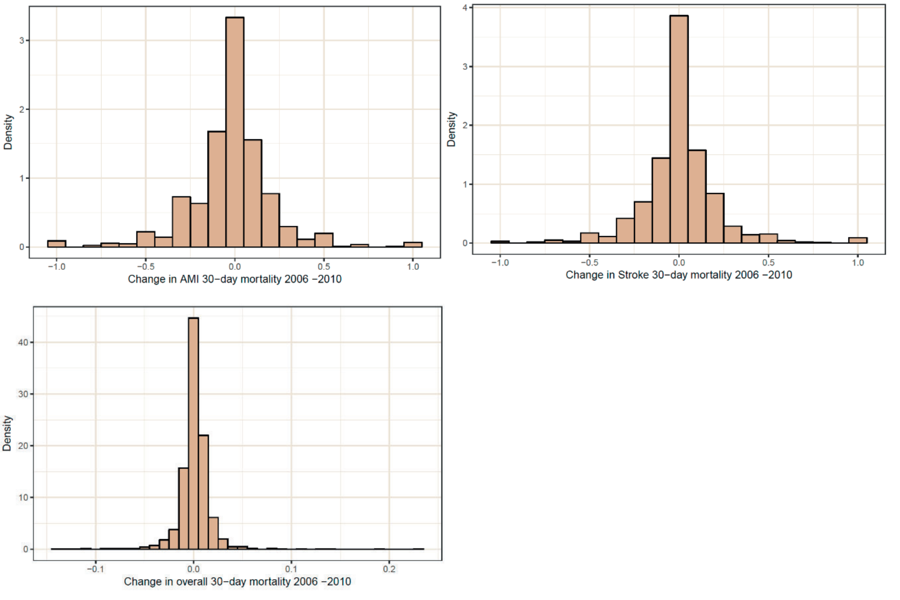
Notes: Estimations are based on Equation (1). The outcome variables have been rescaled to have a mean of zero and a standard deviation of one. Column 1 shows the impact of a 1-percent change in base-rate factors on standardized outcomes. Column 2 and 3 show the lower and upper bound of the 95-percent confidence interval. Column 4 shows robust standard errors, clustered at hospital level. Control variables on county level include unemployment rate, average age of men, average age of women, and a binary indicator whether it is rural area. Control variables on hospital level include binary indicators for different ownership types (public, private and non-for profit, and the number of hospital beds. [1] Estimation for the years 2008 and 2010. ² Estimation for the years 2006 and 2008. ³ These models are based on individual-level sickness fund data and include following individual-level control variables: age dummies (below 30 years, 5 year age bins for age >30 and age < 90 and above 90 years), gender, dummies for Charlson comorbidities and the Charlson Comorbidity Index (CCI) (Charlson et al., 1987). The CCI consists of 17 comorbidities which are coded as binary variables. Afterwards, they are weighted and summed up to an index. In the AMI-model, a dummy for ST-elevated myocardial infarction is included (STEMI, diagnosis codes I21.0–I21.2). In the general-mortality-model dummies for 2-digit-ICD 10 codes are included. * significant at 10%; ** significant at 5%; *** significant at 1%

