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The effect of competition on process and outcome quality within hospital care in the Netherlands*

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Abstract

This study examines the impact of competition on hospital quality. Our panel covers all Dutch hospitals in the period 2004–2008, in which the transparency of hospital quality information increased substantially. The paper contributes to the existing literature by including both outcome and process indicators of quality. We find that competition explains the cross-sectional differences in process indicators, but not in outcome indicators. In particular, more competition in the hospital's catchment area leads to more operation cancellations at short notice and more delays of hip fracture injury operations for elderly patients. Both results suggest that competition increases the utilization of operation capacity. At the same time, hospitals that face more competition perform check-ups for chronic patients more frequently and organize diagnostic processes more efficiently.

Key words: competition in healthcare; quality; voluntary disclosure
JEL code: I1, L1

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1 Introduction

In recent years, government expenditure on healthcare in OECD countries has risen rapidly, with increases between 5% and 10% in real terms per annum.[**] To reduce costs, many countries have chosen to introduce elements of competition into healthcare markets. The idea is that competition increases efficiency by rewarding efficient health care providers or insurers, with efficiency being measured for a given level of quality. Although the economic literature recognizes the positive effect of competition on the efficiency of hospital care, its predictions about the relationship between competition and quality are ambiguous. Increased competition can either lower or raise quality, depending on price regulation, the preferences of marginal consumers and the level of transparency in the market (Gaynor, 2006).

Empirical literature on the relationship between competition and hospital quality is growing rapidly, but so far it has typically focused on clinical outcome quality (see Gaynor (2006) for a review). We argue in this paper that extending the scope of the analysis to process indicators (e.g., those showing the average frequency of tests for chronic patients, the rate of operations cancelled at short notice or the rate of diagnoses accomplished within a certain numbers of days) brings valuable additional insight into the effects of competition on hospital incentives. In accordance with Baker's (2000) idea that less risky and less distorted measures are associated with stronger incentives for an organization's staff, we expect to find that competition affects process indicators more significantly than it affects outcome indicators. This paper contributes to the existing empirical literature by estimating the effect of competition for such an extended range of indicators.

[**] Source: OECD Health Data 2009 - Frequently Requested Data.

This paper uses a data set of quality indicators of Dutch hospitals, the so-called Basis Data Set, to empirically assess the relationship between competition and quality of hospital care. Similar to Blom et al. (2009) and Propper et al. (2004), we use the geographic proximity of other hospitals (the number of competitors adjusted for the population density) as a proxy for competition. This captures the idea that patient flows are more easily diverted from a hospital to hospitals nearby than to hospitals farther away. Thus, a larger number of competitors in the hospital catchment area correspond to a larger threat of losing patients. Of course, different mechanisms can trigger changes in patient flows. For example, patients may prefer one hospital to another because it delivers better quality, but health insurers or general practitioners can also direct patient flows away from a particular hospital. Both these mechanisms may play a role in the Netherlands. Our measure of competition abstracts from the particular underlying mechanism that drives competition.

The Basis Data Set used in this paper was developed in the course of a gradual liberalization process in the Dutch hospital sector. Since January 2005, healthcare insurers and healthcare providers have had to negotiate prices for an increasing subset of healthcare services. Since 2006, all consumers have also been free to choose any health insurer they want. In conjunction with these changes, a set of diagnosis–treatment combinations was introduced, which formed the basis of a new budgetary system for hospitals.[††] This gradual liberalization was accompanied by an initiative to improve the transparency of the quality

[††] Hospitals used to be financed on a lump-sum basis. The lump-sum budgets were in effect until 2001, after which the budgets became flexible and scaled with the number of inpatient admissions, outpatient admissions and inpatient days of stay. For diagnosis–treatment combinations that fall into the liberalized segment, hospitals and insurers have to negotiate prices. From January 1, 2005, the prices of about 10% of services fell in the liberalized segment. In 2007, this was extended to 20%, and in 2009 to 34%. Source: NZa (2004, 2009).

of care in hospitals. In 2004, the Dutch Health Care Inspectorate[‡‡] started to collect and publish data on a standardized set of quality indicators, thereby creating the Basis Data Set. Initially, hospitals could still provide data on a voluntary basis.[§§] However, in 2009 a new and mandatory set of indicators, comprising both medical and subjective quality indicators such as consumer satisfaction, replaced the Basis Data Set. Therefore, the Basis Data Set covers 20 categories of quality indicators in Dutch hospitals over the period 2004–2008. It includes a wide variety of quality indicators, enabling us to differentiate across different categories of hospital quality (i.e., outcome, process and structure indicators). This provides the opportunity to empirically analyze the interrelationship between competition and the quality of healthcare provision in the Dutch hospital sector.

Since our data set covers the period when the disclosure of quality indicators was voluntary, we need to address the potential selection problem in our data. Therefore, we estimate a bivariate model that takes into account the correlation between disclosure and quality. We find significant effects of competition on indicators that measure process quality and not on indicators that measure outcome quality. More specifically, our empirical results indicate that the presence of more competitors in the hospital catchment area improves the timeliness of diagnostics, but increases short-notice cancellations and delays operations for some patients. In addition to the effects of competition between hospitals on process indicators, we find that several indicators (outcome and process indicators) improved over time. This suggests that the recent policy changes were probably beneficial for these indicators, improving them across the board.

[‡‡] De Inspectie voor de Gezondheidszorg (IGZ) in Dutch.

[§§] When a new Health Law was passed in July 2006, the provision of quality information to consumers became mandatory; however, hospitals were allowed to opt out of the Basis Data Set collection if they provided quality information via an alternative publishing outlet.

The paper proceeds by reviewing the related theoretical and empirical literature in section 2. Section 3 discusses our data in more depth. Section 4 describes the econometric model. Section 5 presents our empirical results. Section 6 concludes.

2 Related literature

The theoretical and empirical literature does not offer unambiguous results on whether more competition increases or decreases quality, whether more competition encourages or discourages the voluntary disclosure of quality information and how disclosure interrelates with quality.[***] This section reviews the major conclusions from the literature on these issues.

2.1 Effect of competition on hospital quality

According to the theoretical literature, competition increases hospital quality when prices are regulated, but may have either positive or negative effects on quality under unregulated prices (see Gaynor (2006) for a review). Essentially, if firms cannot compete on price and a larger market share increases profit, they will instead compete on quality to attract consumers. When firms can choose both price and quality, however, the downward pressure of competition on price may place a downward pressure on quality as well. Thus, equilibrium quality choices depend on the elasticities of demand with respect to price and quality. If the quality elasticity of demand is low, whereas the price elasticity is high, quality will decrease as competition increases (Dranove and Satterthwaite, 2000).

[***] Bijlsma and Pomp (2008) reviewed the existing economic literature on the effect of transparency on quality.

A scarce but growing empirical literature also provides ambiguous results on the relationship between competition and hospital quality. Most studies apply a structure–conduct–performance specification and regress performance indicators (quality indices) on indicators of competition and some control variables. Competition is measured either by the number of competitors in the hospital neighborhood[†††] or by concentration indices such as the Herfindahl-Hirschman index.[‡‡‡] As a quality measure, most studies use risk-adjusted mortality indicators (e.g. Volpp et al., 2003; Propper et al., 2004, 2008; Gaynor et al., 2010) or other outcome indicators such as different types of complications and in-hospital infections (e.g., Sari, 2002; Espinosa and Bernard, 2005). Process indicators are rarely used, a notable exception being Bloom et al. (2009), who stress the link between hospital management quality and clinical outcome quality.

As more comprehensive data sets on quality become available, the next step is to collect evidence on the effect of competition on this broader range of indicators to achieve a deeper understanding of the relationship between competition and quality. As shown by Baker (2000), the strength of incentives used in an organization depends to a large degree on the characteristics of the performance measures available. In particular, stronger incentives can be set for tasks where the relationship between the effort and the performance is less distorted by exogenous factors. Hospitals are likely to have more control over processes than over outcomes, which also depend on the health of patients. Therefore, competition probably affects process indicators more significantly than it affects outcome indicators.

[†††] The number of competitors is typically adjusted for population density.
[‡‡‡] The Herfindahl-Hirschman index is the sum of the squares of all firms’ market shares.

2.2 The role of disclosure

Economic theory predicts that as long as quality disclosure is costless, a firm will voluntarily disclose its quality level when it can credibly do so (Viscusi, 1978; Grossman, 1981; Milgrom, 1981). This result holds since under information asymmetry about quality, consumers are willing to pay the price that corresponds to the average expected quality. Therefore, a firm offering a product with a higher-than-average quality will always disclose it to obtain a higher-than-average price. If the firm does not disclose quality, consumers will adjust the expected average price downwards.

A firm's choice of quality effort and its decision to reveal information on quality can be interrelated for several reasons (Dranove and Jin, 2009). Both choices can be affected by competition, but also by other factors, such as the cost of disclosure, the possibility of strategic differentiation or the type of regulation.

Grossman and Hart (1980) and Jovanovich (1982) showed that when disclosure entails private costs, only firms with quality levels above a certain threshold will find it beneficial to disclose their quality. Indeed, some recent empirical studies have found that quality positively correlates with the willingness to participate in voluntary disclosure initiatives (McCornick et al., 2002; Agarwal et al., 2009). By contrast, Gavazza and Lizzeri (2007) provided arguments for why high-quality firms may be unwilling to disclose their quality. The latter result arises under binding capacity constraints or price regulation, in which case high-quality firms do not benefit from the increased consumer demand for their services in response to disclosure.[§§§] Since the hospital sector features both capacity constraints and regulation, the possibility of a negative relationship between hospital quality and its voluntary disclosure cannot be dismissed.