Figure A 1a: Distribution of change in BQS results indicators



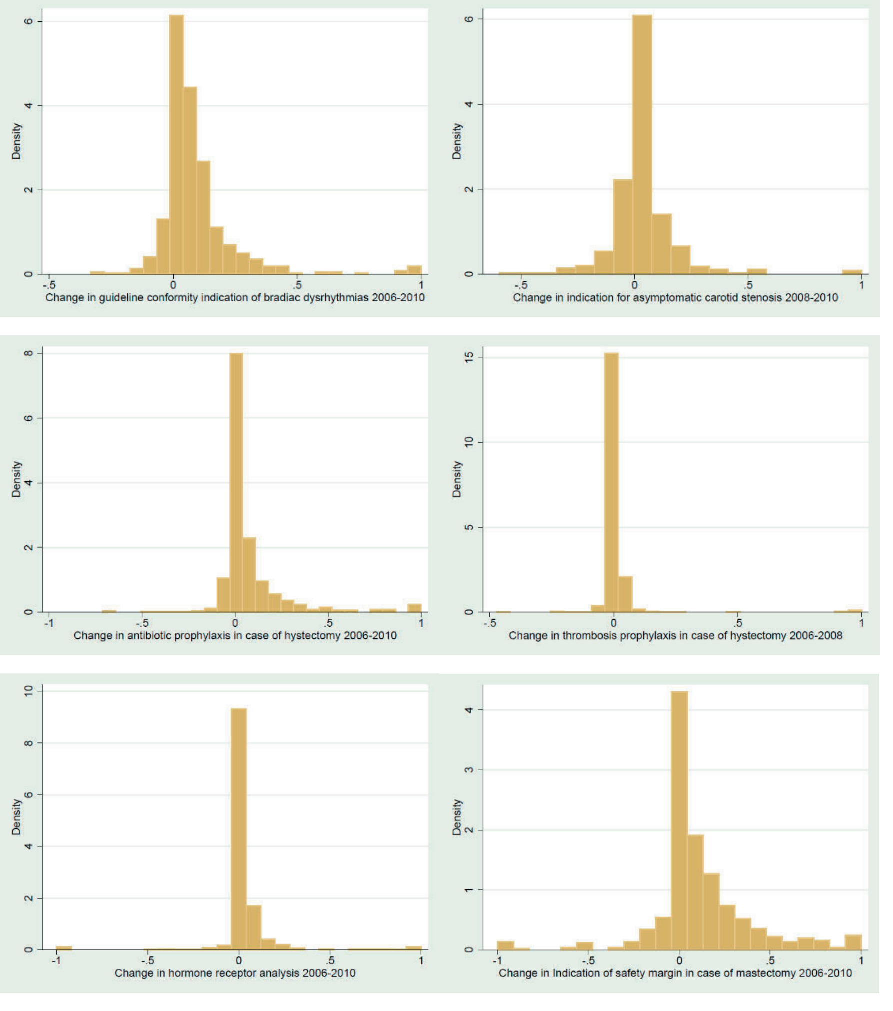
Notes: These figures show the distribution of changes in BQS results indicators between 2006 and 2010. The indicators are defined as log(BQS result indicator_2010) – log(BQS result indicator_2006).

Figure A 1b: Distribution of changes in hospital mortality rates



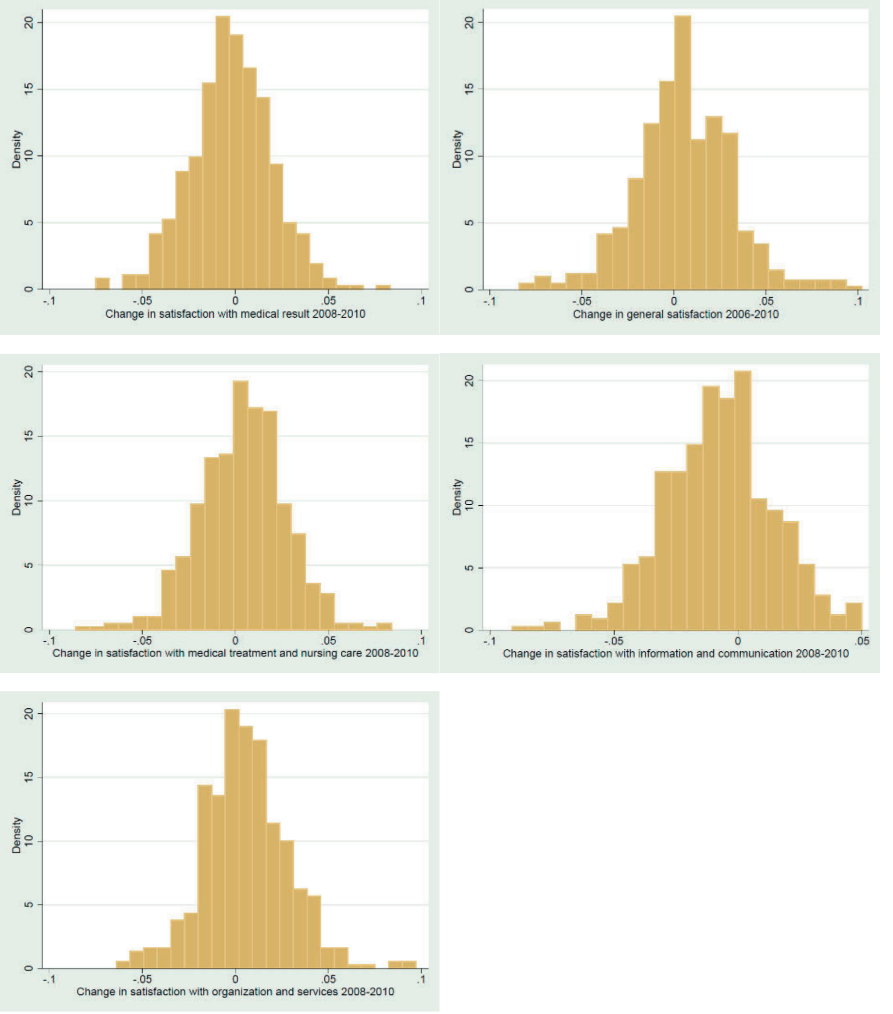
Notes: These figures show the distribution of changes in hospital inpatient mortality rates between 2006 and 2010. The indicators are defined as log(hospital inpatient result indicator_2010) – log(hospital inpatient result indicator_2006).

Figure A 1c: Distribution of change in BQS process indicators



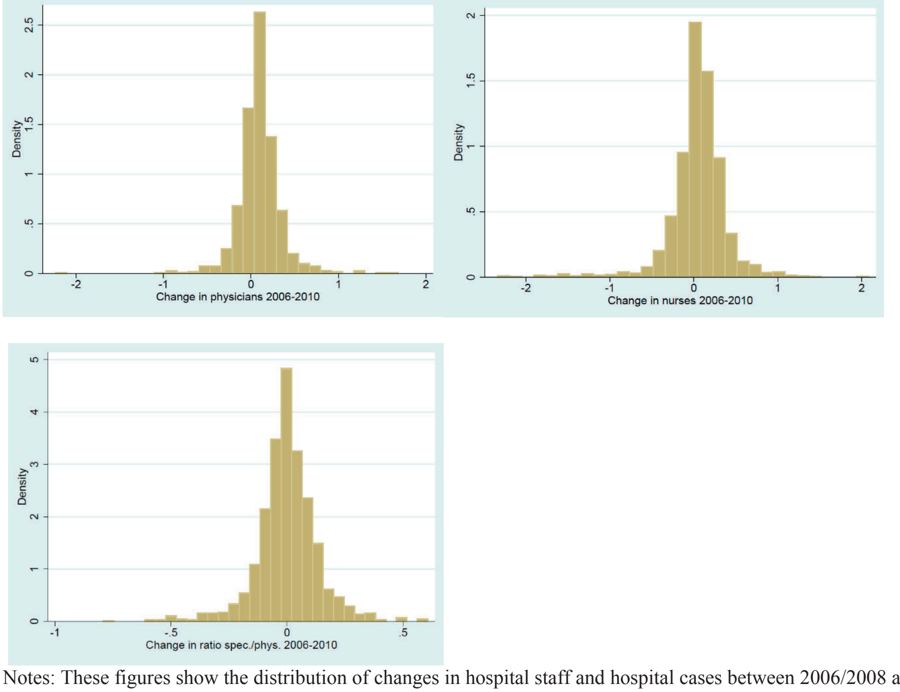
Notes: These figures show the distribution of BQS process indicators between 2006 and 2010. The indicators are defined as log (BQS process indicator_2010) – log(BQS process indicator_2006).

Figure A 1d: Distribution of change in TK Satisfaction indicators



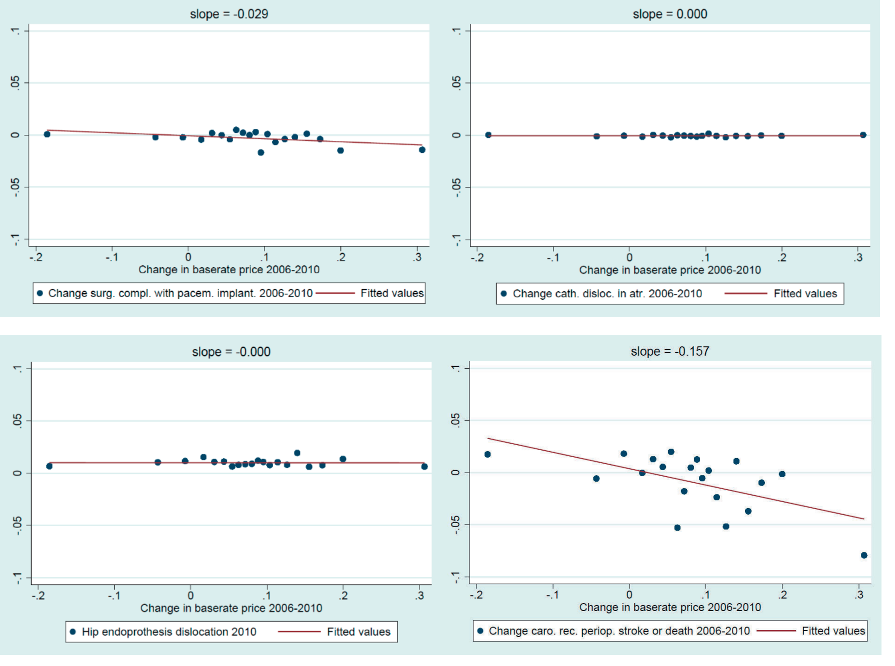
Notes: These figures show the distribution of changes in TK satisfaction indicators between 2006/2008 and 2010. The indicators are defined as log(TK satisfaction indicator_2010) – log(TK satisfaction indicator_2006/2008).