Oligopolistic competition introduces additional mechanisms that can affect firms' disclosure decisions. Two recent theoretical papers on this subject showed that under imperfect competition firms may use (non-)disclosure to strategically differentiate their goods to soften price competition. Both papers predicted less disclosure in an oligopoly setting. In particular, Board (2009) argued that non-disclosure may be a device for firms to reduce competition. In particular, two high-quality firms can vertically differentiate their products if one of them does not disclose. Levin et al. (2009) considered costly quality disclosure with horizontally differentiated products under duopoly and a cartel. Since one firm's disclosure creates a positive externality for another firm, expected disclosure is higher when firms coordinate. Hence, both papers predicted that strategic competition makes voluntary quality disclosure less likely. These theoretical results corroborate the empirical findings by Jin (2005), who analyzed the voluntary disclosure of American HMOs via the National Committee of Quality Assurance reviews in the period 1991–1998. After controlling for cost and demand shifters, Jin found that highly competitive markets feature early disclosers but have lower average disclosure rates. She argued that HMOs use voluntary disclosure as a way to differentiate themselves from competitors.

Overall, the literature provides ambiguous answers about the relationships between competition and quality, and between quality and its disclosure. Yet, it gives some

[§§§] Indeed, consumers do respond to higher hospital quality. Pope (2009) studied the effect of media rankings of US hospitals and found that hospitals that improve their rankings are able to attract significantly more patients.

guidance about the factors underlying these relationships that have to be taken into account in empirical analysis. In particular, the literature stresses that the decisions on quality and its disclosure are not fully independent of each other, which prompts for a careful addressing of selection effects in data sets on quality. It also shows that the level of competition can affect both the disclosure and quality effort decisions of hospitals. So far, the empirical literature on the effect of competition on hospital quality has mostly focused on outcome indicators. Therefore, the inclusion of process indicators may add new insight into the relationship between competition and quality. Based on Baker (2000), the effect of competition may be more pronounced for process indicators than it is for outcome indicators.

3 Data

In this section, we describe the data set used in our empirical analysis. We start with quality indicators (section 3.1), after which we turn to the indicators of competition (section 3.2).

3.1 Quality indicators

The data on hospital quality comes from the Basis Data Set of the Dutch Health Care Inspectorate. This data set covers the period 2004-2008 and includes all Dutch general and academic hospitals.[****] There are almost 100 of such hospitals in the Netherlands, 8 of which are academic hospitals. In addition to academic hospitals, 26 general hospitals

[****] We exclude four specialized hospitals: one eye-hospital (Oogziekenhuis Rotterdam), two orthopaedic clinics (Sint Maartensklinieken Nijmegen/Woerden) and one oncological hospital (Antoni van Leeuwenhoek ziekenhuis Amsterdam).

provide teaching and research possibilities, the so-called ‘medical teaching hospitals’.[††††] These are typically middle-size or large general hospitals, offering the complete range of medical care. Since the data set of the Dutch Health Care Inspectorate contains the names of hospitals, it is possible to merge it with the information from other sources. In particular, we have merged this data set with the data on the all hospital locations and the number of beds from the National Institute for Public Health and Environment (RIVM).[‡‡‡‡]

Table 1 shows some characteristics of hospitals in our data set. According to Blank et al. (2008), Dutch hospitals are on average substantially larger than hospitals in other countries, with a greater number of beds. Table 1 also shows summary statistics for the number of elective operations and the number of patients in the hospital’s recovery room over the year. These variables relate to the hospital scale, but also illustrate the intensity of hospital activities. Finally, the table shows some characteristics of hospital intensive care (IC) units, such as their level, the number of intensivists at these units and the number of patient artificial respiration days. These characteristics are related to the severity of patients in the hospital. In general, a higher level of IC corresponds to more advanced care. Therefore, hospitals with a higher IC-level typically have a greater number of intensivists and severer patients (who possibly have a larger number of artificial respiration days).

<Table 1>

In 2004 and 2005, the data on quality indicators were gathered retrospectively, that is, hospitals received the questionnaire about the previous year on January 1 of the subsequent

[††††] Information about these hospitals is provided on http://www.stz-ziekenhuizen.nl/
[‡‡‡‡] The full name of RIVM is the Rijksinstituut voor Volksgezondheid en Milieu (The National institute for Public Health and Environment).

year. From 2006, hospitals have received questionnaires in advance and have delivered them back to the Inspectorate at the end of the year (Van den Berg et al., 2009, p.23). The quality survey is divided into three broad classes of indicators: hospital-wide indicators, high-risk treatment indicators and special treatment indicators (the complete list and a description of each indicator are provided in Appendix A). Each class of indicators comprises several dimensions of hospital care, summing up to 20 quality dimensions for each year. In this paper, we focus on indicators that were requested for at least three years and are relevant to all hospitals in our data set.[§§§§] See Appendix A for more detail about the survey and the indicators used in this paper.

Table 2 shows summary statistics of the quality indicators considered. The indicators can be divided into three types: structure, process and outcome indicators.[*****] The second column of Table 2 shows the respective types of indicators, as we classify them in our study. Most indicators are expressed as proportions. Only the indicators of care for diabetic patients are expressed in absolute terms: average number of fundoscopies per patient and average number of HbA1c-tests per patient.[†††††]

Table 3 shows the availability of the indicators over the period. Although all the hospitals participated in the survey, they did not always deliver all the figures asked. Therefore, there is a variation in the degree of disclosure both across hospitals and across indicators. We

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[§§§§] We do not include the categories of indicators that were added in the last one or two years. Furthermore, we do not include category 'Pregnancy', where reporting problems were encountered, according to Berg et al. (2009). We also leave out the indicators of high risk operations, such as an aneurysm of the abdominal aorta (AAA) and an esophagus cardiac resection (OCR), since not all hospitals conduct these high-risk operations. Certain indicators, such as the number of operations and intensive care parameters, are included as control variables, rather than quality.

[*****] The classification in these three types, suggested by Donabedian (1966), is accepted in the health economics literature.

[†††††] Fundoscopies and HbA1c-tests are the procedures to maintain the health condition of diabetic patients. See Appendix A for more detail about these indicators.

observe an increase in the openness over the requested indicators by the end of the period and virtually no reversion in disclosure decisions. This suggests that we can use a hazard specification in modelling these decisions (see section 4).

<Table 2>

<Table 3>

3.2 Measuring competition

The issue of measuring hospital competition has regularly been debated in the literature. This issue concerns both the type of the measure used (e.g., the number of competitors or HHI) and the definition of the geographic area within which hospitals compete with each other. See, for example, the discussion of advantages and disadvantages of different approaches in Cooper et al. (2010). Since there is no single way of measuring competition that would provide a perfect measure, in our analysis we use several measures that are relatively simple to construct, and we test the robustness of our results comparing them across these measures.

In particular, we focus on three measures of competition: the number of competitors in the hospital catchment area (defined as a circle of a fixed radius around the hospital postcode zone), the number of competitors adjusted for the size of population, and the distance to the closest competitor. To investigate whether the choice of the radius of the catchment area affects the estimation results, we estimate model variants for three different radiuses (10, 15 and 20 km). Within these radiuses, hospitals are assumed to be competitors to each other.

Next to hospitals, independent treatment centers can provide healthcare within the liberalized segment of hospital care. These suppliers are typically much smaller and have a narrow specialization. Thus, these centers only compete with hospitals within certain specialisms. The entry of independent treatment centers is allowed since 2005. However, their market share is still relatively small: just 4% of the liberalized segment in 2009 and less in earlier years (NZa, 2009). According to the Dutch regulator, Dutch hospitals still mainly compete with each other, and they see other general hospitals as their main competitors (NZa, 2009).[‡‡‡‡‡]

The set of hospital locations has hardly changed over the period 2004-2008. There was also little merger activity among hospitals in this period. There were no mergers among academic hospitals and only three mergers among general hospitals. This contrasts to the earlier period, 1998-2003, in which the number of hospitals decreased by 16 (NZa, 2009.)

One fourth of Dutch hospitals have one location. The rest have more than one location (either several hospital locations or some hospital locations and some policlinic locations[§§§§§]). We will refer to hospitals comprising several locations as a ‘group’.[******] Locations that belong to the same group do not compete with each other. In fact, they often

[‡‡‡‡‡] The authors’ translation of the original text in Dutch “Ook dit jaar komt uit de antwoorden in de vragenlijsten naar voren dat een grote meerderheid van de ziekenhuizen, andere ziekenhuizen als belangrijkste concurrenten ervaart.” (NZa, 2009, p.22.)

[§§§§§] Policlinic locations are locations of outpatient treatment centres.

[******] Some of these groups, typically those that merged some years ago, have reported quality on the aggregate group level. In contrast, those that merged relatively recently reported data at the location level for some years, while reporting the aggregate data for some other years.

share specialists and refer patients between each other if necessary. Therefore, when constructing the number of hospitals within a fixed radius from a certain location, we count each group as a single competitor. A group is counted as a competitor if at least one of its locations falls within the circle. The indicators of competition were constructed based on the full set of hospitals and their locations and merged with the data set on quality, taking the location of the largest hospital within the group as the location of the group. This assumption is consistent with the presence of one board of directors in each group.