Figure A 1e: Distribution of change in quantity and quality of hospital staff



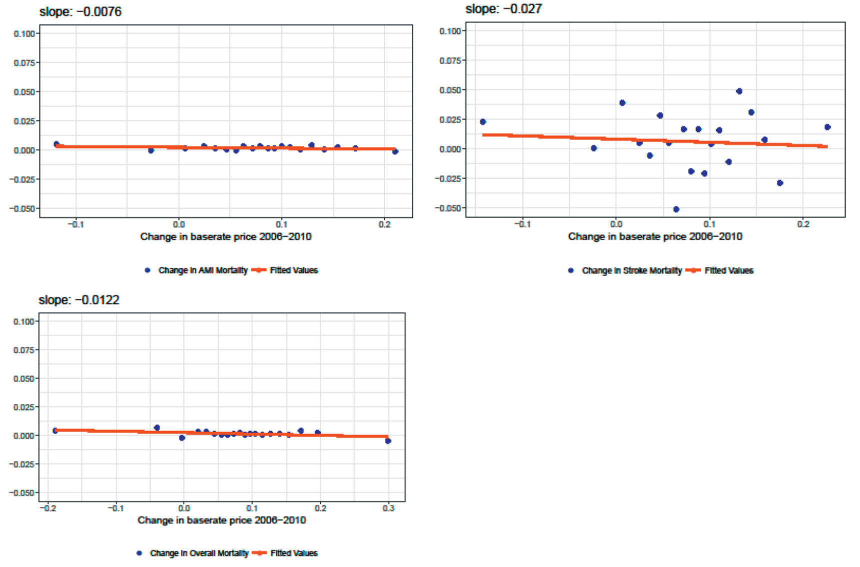
Notes: These figures show the distribution of changes in hospital staff and hospital cases between 2006/2008 and 2010. The indicators are defined as log(staff_indicator_2010) – log(staff_indicator_2006).