The second measure of competition that we consider accounts for population density. We use the population data at the level of postcode from the Central Bureau of Statistics of the Netherlands, to compute the size of the population per catchment area. Table 4 shows the summary statistics of the respective indicators of competition; and Table 5 shows correlations between them. Here notation *An* corresponds to the number of competitors within *n* km from the hospital, and *Bn* is equal to *An* divided by the population within *n* km from the hospital. As expected, indicators *An* and *Bn* are positively correlated, and both are negatively correlated with indicator *C*.

<Table 4>

<Table 5>

4 Empirical model

We argued earlier that the primary interest of our analysis lies in the effect of competition on hospital quality indicators. When estimating this effect, however, one should be aware that the quality indicators are not disclosed for all hospitals and for all yearly observations. Since it may well be that the decisions affecting quality and its disclosure are mutually interdependent, our modeling approach entails a joint estimation of the disclosure decision of quality indicators and the values of the disclosed indicators. In doing this, we recognize that the initial costs of disclosing quality information may be substantial. Hence, instead of being a year-to-year decision, disclosure typically applies to all future years in the period under consideration as well. Consequently, we model the disclosure decision as a duration process, with time measured as a discrete variable. In addition, quality information is observed for the subset of hospitals that have disclosed information. To take into account this self-selection by hospitals, we allow for correlation in the unobserved terms of both processes. We use a Logit specification for the discrete disclosure probability $\boldsymbol{\theta}$ and a Normal distribution for the quality outcomes $\boldsymbol{y}$ for hospital i ($i = 1,.., 103$), quality indicator j ($j = 1,.., 18$) measured in year t ($t = 1,.., 5$).

$$(1) \qquad \ln \{ \theta_{ijt} / (1 - \theta_{ijt}) \} = \boldsymbol{X} \beta_j + \psi_j (t) + \nu_{ij}$$

$$(2) \qquad y_{ijt} = \boldsymbol{X} \gamma_j + f_j(t) + \upsilon_{ij} + \varepsilon_{ijt}$$

with $\varepsilon_{ijt} \sim N(0 , \sigma_{ijt}^2)$ and

$$(3) \qquad \sigma_{ijt}^2 = \sigma_{0j}^2 \, S_{ijt}^{\alpha(j)}.$$

Here, equation (1) makes apparent that the disclosure hazard is modeled using the familiar Mixed Proportional Hazard (MPH) model specification with time varying coefficients, while using discrete time durations. Equation (2) characterizes quality, and equation (3) specifies the variance for the heteroscedastic error term ε_{ijt} used in equation (2). We describe the variables and parameters included in each equation in more detail below.

In equations (1) and (2), $\boldsymbol{X}$ includes time-variant and time-invariant variables that may affect both the disclosure decision and the respective quality-indicator value. The effects of these variables are described by the parameter vectors β and γ, respectively. The main variable of interest here is our measure of competition. In addition to competition, we include hospital characteristics, regional characteristics, and a linear time trend in both equations. We also control for the level of transparency of competitors in equation (1). Among the hospital characteristics, we include a teaching-hospital dummy, bed number, patient number, number of elective operations, and the number of intensivists at the hospital's intensive-care unit. As a regional characteristic, we include regional mortality to correct for the health status of the population in the area.[††††††] Mortality data are available at the Netherlands Central Bureau of Statistics at the level of postcodes. We use this data together with the data on the size of population within the postcode area to construct the indicators of mortality within the catchment area of each hospital.

Next to the set of variables $\boldsymbol{X}$, equations (1) and (2) include time-trend variables. Function $\psi(t)$ in equation (1) represents the effect of calendar time on the disclosure probability. In principle, this function can be specified by using year dummies. Since the starting date in our sample is the same for all hospitals and quality measures, the coefficient values of ψ

[††††††] Hospitals that face more competition are typically located in more densely populated areas, with more diverse population. It is plausible that they serve patient groups that are on average less healthy, causing a severer case mix for these hospitals. Without a correction for the health status, the estimates of competition effects will be biased downwards.

also capture the effect of genuine duration dependence — that is, the remaining hospitals that have not disclosed this information so far become either more or less likely to disclose as time evolves. As calendar-time effects may also be relevant for the observed quality levels, this effect is represented by $f(t)$ in equation (2) as well.

Equation (3) shows that the error terms of the quality equations are specified as heteroscedastic functions with σ_{0j}^2 as baseline values per quality indicator. The variance of the error terms is allowed to vary with the sample size of the number of observations S_{ijt} for hospital i at time t underlying the construction of the respective quality indicator j. Hospital quality indicators represent an average for a certain subsample of the patients treated, and thus may be sensitive to measurement errors.[‡‡‡‡‡‡] Therefore, the efficiency of quality coefficient estimates improves with respect to the patient group over which the average is taken. In particular, one would expect the variance to decrease in the sample size ($\alpha(j) < 0$), which is taken into account by the heteroscedastic specification of the error terms. Within the context of reported hospital-quality information, the interpretation of the error term in equation (3) is twofold. First, quality outcomes are driven by factors that vary over time and cannot be observed – as in any model with random effects. The second interpretation is that the outcomes can be measured with error. Under classical assumptions, these 'left-hand-side' measurement errors only affect the efficiency of estimated effects (Hausman 2001).

[‡‡‡‡‡‡] These undesirable effects occur when the sample of patients that is used to measure the indicator does not represent the hospital population for which the indicator was relevant, or when the group of patients is small and an outlier has a large effect on the average. These problems are well known in the literature on measuring hospital quality. See, e.g., Dimnick et al. (2004) and Zaslavsky (2001).

In both equations (1) and (2), we allow for unobserved, time-constant effects per combination of hospital i and quality outcome j. These are represented by v_{ij} and υ_{ij}, respectively. We specify these random effects using a non-parametric bivariate distribution of mass points to approximate their distributions.[§§§§§§] We thus follow Heckman and Singer (1984), who first proposed this specification for the non-parametric estimation of (univariate) duration models. More specifically, we take the joint distribution of the unobserved heterogeneity terms v_{ij} and υ_{ij} to be bivariate discrete, with two unrestricted mass-point locations for each term. We denote v^a, v^b, υ^a and υ^b as the points of support of v and υ, respectively. The associated probabilities are denoted as follows:

$$\Pr(v = v^a, \upsilon = \upsilon^a) = p_{aa},$$
$$\Pr(v = v^a, \upsilon = \upsilon^b) = p_{ab},$$
$$\Pr(v = v^b, \upsilon = \upsilon^a) = p_{ba},$$
$$\Pr(v = v^b, \upsilon = \upsilon^b) = p_{bb}$$

with $0 \leq p_{kl} \leq 1$ for $k = a, b$ and $l = a, b$ and $p_{bb} = 1 - p_{aa} - p_{ab} - p_{ba}$.

By modeling the joint distribution of mass points, we take explicit account of the fact that the decision to disclose quality information and the actual (observed) values of quality indicators may be correlated. A simple test for this entails the computation of the covariance of v and υ:

$$\text{cov}(v, \upsilon) \quad = \quad (p_{aa}\, p_{bb} - p_{ab}\, p_{ba})\,(v^b - v^a)\,(\upsilon^a - \upsilon^b).$$

[§§§§§§] By including random effects in our specification, the (total) disturbance terms in our models cannot be regarded as (fully) independent draws. Thus, clustering effects are controlled for and the standard errors of our explanatory variables are consistent.

All together, the parameters of our model for each quality indicator j are

$$\{ \beta_j , \psi_j , \gamma_j , f_j , \sigma_{j0}^{2}, \alpha_j , p_{aa} , p_{ab} , p_{ba} , v^a, v^b , \upsilon^a , \upsilon^b \},$$

which can be estimated by Maximum Likelihood. Conditional on the values of v and υ, the likelihood contribution L explaining the disclosure duration τ and quality outcomes y of hospital i and indicator j is equal to

$$(4) \qquad L (\tau_{ij}, y_{ijt} \mid v , \upsilon) \quad = \quad \theta_{ij,\tau} \Pi_{t=\tau-1} [1 - \theta_{ijt}] \times \Pi_{t=\tau} \varphi (y_{ijt}) / \sigma_{ijt}^{2},$$

with φ (.) indicating the standard normal distribution density function. Equation (4) can be integrated out over the discrete distribution of v and υ, yielding the integrated Likelihood:

$$(5) \qquad L (\tau_{ij}, y_{ijt}) \quad = \quad \Sigma_{k=a,b} \Sigma_{l=a,b} \; p_{kl} \, L (\tau_{ij}, y_{ijt} \mid v_k , \upsilon_l).$$

When estimating equation (5), special interest lies in the number of mass points and respective weights that can be estimated. With four mass points and two parameters for the unobserved effects (v^a and υ^a) that are absorbed by the constant terms in the equations, we have three probability parameters and two unobserved-effect parameters that can be estimated. It however often occurs in practice that corner solutions are obtained for the probability parameters. This reduces the effective number of mass points. We return to this issue when discussing our estimation results.

5 Empirical results

We have estimated the bivariate model presented in section 4 for 18 separate quality indicators (representing 10 quality dimensions from the Basis Data Set) and the seven different measures of competition described in section 3. As already mentioned, we have included both process indicators and outcome indicators. Where it was possible, the indicators have been expressed as percentages and transformed in such a way that their increase corresponds to an improvement of quality.[*******] For example, instead of using the percentage of re-operations itself, we use the complementary indicator '100% minus the percentage of re-operations'.

In this section, we first discuss our results concerning quality (sections 5.1 and 5.2), followed by results on disclosure and model parameters (section 5.3).

5.1 Effect of competition on quality

Table 6 shows the estimation results for the effect of competition on quality. In nearly all regressions, we find a significant negative effect of competition on decubitus prevalence and cancelled operations at short notice, and a significant positive effect on the frequency of HbA1c-tests on diabetic patients. The effect of competition is also significant (although not in each regression) for several other quality indicators: a negative effect on the share of hip fracture injury operations to 65+ patients made within 1 day, and positive effects for the

[*******] For many indicators in our data set (e.g., for AMI-mortality) the monotonicity of their relationship to quality is obvious. However, for some indicators (e.g. for cancelled operations and test frequency) the relationship to quality is not monotonous. This means that the interpretation that an increase in the respective indicator corresponds to an improvement of quality is only valid within the relevant range of values. This interpretation agrees with the explanation given in the questionnaire that was used for the collection of these indicators.

number of fundoscopies for diabetic patients, completing diagnoses within 5 days, and pain checks.[†††††††] For the rest of indicators, the effect of competition is insignificant.

Note that we typically find significant effects of competition on process indicators and insignificant effects on outcome indicators, except for the negative effect on the indicator concerning decubitus prevalence. The interpretation of the latter result, however, is not straightforward, since the definition of decubitus prevalence that was used in the questionnaire makes no distinction in degrees of decubitus, hence neglecting differences in the severity of patients' conditions. Besides, perhaps not all hospitals used the same definition of decubitus in this period (Houwing et al., 2007). A possible reason for the more pronounced effect of competition on process indicators, rather than on outcome indicators, may be that hospitals have more control over process quality rather than over outcome quality, because the latter is also influenced by the patients' conditions. Hence, our finding lends support to the arguments made by Baker (2000).

To assess the relative magnitude of these effects, we look at the observed difference in quality between the most competitive and the least competitive areas. Table B (Appendix B) shows the expected difference in quality indicators between a hospital that has no competitors in its catchment area and a hospital with the largest number of competitors in its area. For example, column A10 in this table shows the difference between a hospital without competitors within 10 km and a hospital with 8 competitors within 10 km (since the maximum value of A10 in our sample is equal to 8, see Table 4). For the quality

[†††††††] Note that when the effect of competition on a quality indicator is significant, all our measures of competition result in the same direction of the effect (i.e., the same sign of the coefficients in columns on A and B and an opposite sign in column C).

indicators for which the effect of competition is significant, the effects vary between 30% and 80% of standard deviations.

We interpret the effects of competition on process indicators in the following way. First, we find a negative effect of competition on quality measured by the indicators related to operation planning (cancelled operations and hip fracture injury operations for elderly patients).[‡‡‡‡‡‡‡] A larger share of cancellations of planned operations, as well as longer waiting times for operations on acute hip fracture injuries of elderly patients in competitive areas probably indicate that hospitals in these areas tend to plan tighter. Secondly, we observe a positive effect of competition on pain checks in the hospital recovery room, checks of diabetic patients, and the diagnoses of breast cancer completed within 5 days. This may indicate the increased attention of hospital management to these activities.

This explanation is consistent with the hypothesis that hospitals in more competitive areas might experience more pressure on profit margins and therefore have stronger incentives to increase their production efficiency. On the one hand, the pressure to improve efficiency increases the utilization of hospitals' resources, making the hospitals plan tighter. On the other hand, it creates the incentive to focus on improving the hospital processes that may be beneficial for the hospital. For example, patient may interpret certain process indicators (such as timely diagnoses, or perhaps also test frequency for chronic patients) as a 'signal' of quality. Then the presence of competitors strengthens the hospital's incentive to perform well on these particular indicators, since the hospital would like to prevent its patients from choosing a competitor. All together, this may explain why we observe a negative effect on

[‡‡‡‡‡‡‡] Short term cancellations of planned operations are stressful for patients. Delays of hip fracture injury operations to 65+ patients substantially decreases full recovery chances for these patients.

indicators concerning operation planning and a positive effect on indicators concerning test frequency for chronic patients and diagnostic.

We conclude that competition between hospitals in the Netherlands has so far affected process quality only. The direction of these effects indicates that hospitals in more competitive areas have a stronger incentive to be efficient.

5.2 Effect of control variables on quality

Table 7 shows the results on control variables in the equation for quality. We confine the presentation of the results to the regressions with the competition measure B10. The results of regressions with other competition indicators are qualitatively similar to the results in Table 7.

With respect to hospital characteristics, we find that larger hospitals (the size been measured by beds, operation number and patient number) perform better than other hospitals in preventing decubitus, reducing pain for patients during their recovery after operations and helping AMI-patients, but they perform worse in terms of reoperations. For the indicator of cancelled planned operations, the effect of scale is not straightforward. The results show that more beds are associated with more cancellations, whereas more elective operations are associated with fewer cancellations. When combining these two findings, it seems that hospitals with a larger number of elective operations per bed cancel operations less often. Although this seemingly contradicts to our earlier finding about a tighter planning of operations under competition, these two results can be reconciled with each other as follows. Firstly, operation cancellations at short notice are likely to be caused by the shortage of doctors or operation room capacity, rather than by the shortage of bed capacity. Secondly, reverse causality may play a role here, since for a given number of operations planned by a hospital, more cancellations imply that fewer operations are actually performed.

Regarding the control variables included to correct for patient mix, we find that the teaching status is associated with less decubitus incidence, but with a greater share of cancelled operations. This is perhaps because of the better use of decubitus prevention techniques but severer patient mix at these hospitals. As expected, regions with a higher mortality also have higher AMI-mortality rates, reflecting the effect of a worse health status in these regions.[§§§§§§§]

Finally, the effect of time is positive and highly significant for many quality indicators considered. We observe improvements over time in outcome indicators, namely in decubitus, AMI, and reoperations, as well as in process indicators related to operation planning, namely in cancelled operations and hip fracture injury operations. This effect may be due to the increasing disclosure of quality and policy attention to quality in this period. This effect, however, cannot be separately identified from other time-related effects, such as the effect of new technology.

[§§§§§§§] One can argue that the effect can go both ways. However, AMI is responsible only for a small share of death in the region.

5.3 Results on disclosure and model parameters

Table 8 presents the results for the disclosure equation in regressions that employ B10 as a measure of competition.[********] Generally, we find no significant effects of competition on disclosure decisions, while find strong positive effects of scale and, sometimes, of time trend. In particular, we observe a positive significant (95% and higher) effect of the following variables: ‘number of elective operations’ (eight times), ‘patient number’ (five times), and ‘number of IC-intensivists’ (two times). Since these three variables relate to hospital scale, at least to some extent, these results signify a positive effect of hospital scale on disclosure. We also find a significant positive effect of time on disclosure for cancelled operations and pain-scores. This indicates some acceleration in the disclosure rate of these indicators over time. The effects of other control variables on disclosure are insignificant. Therefore, overall we conclude that the disclosure decisions have probably been driven by scale rather than by competition.

Table 9 shows the results for other model parameters. We have argued earlier that the bivariate setup of our model with unobserved (‘random’) effects allows for correlation between the disclosure decision and the quality measures. This correlation is determined by the probability parameters, together with unobserved effect parameters. For all variables, the best fit to the data of our model is obtained for parameter values where there is full correlation between the processes, that is, when $p_{ab} = p_{ba} = 0$. This means that there are two

[********] The results using other competition measures are similar. In addition to the indicators of competition, we have also controlled in the disclosure equation for the average degree of disclosure by competitors. The respective variable was constructed as an average of the disclosure decisions by the hospitals in the catchment area over all the indicators, accounting only the indicators that were available for all years. The idea was that a hospital’s disclosure decision may be affected by the rate of disclosure in the neighborhood; in particular, more disclosure by competitors could place pressure on the hospital to disclose. However, we have never found a significant effect of this variable.

mass points for which the unobserved effects are allowed to vary. For nine quality variables the implied correlation is negative, whereas for the other nine quality variables it is positive. It should be stressed however that the value estimates of the unobserved heterogeneity terms for the disclosure decision are insignificant in most cases, rendering the implied correlation estimates insignificant as well. Thus, it seems that the disclosure decision of individual quality measures has not been influenced by the expected gains from transparency for hospitals with higher than average quality scores because of more demand for their services. This confirms our earlier finding that the disclosure decision of hospitals is typically not influenced by competition. Moreover, our estimates of the competition parameters remain virtually unchanged when unobserved effects in the disclosure decision model are assumed to be equal to zero.

In contrast to the disclosure decision, we find the quality levels to be driven to some extent by unobserved, time constant hospital-specific effects. In our model, the explained variance in quality outcomes comes from two sources: the hospital specific random effects and the residual variance. The respective effects are captured by the terms υ_{ij} and ε_{ijt} in equation (2) of the model. As the last column of Table 9 shows, the share of the hospital-specific effect in most cases ranges from to 12 to 40% of the total explained variance. Exceptions are the share of cancelled operations (43%), the share of (all) reoperations (69%), and the AMI-mortality rate within 30 days (52%). Furthermore, the coefficient estimates of 'scale' in Table 9 capture the relationship between the size of the patient sample used and the quality indicator's variance. Our expectation that the indicators based on larger patient samples are less volatile is confirmed for most quality dimensions.[††††††††]

<Table 6>

<Table 7>

<Table 8>

<Table 9>

6 Conclusions

This paper addresses the relationship between hospital competition and quality. Although the econometric literature about the effect of competition on hospital quality typically focuses on outcome indicators of quality, in our analysis we also include process indicators. We argue that the inclusion of process indicators contributes to a better understanding of the effects of competition on the strategies employed by hospitals. Since hospitals have more control over their processes rather than over the resulting health outcomes for patients (because the latter are also affected by patient conditions), the effect of competition may be more profound for process indicators. Indeed, we find a significant effect of competition between hospitals on nearly each process indicator included in the study, whereas we generally find no significant effect of competition on outcome indicators.