Figure A 2a: Non-linear effects of price changes on BQS results indicators



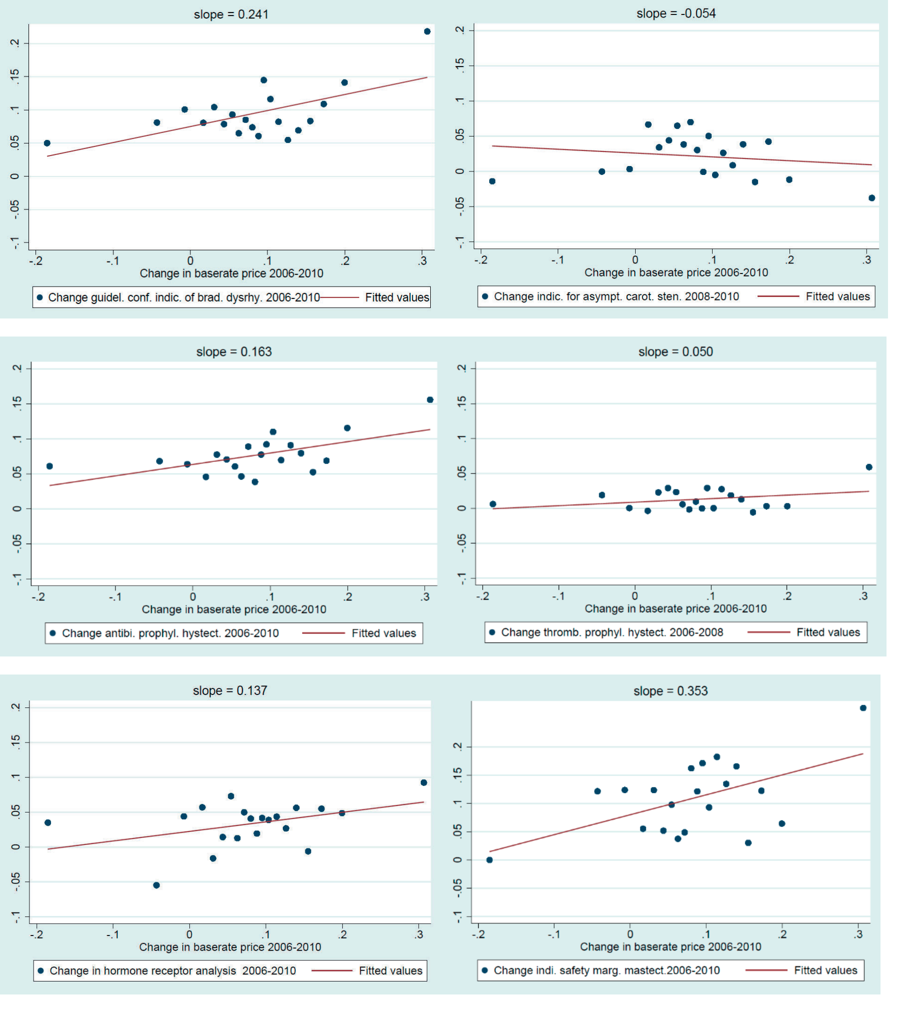
Notes: We group the sample of hospitals into 20 bins of equal size ("ventiles") according to their total change in base-rate factors over 2006-2010. The x-axis displays the mean of price changes for hospitals in each ventile. The y-axis shows, for each ventile, the average difference in the log of the according BQS result indicator between 2006 and 2010. We estimate a trend line from OLS regression using the 20 data points shown in the graph.

Figure A 2b: Non-linear effects of price changes on Mortality rates



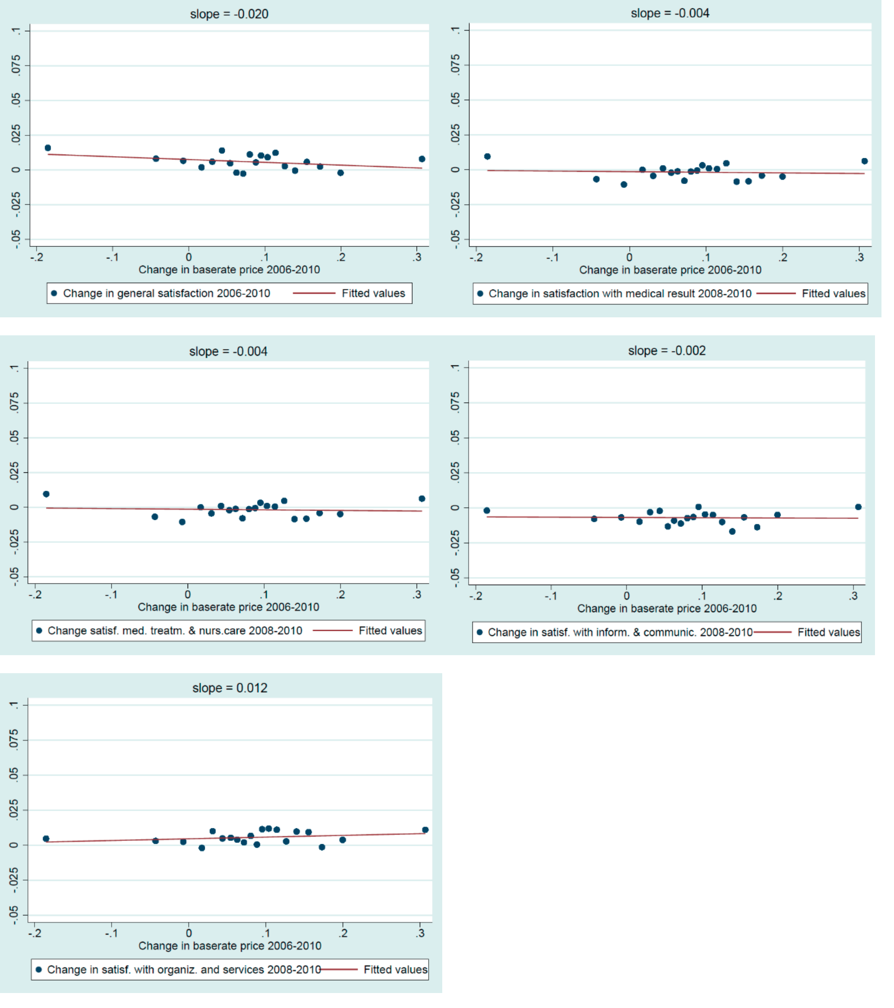
Notes: We group the sample of hospitals into 20 bins of equal size ("ventiles") according to their total change in base-rate factors over 2006-2010. The x-axis displays the mean of price changes for hospitals in each ventile. The y-axis shows, for each ventile, the average difference in the mortality indicator between 2006 and 2010. We estimate a trend line from OLS regression using the 20 data points shown in the graph. Mortality rates refer to 30-day mortality.