More specifically, it more competition decreases quality in terms of cancelled operations at short notice and delays on acute hip fracture injury operations to elderly patients, whereas it

[††††††††] Exceptions are the indicators of decubitus. The standard deviation of an indicator can increase with the size of the sample, if an indicator was initially available only for a targeted very homogeneous group of patients, but later become to be measured for a more diverse group of patients.

increases the frequency of tests on chronic patients and the share of the diagnoses of breast cancer completed within five days. This suggests that competition between hospitals places pressure on hospitals' profit margins, forcing them to employ strategies that improve their production efficiency. For example, one way to improve efficiency entails the more intensive use of hospital operation capacity, which may explain a greater proportion of cancellations at short notice and delays of hip fracture operations in more competitive areas. Furthermore, competition can provide hospitals with incentives to improve on quality indicators that can be easily observed by patients and perceived as a signal of quality, such as the time the patient has to wait for a diagnosis and check-up frequency for chronic patients.

Interestingly, we find a positive significant effect of time trend on several outcome indicators (Decubitus, AMI, reoperations), indicating that outcome quality has improved over time. A positive trend is also present in both indicators of cancelled operations and delayed hip fracture injury operations, thereby compensating for the negative effect of competition on these process indicators. Therefore, the country-wide institutional changes that increased competitive pressure in the hospital sector and brought more attention to quality during this period probably contributed to these quality improvements.

To cope with the possible selection effects in our sample, our modeling approach entails a joint estimation of the disclosure decision of quality indicators and the disclosed indicator values. Although for this particular data set, the coefficient estimates from the full bivariate model are close to those from a restricted model including two univariate equations, we argue that this generally should not be taken for granted in all institutional settings.

Moreover, the bivariate model both provides a better fit and offers the possibility for cross checking the interpretations of the effects found. Although we observe a gradual increase in the average disclosure rate of each indicator over the period considered, this does not seem to be driven by competitive pressure from the neighboring hospitals, but rather by the common belief that policymakers would enforce the disclosure of quality information in the future. Therefore, it seems that policy attention to quality was the major contributing factor to the increased openness over hospital quality in the Netherlands.

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Appendix A: Description of the Basis Data Set

Below, we provide a more detailed description on the indicators included in the analysis. Table A at the end of the section gives an overview of the complete questionnaire and data availability.

Decubitus

Decubitus prevalence (share of patients with decubitus at a particular moment in time) and incidence (share of patients with decubitus within a certain relatively homogeneous group of patients, hip fracture patients in this case) show the quality of nursing in the hospital. These data were collected in each year of the questionnaire aggregated over degrees 2-4 of decubitus.

Post-operation pain

Post operation pain reflects the quality as experienced by patients. Different definitions of the pain score were used in 2004-2006 (pain score below 4) and in 2007-2008 (pain score above 7). Therefore, we include three separate indicators on pain in the analysis: share of patients in the hospital recovery room who were asked about their pain on a regular basis, share with a pain score below 4, share with a pain score below 7.

Unplanned re-operations

Hospitals report the number of operations as well as the number of unplanned re-operations. The availability of indicators depends on the year of the questionnaire. In particular, the data were reported either at the overall hospital level (in 2004-2005), or for some types of operations (hernia in 2005-2006[31] and colorectal operations in 2006-2008).

Cancelled operations

This indicator accounts for cancellations of planned operations made at short notice (<24 hours in advance) and characterizes the quality of logistic processes. Both hospitals and patients can sometimes cancel operations. The number of operations cancelled by hospital is typically two or three times larger than the number of cancellations by patients. According to the Dutch Health Care Inspectorate, the inclusion of patient cancellations is important as well, since a patient is less likely to cancel if the hospital gives him a timely notice before the operation. Hence, we use the cumulative percentage of cancellations in the analysis.

Cardiology

In the data set, the quality in cardiology is reflected by readmissions for heart failures and mortality rates from acute myocardinfarct (AMI). Prior to 2007, the data on cerebrovascular accident (CVA) were collected as well, but the definition of this indicator has changed over the years. Therefore, we do not include CVA indicators in the analysis.

The data on readmissions for heart failure are available for all years, split by age groups: under 75 and above 75 years. Here we use an aggregated indicator that covers all ages. The AMI-mortality rates also cover all ages. In the first three years, hospitals were asked to

[31] According to the questionnaire of 2007, data on hernia reoperations should be also available in 2007, however, the definition for this type of reoperations was revised in that year. Since some hospitals have not adjusted the definition, the data of 2007 are inconsistent across hospitals. (Dutch Health Care Inspectorate, 2008)

report 30-day AMI mortality rates, but if that figure was not readily available, it was sufficient to report hospital AMI-mortality rates (i.e. mortality during hospital admissions). Most hospitals report the second indicator, some report both, and some report only the first indicator. Both indicators were included in the questionnaire of 2007, whereas only the hospital AMI-mortality rate was requested in 2008. Based on the data of 2007, for which both indicators are available, the difference between the two is very small. Therefore, in addition to regressions with hospital AMI mortality and 30-day AMI-mortality, we also consider a 'pooled AMI-indicator', which takes the value of 30-day AMI mortality where that was available, and otherwise, takes the value of hospital AMI mortality. Although the results with respect to quality levels measured by the pooled indicator should be interpreted with care, the indicator provides a correct picture on disclosure of AMI-mortality.

Diabetes Mellitus

Regular control procedures for diabetic patients, such as HbA1c- level tests and fundoscopies, allow doctors to reveal problems and timely prescribe medicines to maintain the health of patients. Therefore, the frequency of these checks can be an important process indicator on diabetes. We include data on the frequency of HbA1c-level tests and fundoscopy procedures.

Mamma tumor

The percentage of test outcomes that are ready within 5 days reflects the policlinic quality of the hospital. This indicator was collected in 2004-2006.

Hip fracture

Patients with hip fracture injuries operated within one day usually have better outcomes. Especially for elderly patients, the chance on healthy life after this operation depends on the time within which the patient has been operated. Therefore, the quality is measured by the share of patients aged 65+ operated within one day. This indicator is available for all years. The split by degree (1-2 and 3-5) is available in some cases, but not always, especially in the first years of the questionnaire. Therefore, we use cumulative figures for degrees 1-5.

<Table A>

Appendix B: Relative magnitude of the effect of competition on quality

<Table B>

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Tables

Table 1	Summary statistics on hospital specific factors, 2004-2008				
	Mean	St.D.	Min[a)]	Max	N.obs.
Number of beds	486	293	0	1368	499
Number of patients in the recovery room (over the year)	8242.26	6263.44	0	43008	379
Number of elective operations	11698.17	6311.64	688	43008	437
Level of intensive care (IC)	1.79	0.82	1	3	476
Number of intensivists at IC	4.35	5.57	0	39	466
Number of respiration days at IC	2252.04	2881.11	0	18673	380

[a)] Zero minimum values for the number of patients in the recovery room and intensive care variables can arise for some separate locations of hospitals having several locations. A zero minimum value for beds arises because some hospitals in our data set provide only aggregate number of beds, allocating them to the main location.

Table 2 Summary statistics of quality indicators, 2004-2008

Quality indicator	Type	Mean	St. D.	Min	Max	N
Decubitus						
(1- Prevalence)	Outcome	0.95	0.03	0.77	1.00	457
(1- Incidence)	Outcome	0.98	0.03	0.73	1.00	389
Pain						
Share of patients in the recovery room for whom the score was measured	Process	0.89	0.24	0.00	2.16	373
Share of patients with the pain score below 4	Outcome	0.83	0.17	0.07	1.00	151
Share of patients with the pain score below 7	Outcome	0.92	0.105	0.27	1.00	152
Cancelled operations: (1-Share of operations cancelled at short notice)	Process	0.98	0.01	0.93	1.00	401
Reoperations						
(1-Share of reoperations)	Outcome	0.99	0.02	0.89	0.99	103
(1-Share of reoperations hernia)	Outcome	0.94	0.05	0.79	1.00	170
(1-Share of reoperations colorectal)	Outcome	0.93	0.04	0.75	1.00	280
Heart failures: Share of patients without readmissions for heart failure	Outcome	0.91	0.06	0.50	1.00	429
AMI-mortality						
(1- AMI mortality during admission)	Outcome	0.94	0.03	0.84	1.00	323
(1- AMI mortality within 30 days)	Outcome	0.93	0.04	0.81	0.99	177
(1- AMI mortality pulled)	Outcome	0.93	0.04	0.81	1.00	441
Cholecystomy: (1-Share of gall duct injuries)	Outcome	0.99	0.01	0.93	1.00	450
Diabetes						
Number of HbA1c-tests per patient	Process	2.55	0.71	0.76	5.74	367
Number of fundoscopy procedures per patient	Process	0.79	0.21	0.00	1.89	384
Mamma tumor: Share with diagnoses within 5 days	Process	0.86	0.14	0.27	1.00	241
Hip fracture: Share of 65+ patients operated within 1 day	Process	0.83	0.12	0.22	1.00	452
Structure indicators						
Medication safety: share of shared information across sections	Structure	0.25	0.22	0.00	1.00	499
Infection registration: participation in the national registration	Structure	0.68	0.46	0.00	1.00	440
Complication registration: participation in the national registration	Structure	0.29	0.19	0.00	1.00	289

Table 3	Evolution of the rate of disclosure over the period 2004-2008				
Quality indicator	2004	2005	2006	2007	2008
Decubitus					
(1- Prevalence)	0.81	0.83	1.00	1.00	0.95[a)]
(1- Incidence)	0.44	0.66	0.93	0.93	0.96
Pain					
Share of patients in the recovery room for which the pain score was measured	0.40	0.61	0.88	0.94	0.93
Share of patients with the pain score below 4	0.26	0.51	0.72	n.a.	n.a.
Share of patients with the pain score below 7	n.a.	n.a.	n.a.	0.67	0.89
Cancelled operations: (1-Share of operations cancelled at short notice)	0.45	0.75	0.94	0.94	0.95
Reoperations					
(1-Share of reoperations)	0.41	0.57	n.a.	n.a.	n.a.
(1-Share of reoperations hernia)	n.a.	0.71	0.96	n.a.	n.a.
(1-Share of reoperations colorectal)	n.a.	n.a.	0.94	0.97	0.97
Heart failures: Share of patients without readmissions for heart failure	0.63	0.79	0.97	0.97	0.96
AMI-mortality					
(1- AMI mortality during admission)	0.33	0.35	0.72	0.92	0.95
(1- AMI mortality within 30 days)	0.37	0.48	0.38	0.53	n.a.
(1- AMI mortality pulled)	0.71	0.83	0.97	0.97	0.95
Cholecystomy: (1-Share of gall duct injuries)	0.74	0.84	0.98	0.99	0.97
Diabetes					
Number of HbA1c-checks per diabetic patient	0.42	0.61	0.73	0.96	0.97
Number of fundoscopy procedures per patient	0.48	0.70	0.85	0.86	0.96
Mamma tumor: Share of diagnoses within 5 days	0.71	0.81	0.86	n.a.	n.a.
Hip fracture: Share of 65+ patients operated within 1 day	0.82	0.87	1.00	0.95	0.90
Structure indicators					
Medication safety: share of shared information across sections	0.53	0.83	0.94	0.96	n.a.
Infection registration: participation in the national registration	0.61	0.82	1.00	0.99	1.00
Complication registration: participation in the national registration	n.a.	0.90	0.99	1.00	n.a.
Number of observations	99	108	97	96	99

[a)] The value for 2008 is lower than that in 2007 because extra observations were added in 2008 corresponding to separate locations.

Table 4 Competition indicators

Competition indicator	Mean	St. D.	Min	Max	N. Obs
A10: The number of hospitals within 10 km	1.60	2.21	0	8	499
A15: The number of hospitals within 15 km	2.97	3.38	0	12	499
A20: The number of hospitals within 20 km	4.66	4.23	0	15	499
B10: A10 divided by the population within 10 km	0.31	0.34	0	.97	499
B15: A15 divided by the population within 15 km	0.38	0.30	0	.88	499
B20: A20 divided by the population within 20 km	0.49	0.22	0	1.02	499
C: Distance to the closest competitor (in km)	11.57	7.61	0	36.17	499

Table 5 Correlations between competition indicators

	A10	A15	A20	B10	B15	B20	C
A10: The number of hospitals within 10 km	1						
A15: The number of hospitals within 15 km	0.92	1					
A20: The number of hospitals within 20 km	0.86	0.96	1				
B10: A10 divided by the population within 10 km	0.84	0.77	0.72	1			
B15: A15 divided by the population within 15 km	0.68	0.81	0.75	0.74	1		
B20: A20 divided by the population within 20 km	0.39	0.46	0.56	0.36	0.49	1	
C: Distance to the closest competitor (in km)	– 0.69	– 0.73	– 0.70	– 0.78	– 0.78	– 0.44	1

Table 6 Effect of competition on quality

	A10	A15	A20	B10	B15	B20	C
Decubitus							
(1- Prevalence)	– 0.230**	– 0.171***	– 0.137***	– 1.026**	– 2.039***	– 0.333	0.053*
	(0.093)	(0.051)	(0.040)	(0.508)	(0.527)	(0.745)	(0.028)
(1- Incidence)	0.030	0.011	0.002	0.120	0.311	– 0.114	– 0.007
	(0.060)	(0.039)	(0.034)	(0.436)	(0.466)	(0.731)	(0.018)
Pain							
Pain checks in the recovery room	0.997	0.503	0.389	4.575	4.749	18.742***	– 0.291*
	(0.610)	(0.410)	(0.341)	(3.510)	(4.467)	(6.095)	(0.170)
Pain score below 4	0.571	0.424	0.379	1.246	4.191	5.755	– 0.184
	(0.707)	(0.439)	(0.367)	(3.862)	(4.501)	(5.970)	(0.144)
Pain score below 7	0.151	0.116	0.141	– 0.750	0.024	3.069	– 0.040
	(0.618)	(0.373)	(0.296)	(4.231)	(3.813)	(4.469)	(0.151)
Cancelled operations	– 0.132***	– 0.089***	– 0.065***	– 0.531***	– 0.729***	– 0.974***	0.024***
(1-Share cancelled at short notice)	(0.020)	(0.011)	(0.009)	(0.133)	(0.148)	(0.239)	(0.006)
Unplanned reoperations							
(1– Share of reoperations)	0.010	– 0.001	0.000	– 0.182	0.141	0.034	0.003
	(0.047)	(0.029)	(0.023)	(0.261)	(0.362)	(0.579)	(0.015)
(1-Share of reoperations hernia)	0.213	0.117	0.094	1.449	0.444	3.208	– 0.040
	(0.221)	(0.137)	(0.104)	(1.113)	(1.403)	(2.123)	(0.064)
(1-Share of reoperations colorectal)	0.141	0.064	0.066	1.028	1.149	1.395	– 0.033
	(0.132)	(0.088)	(0.065)	(0.876)	(0.987)	(1.083)	(0.034)
Heart failure	0.047	– 0.005	0.042	0.565	0.066	2.139	0.026
No readmission for heart failure	(0.152)	(0.084)	(0.065)	(1.039)	(1.010)	(1.570)	(0.042)
AMI- mortality							
(1- AMI mortality pulled)	– 0.049	– 0.045	– 0.044	– 0.104	– 0.159	– 0.783	– 0.014
	(0.094)	(0.058)	(0.044)	(0.532)	(0.595)	(1.057)	(0.025)
(1- AMI mortality during admission)	– 0.091	– 0.071	– 0.039	– 0.473	– 0.652	– 1.004	0.014
	(0.096)	(0.061)	(0.047)	(0.627)	(0.697)	(1.213)	(0.032)
(1- AMI mortality within 30 days)	– 0.097	– 0.037	– 0.018	– 0.967	– 0.312	– 0.716	0.018
	(0.167)	(0.111)	(0.085)	(0.812)	(0.925)	(1.471)	(0.045)
Cholecystomy	– 0.006	– 0.004	– 0.010	0.004	– 0.062	– 0.115	– 0.002
No gall duct injury	(0.017)	(0.014)	(0.011)	(0.100)	(0.171)	(0.215)	(0.006)
Diabetes							
Number of HbA1c-tests per patient	0.037**	0.028***	0.024***	0.220**	0.242*	0.543***	– 0.014**
	(0.015)	(0.010)	(0.008)	(0.104)	(0.136)	(0.181)	(0.006)
Fundoscopy	1.027	0.587*	0.450*	(5.350	7.065*	6.078	– 0.305**
	(0.683)	(0.351)	(0.251)	(4.288)	(3.825)	(5.253)	(0.154)
Mamma tumor	1.151*	0.719**	0.444*	7.429**	6.386*	1.668	– 0.229
Share of diagnoses within 5 days	(0.601)	(0.346)	(0.263	(3.058)	(3.309)	(5.480)	(0.145)
Hip fracture							
Share of 65+ patients operated	– 0.740*	– 0.560**	– 0.410**	– 4.179*	– 5.731*	– 0.928	0.089
within 1 day	(0.404)	(0.268)	(0.205)	(2.404)	(3.243)	(3.296)	(0.110)

All the quality indicators except for the first indicator on Diabetes have been expressed as percentages.

The stars indicate the significance levels: * 90%; **95% and ***99%.