Figure A 2c: Non-linear effects of price changes on BQS process indicators



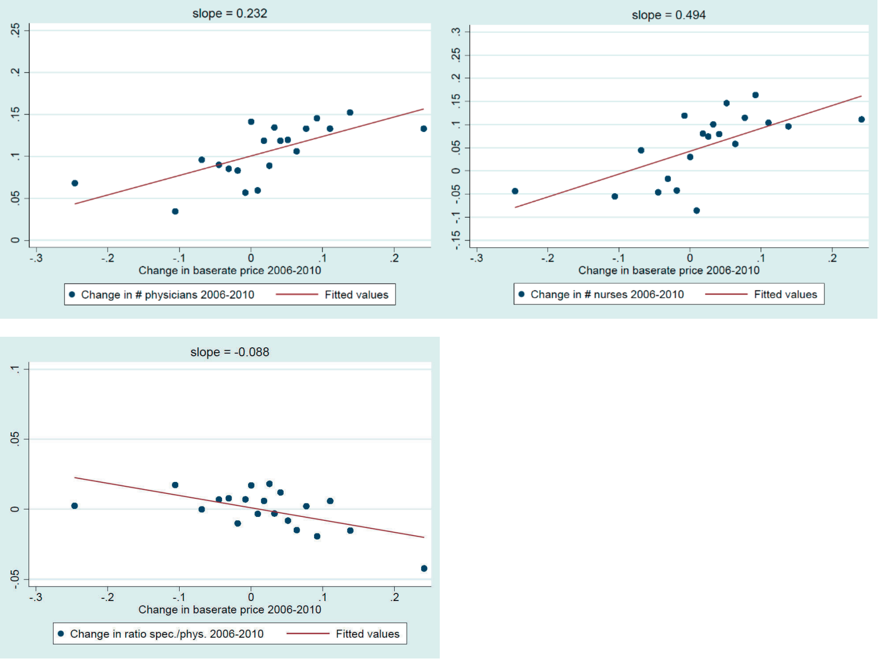
Notes: We group the sample of hospitals into 20 bins of equal size ("ventiles") according to their total change in base-rate factors over 2006-2010. The x-axis displays the mean of price changes for hospitals in each ventile. The y-axis shows, for each ventile, the average difference in the log of the according BQS process indicator between 2006 and 2010. We estimate a trend line from OLS regression using the 20 data points shown in the graph.

Figure A 2d: Non-linear effects of price changes on TK satisfaction indicators



Notes: We group the sample of hospitals into 20 bins of equal size ("ventiles") according to their total change in base-rate factors over 2006-2010. The x-axis displays the mean of price changes for hospitals in each ventile. The y-axis shows, for each ventile, the average difference in the log of the according TK satisfaction indicator between 2006/2008 and 2010. We estimate a trend line from OLS regression using the 20 data points shown in the graph.

Figure A 2e: Non-linear effects of price changes on quantity and quality of hospital staff



Notes: We group the sample of hospitals into 20 bins of equal size ("ventiles") according to their total change in base-rate factors over 2006-2010. The x-axis displays the mean of price changes for hospitals in each ventile. The y-axis shows, for each ventile, the average difference in the values of the indicator between 2006 and 2010. We estimate a trend line from OLS regression using the 20 data points shown in the graph.