Table 7 Results for the effects of control variables on quality (competition measure B10)

	Constant	Beds	Elective operations	Patient number	IC-intensivists	Teaching dummy	Time trend	Mortality
Decubitus								
(1- Prevalence)	91.158***	– 1.634	0.000	0.001***	0.000	0.286	0.683***	0.239
	(1.775)	(1.107)	(0.001)	(0.000)	(0.001)	(0.741)	(0.089)	(0.184)
(1- Incidence)	92.469***	– 0.341	0.000	0.000	0.001	0.993***	0.493***	0.100
	(1.177)	(0.489)	(0.001)	(0.000)	(0.001)	(0.382)	(0.120)	(0.141)
Pain								
Pain checks in the recovery room	34.749***	8.517	– 0.002	– 0.204	– 0.007	1.898	2.680**	0.936
	(8.890)	(9.250)	(0.005)	(0.219)	(0.020)	(4.193)	(1.111)	(0.870)
Pain score below 4	71.149***	– 5.459	0.014***	0.006	– 0.001	4.046	– 0.002	– 0.829
	(10.057)	(4.893)	(0.003)	(0.007)	(0.004)	(2.675)	(2.015)	(1.159)
Pain score below 7	56.194**	– 0.689	0.000	0.001	– 0.002	0.538	2.131	– 0.095
	(23.902)	(5.317)	(0.011)	(0.009)	(0.038)	(2.833)	(2.842)	(0.682)
Cancelled operations	95.759***	– 1.128***	0.044***	0.000	0.000	– 0.469***	0.093**	0.062
(1-Share cancelled at short notice)	(0.487)	(0.165)	(0.009)	(0.000)	(0.000)	(0.111)	(0.042)	(0.051)
Unplanned reoperations								
(1– Share of reoperations)	96.181***	– 1.414**	0.000	0.000	– 0.001	– 0.355	0.017	– 0.075
	(0.965)	(0.639)	(0.000)	(0.000)	(0.001)	(0.387)	(0.268)	(0.085)
(1-Share of reoperations hernia)	88.200***	1.688	0.003	– 0.001	– 0.002	– 0.666	3.290***	– 0.387
	(3.013)	(1.612)	(0.003)	(0.001)	(0.002)	(1.160)	(0.632)	(0.320)
(1-Share of reoperations colorectal)	90.036***	– 0.789	– 0.001	0.000	– 0.004	– 0.714	0.434*	– 0.097
	(3.226)	(1.341)	(0.002)	(0.001)	(0.004)	(0.780)	(0.248)	(0.315)
Heart failure	85.434***	2.408*	– 0.002*	0.000	0.003***	– 1.186	0.445**	– 0.032
No readmission for heart failure	(2.504)	(1.378)	(0.001)	(0.001)	(0.001)	(0.779)	(0.220)	(0.238)
AMI- mortality								
(1- AMI mortality pulled)	92.529***	0.265	0.000	0.000	0.000	0.491	1.117***	– 0.415***
	(1.326)	(0.769)	(0.000)	(0.000)	(0.001)	(0.593)	(0.107)	(0.161)
(1- AMI mortality during admission)	92.845***	0.474	0.001**	– 0.001	0.001	0.209	1.122***	– 0.408**
	(1.610)	(0.838)	(0.001)	(0.001)	(0.001)	(0.594)	(0.129)	(0.175)
(1- AMI mortality within 30 days)	93.815***	0.585	– 0.001	0.001*	– 0.001	– 0.032	0.936***	– 0.767***
	(1.863)	(1.253)	(0.001)	(0.001)	(0.001)	(0.915)	(0.239)	(0.238)
Cholecystomy	92.655***	– 0.251*	0.000**	0.000	0.000	0.107	0.060**	– 0.001
No gall duct injury	(0.123)	(0.134)	(0.000)	(0.000)	(0.000)	(0.081)	(0.027)	(0.030)
Diabetes								
HbA1c-checks per patient	2.225***	0.355*	0.000	0.000	0.000	0.010	0.044*	– 0.038
	(0.298)	(0.198)	(0.000)	(0.000)	(0.000)	(0.130)	(0.024)	(0.031)
Fundoscopy	43.799***	3.786	0.005	0.003	0.002	– 6.572	1.359	1.569
	(11.073)	(7.210)	(0.004)	(0.004)	(0.008)	(4.153)	(0.917)	(1.122)
Mamma tumor	83.951***	– 2.131	0.001	0.004	0.002	– 0.369	– 0.803	– 1.567*
Share of diagnoses within 5 days	(10.557)	(4.837)	(0.003)	(0.002)	(0.005)	(2.851)	(1.599)	(0.941)
Hip fracture								
Share of operations of 65+ patients	82.471***	– 7.317	0.003	0.001	0.002	1.092	0.702*	– 0.495
within 1 day	(6.833)	(4.550)	(0.002)	(0.001)	(0.003)	(2.477)	(0.412)	(0.713)

All the quality indicators except for the first indicator on Diabetes have been expressed as percentages.
The stars indicate the significance levels: * 90%; **95% and ***99%.

Table 8 Results for the disclosure equation (competition measure B10)

	B10	Beds	Elective oper.	Patient number	IC-inten-sivists	Teaching dummy	Time trend	Mortality
Decubitus								
(1- Prevalence)	2.754	1.592	0.002**	0.000	0.001	– 0.605	0.460	– 0.097
	(2.053)	(1.067)	(0.001)	(0.001)	(0.001)	(0.780)	(0.642)	(0.303)
(1- Incidence)	0.806	– 0.723	0.001***	0.001**	0.001	0.127	0.322	– 0.007
	(1.353)	(0.832)	(0.000)	(0.000)	(0.001)	(0.471)	(0.227)	(0.165)
Pain								
Pain checks in the recovery	0.288	– 0.705	– 0.024	0.290	– 0.005	– 1.719	0.970	– 0.505
	(50.321)	(7.942)	(0.333)	(0.499)	(0.431)	(3.707)	(2.519)	(1.081)
Pain score below 4	– 0.386	0.508	0.001	0.002***	0.000	– 0.574	0.153	0.321*
	(1.078)	(0.839)	(0.001)	(0.000)	(0.001)	(0.506)	(0.244)	(0.164)
Pain score below 7	0.313	0.916	0.001	0.001	0.002	– 0.703	1.367**	– 0.125
	(1.436)	(1.213)	(0.001)	(0.001)	(0.004)	(0.709)	(0.660)	(0.234)
Cancelled operations	– 1.416	– 0.850	0.049	0.000	0.000	0.002	0.654*	0.068
(1-Share cancelled)	(1.827)	(1.441)	(0.069)	(0.001)	(0.001)	(0.853)	(0.356)	(0.253)
Unplanned reoperations								
(1– Share of reoperations)	– 0.507	0.599	0.001	0.000	0.001	– 0.791	0.318	– 0.058
	(1.289)	(0.921)	(0.001)	(0.000)	(0.001)	(0.588)	(0.543)	(0.226)
(1-Share of reoper. hernia)	0.009	0.078	0.002**	0.000	0.000	– 1.259	1.062	– 0.077
	(1.645)	(1.212)	(0.001)	(0.001)	(0.001)	(0.885)	(0.886)	(0.316)
(1-Share of reoper. colorectal)	– 0.950	1.043	0.005	– 0.001	0.003	– 0.439	0.021	– 0.398
	(3.715)	(4.373)	(0.004)	(0.007)	(0.009)	(3.809)	(3.785)	(0.816)
Heart failure	– 0.225	0.756	0.000	0.001**	0.001*	– 0.558	0.358	– 0.055
No readmission	(1.146)	(0.746)	(0.000)	(0.000)	(0.001)	(0.484)	(0.347)	(0.213)
AMI- mortality								
(1- AMI mortality pulled)	1.592	0.834	0.001**	0.001**	0.001	– 0.617	– 0.110	0.052
	(1.647)	(1.024)	(0.001)	(0.001)	(0.001)	(0.561)	(0.381)	(0.235)
(1- AMI mortality during adm.)	– 0.775	0.710	0.000	0.000	0.001	– 0.398	0.462**	0.074
	(1.132)	(0.573)	(0.000)	(0.000)	(0.001)	(0.377)	(0.184)	(0.155)
(1- AMI mortality within 30	1.492	0.817	0.000	0.001**	0.000	– 0.870*	– 0.171	– 0.142
	(1.105)	(0.869)	(0.000)	(0.000)	(0.001)	(0.508)	(0.253)	(0.126)
Cholecystomy	2.615*	– 0.007	0.001**	0.000	0.002**	– 1.189**	0.310	– 0.291
No gall duct injury	(1.503)	(0.837)	(0.001)	(0.001)	(0.001)	(0.568)	(0.391)	(0.234)
Diabetes								
HbA1c-checks per patient	0.991	– 0.018	0.001	0.000	0.001*	0.364	0.340*	– 0.012
	(1.043)	(0.617)	(0.000)	(0.000)	(0.001)	(0.383)	(0.205)	(0.129)
Fundoscopy	0.084	– 0.253	0.001**	0.001	0.001	– 0.173	0.225	0.133
	(1.097)	(0.692)	(0.000)	(0.000)	(0.001)	(0.427)	(0.261)	(0.130)
Mamma tumor	1.666	– 1.488	0.001**	0.000	0.001	0.491	– 0.051	– 0.079
Share of diagnoses within 5 d.	(1.706)	(1.126)	(0.001)	(0.001)	(0.001)	(0.787)	(0.524)	(0.231)
Hip fracture								
Share of 65+ patients	0.015	– 1.477	0.001**	0.000	0.002**	0.101	– 0.238	0.090
operated within 1 day	(1.868)	(1.709)	(0.001)	(0.001)	(0.001)	(1.017)	(0.524)	(0.274)

The stars indicate the significance levels: * 90%; **95% and ***99%.

Table 9 Estimates of the other model parameters (competition measure B10)

	Sigma σ_{0j}^{2}	Scale $\alpha(j)$	$\ln[p_{bb}/(1-p_{bb})]$	u^{b} (disclosure)	v^{b} (quality)	Share of hospital specific effect
Decubitus						
(1- Prevalence)	0.910***	– 0.191***	– 0.809	– 1.896	2.084***	0.12
	(0.028)	(0.046)	(0.700)	(1.864)	(0.415)	
(1- Incidence)	0.829***	– 0.591***	– 1.758***	0.064	4.099***	0.15
	(0.038)	(0.053)	(0.564)	(0.650)	(0.346)	
Pain						
Pain checks in the recovery room	2.902***	– 0.267***	– 1.662***	– 2.152	41.972***	0.34
	(0.029)	(0.030)	(0.567)	(10.409)	(2.664)	
Pain score below 4	2.315***	– 0.254***	– 2.192***	– 1.167	25.639***	0.22
	(0.084)	(0.039)	(0.788)	(1.917)	(3.494)	
Pain score below 7	2.148***	0.073	– 3.113	– 0.141	30.242*	0.35
	(0.095)	(0.051)	(1.930)	(4.155)	(15.623)	
Cancelled operations	– 0.042	– 0.171**	– 1.725***	– 1.070	2.335***	0.43
(1- Share cancelled)	(0.034)	(0.082)	(0.352)	(1.136)	(0.102)	
Unplanned reoperations						
(1- Share of reoperations)	– 0.014	0.425**	– 1.478*	2.473	3.831***	0.69
	(0.093)	(0.201)	(0.840)	(1.809)	(0.468)	
(1- Share of reoperations hernia)	1.272***	– 0.314***	– 0.732	– 1.535	4.148***	0.21
	(0.092)	(0.118)	(1.066)	(2.169)	(0.900)	
(1- Share of reoperations colorec.)	1.129***	0.005	– 0.485	2.496	4.156***	0.30
	(0.046)	(0.089)	(0.387)	(2.367)	(0.588)	
Heart failure	1.473***	– 0.422***	– 1.291***	0.499	5.052***	0.15
No readmission for heart failure	(0.027)	(0.029)	(0.420)	(0.722)	(1.005)	
AMI– mortality						
(1- AMI mortality pulled)	0.940***	– 0.178***	– 0.220	– 0.613	3.224***	0.27
	(0.037)	(0.057)	(0.363)	(0.935)	(0.291)	
(1- AMI mortality during admission)	0.827***	– 0.270***	– 0.194	0.000	2.812***	0.25
	(0.050)	(0.072)	(0.397)		(0.317)	
(1- AMI mortality within 30 days)	0.916***	– 0.012	– 0.364	1.558*	5.444***	0.53
	(0.069)	(0.088)	(0.381)	(0.866)	(0.588)	
Cholecystomy	– 0.401***	– 0.517***	– 4.718	– 2.098	6.599***	0.41
No gall duct injury	(0.024)	(0.073)	(4.442)	(163.524)	(0.123)	
Diabetes						
HbA1c- checks per patient	– 0.580***	– 0.215***	0.842***	0.346	0.902***	0.34
	(0.029)	(0.048)	(0.284)	(0.478)	(0.070)	
Fundoscopy	2.888***	0.082**	– 1.292***	0.158	23.763***	0.23
	(0.024)	(0.042)	(0.408)	(0.756)	(3.095)	
Mamma tumor	2.458***	– 0.123*	– 1.497**	2.294**	17.973***	0.25
Share of diagnoses within 5 days	(0.045)	(0.067)	(0.684)	(0.981)	(4.889)	
Hip fracture						
Share of 65+ patients operated	2.344***	0.046	– 0.866*	– 0.696	12.177***	0.22
within 1 day	(0.029)	(0.042)	(0.461)	(1.134)	(1.535)	

The stars indicate the significance levels: * 90%; **95% and ***99%.

Table A Data availability: the indicators in each category and their availability in 2004-2008

Indicator [a)]	Data availability
Hospital-wide indicators	
Decubitus	Prevalence of decubitus degree 2-4 (2004-2008) Incidence decubitus for hip patients (2004-2008)
Medication safety	11 subindicators of the availability of information (2004-2007) They concern *clinically* prescribed medications (in policlinics, nursing sections, pharmacies, outside the hospital); *policlinically* prescribed medications (in policlinics, nursing sections, pharmacies, outside the hospital); and *externally* prescribed medications (in policlinics, nursing sections, pharmacies). These are structure indicators, hence, not included in the analysis.
ICT	18 sub-indicators of the availability of electronic data (2004-2008) They show the availability in the *policlinic* and in the *department of* administrative data; namely, laboratorial data; external correspondence; radiology; bacteriology; PA; medical data; operation reports; photo's such as X-ray). These are structure indicators, hence, not included in the analysis.
Blood-transfusion reaction registration	Indicator of participation in the TRIP-registration (2004-2006) This is a structure indicator, hence, not included in the analysis.
Wound infection registration	Indicator of participation in the registration system PREZIES measurement of incidence. This is a structure indicator, hence, not included in the analysis.
Complication registration	Indicator of the scope of specialisms for which the hospital participates in the national registration and/or owns its own registration of complications. This is a structure indicator, hence, not included in the analysis.
High-risk treatments	
Post-operation pain	Share of post-operative patients for whom the score was measured within 72 h (2004-2008) Share with a systematically-measured score below 4 (2004-2006) Share with a systematically-measured score above 7 (2007-2008) Split between recovery and nursery is available in some cases.
Cholecystectomy	Share of patients with gall duct injuries after cholecystectomy operations (2004-2008)
Unplanned reoperations	Share of unplanned reoperations (2004-2005) Share of unplanned reoperations for hernia (2005-2006) Share of unplanned colorectal reoperations (2006-2008)
Cancelled operations	Share of operations cancelled by hospital within 24 hours before the operation (2004-2008) Share of operations cancelled by patients within 24 hours before the operation (2004-2008)
Volume of high-risk interventions	The number of two types of operations (AAA and OCR) Not included in the analysis, since the relationship with quality is not straightforward.

Intensive care (IC)	The level of IC; the number of artificial respiration days per patient; and the number of intensivists f.t.e. This indicator is included as a control variable.
Special treatments	
Diabetes mellitus	Tests HbA1c: Number of patients, number of measurements, and the sum of the values. Fundoscopy: Number of checks per patient (2004-2008)
Cardiology	Share of readmissions for heart failure for patients under and above 75 years (2004-2008) 30-day AMI-mortality rates (split under and above 65 years) AMI-mortality during admission
Hip fracture	Share of 65+ patients operated within one day (2004-2008)
Mamma tumor	Share of diagnoses on which the results were available within 5 days (2004-2006).
Pregnancy	The respective indicator, called VOKS-score (from 'Verloskundige Onderlinge Kwaliteitsverspigeling' in Dutch), has been reported inconsistently (Van den Berg et al., 2009, p.119), hence, not included in the analysis.

[a] We leave out the three indicators introduced in the last two years of the questionnaire (Undernourishment, Cataract and Child Surgery).

Table B **Magnitude of the effect of competition expressed in terms of standard deviations of indicators**

Quality indicator	A10	A15	A20	B10	B15	B20	C
Decubitus							
Share of patients checked	0.13	0.18	0.12	0.01	0.12	0.09	0.09
(1- Prevalence)	0.59**	0.66***	0.66***	0.32**	0.58***	0.11	0.62*
(1- Incidence)	0.07	0.04	0.01	0.04	0.08	0.04	0.08
Pain							
Pain checks in the recovery room	0.334	0.25	0.24	0.18	0.17	0.79***	0.43*
Pain score below 4	0.26	0.29	0.33	0.07	0.21	0.34	0.38
Pain score below 7	0.11	0.13	0.20	0.07	0.00	0.29	0.14
Cancelled operations							
(1-Share cancelled)	0.76***	0.76***	0.69***	0.37***	0.46***	0.71***	0.61***
Reoperations							
(1-Share of reoperations)	0.05	0.01	0.25	0.09	0.42	0.02	0.07
(1-Share of reoperations hernia)	0.36	0.30	0.30	0.30	0.08	0.70	0.31
(1-Share of reoperations colorectal)	0.30	0.25	0.27	0.26	0.30	0.41	0.32
Heart failures							
No readmissions for heart failure	0.07	0.01	0.11	0.10	0.01	0.39	0.17
AMI-mortality							
(1- AMI mortality pulled)	0.12	0.16	0.20	0.03	0.04	0.24	0.15
(1- AMI mortality during admission)	0.18	0.21	0.16	0.11	0.15	0.28	0.10
(1- AMI mortality within 30 days)	0.22	0.13	0.08	0.27	0.08	0.21	0.19
Cholecystomy							
No gall duct injury	0.06	0.07	0.19	0.00	0.07	0.15	0.08
Diabetes Mellitus							
Number of HbA1c-tests per patient	0.41**	0.48***	0.51***	0.30**	0.30*	0.78***	0.71**
Fundoscopy	0.40	0.34*	0.33*	0.25	0.30*	0.30	0.53**
Mamma tumor							
Share of diagnoses within 5 days	0.67*	0.63**	0.49*	0.53**	0.41*	0.12	0.60
Hip fracture							
Share of 65+ patients operated within 1 day	0.49*	0.55**	0.50**	0.33*	0.41*	0.08	0.26

The magnitude of the effect is computed as the maximum value of the competition indicator multiplied by the absolute value of the coefficient and divided by the standard deviation of the quality indicator.

The stars indicate the significance levels: * 90%; **95% and ***99%.