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by
Søren Rud Kristensen[a,c], Eduardo Fé[b], Mickael Bech[c], Jan Mainz[c]
[a]Centre for Health Economics, University of Manchester, U.K.
[b]Health Economics Research Centre, University of Oxford, U.K
[c]COHERE, University of Southern Denmark, Denmark

COHERE, Department of Business and Economics
Faculty of Business and Social Sciences
University of Southern Denmark
Campusvej 55
DK-5230 Odense M
Denmark
www.cohere.dk

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Søren Rud Kristensen[a,c,*], Eduardo Fé[b], Mickael Bech[c], Jan Mainz[c]

[a] *Centre for Health Economics, University of Manchester, U.K.*
[b] *Health Economics Research Centre, University of Oxford, U.K.*
[c] *COHERE, University of Southern Denmark, Denmark.*

Abstract

This paper estimates the price sensitivity of the quality of acute stroke care using a regression kink design. When Danish hospitals reach a production target, marginal tariffs for treating acute stroke patients falls by 50%–100%. This reimbursement scheme allow us to identify local average treatment effects of reimbursement tariffs on the quality of hospital care. A rich data set of the process quality of stroke care allows us to detect minor changes in the quality of care that are important for the long term outcomes but do not lead to dead or readmission captured by commonly employed outcome indicators. Hospitals that were exposed to reductions in the marginal tariff of less than 100% did not appear to respond in quality to reductions in tariffs. Hospital for which the marginal tariff for acute stroke patients dropped to 0 responded to tariff reductions by slightly decreasing the level of quality for acute stroke care patients. The estimated size of the effect is minor but robust to various tests of sensitivity, indicating that the estimated effect is not spurious.

Keywords:
Quality of health care, Price regulation, Activity based reimbursement, Supply side incentives
JEL classification: I1, L5, H4

*Correspondence to: Søren Rud Kristensen, Manchester Centre for Health Economics, University of Manchester, Oxford Road, Manchester M13 9PL, United Kingdom
Email address: soren.kristensen@manchester.ac.uk (Søren Rud Kristensen)

1. Introduction

Pay for performance (P4P) schemes that link financial bonuses to hospitals' performance on specific quality indicators are currently subject of much research and popular among policy makers, despite lack of evidence about the (cost) effectiveness of such schemes (Rosenthal and Frank, 2006; Maynard, 2012). However, quality related payments make out only a small percentage of hospital reimbursement, while the bulk of hospital reimbursement in most developed countries is distributed through so called activity based reimbursement (ABR) schemes that link hospital reimbursement to activity through a fixed tariff per admission (Paris et al., 2010).

ABR relies on classifications of hospital activity into diagnosis related groups (DRGs) that are unrelated to the level of quality provided. Considering the recent research and policy interest in understanding how higher quality of care can be incentivised, understanding the sensitivity of hospital care quality to changes in the marginal per admission tariff paid in ABR schemes is thus an important albeit somewhat neglected topic.

A possible reason for the lack of research into the impact of changes in the marginal tariff in ABR schemes on the hospital care quality is the lack of data to address the question. To assess how reductions in the marginal tariff affect the quality of the care, this paper takes advantage of a special design feature of the ABR scheme covering all public Danish hospitals (the only providers of stroke treatment in Denmark) and utilise the availability of detailed data on the quality of acute stroke care at these hospitals.

We consider a payment scheme in which tariffs are volume dependent. All hospitals we observe are given a yearly hospital wide production target and are reimbursed by one tariff per admission within this target. The marginal tariffs for production beyond the target, are decreased by 55%–100% until the end of the financial year when a new production target is set and the hospital is again reimbursed by the full tariff. This reimbursement design allows us to identify local average treatment effects of the change in marginal tariffs on the quality of care using a kinked regression design (Card et al., 2009; Dong, 2011) that seeks to identify a kink in the relationship between quality and reimbursement at the point in time when the marginal tariff for treatment is reduced.

Volume dependent tariffs can be seen as an attempt to counteract the potentially uncontrollable macro level costs at in open-ended systems that base their hospital reimbursement on activity (Jegers et al., 2002; Street

et al., 2011). Expectations of decreasing marginal costs for higher levels of production has been suggested as a further justification for volume dependent pricing (Street et al., 2011). The regional and temporal variation of the tariff reductions in our data allow us to explore this hypothesis by testing whether the impact of a tariff reduction on quality increase with the size of the tariff reduction.

The obvious mechanism guarding against quality reductions following of price reductions is patient demand (Pope, 1989; Allen and Gertler, 1991; Hodgkin and McGuire, 1994; Rogerson, 1994; Ma, 1994). However, if demand is inelastic with respect to quality, either because of information asymmetries (Arrow, 1963) or when the acute nature of a condition makes hospitals de facto local monopolists, depending on the level of altruism of the provider (on this issue, see also Newhouse, 1970), ABR schemes provide hospitals with cost reduction incentives that may lead to reductions in quality (Chalkley and Malcomson, 1998).

While one of our reasons for choosing acute stroke care for our analysis is its insensitivity of demand with respect to quality, acute stroke is also the second most common cause of death in the world, causing 9 percent of worldwide deaths and 10-12 percent in western countries and thus an important topic in itself. It is the sixth most common cause of reduced disability-adjusted life years, and the costs of acute stroke to society has been estimated to be US$ 100 per capita per year for the U.S.(Donnan et al., 2008). In the U.K. the estimated annual cost of stroke to society is GBP 8.9 billion, with treatment costs accounting for approximately 5% of total UK National Health Service expenditure (Saka et al., 2009)

We operationalise the quality of stroke care using a unique data set of 9 evidence based process indicators. The indicators have been developed according to national clinical practice guidelines by an interdisciplinary national panel of physicians, nurses, physiotherapists and occupational therapists appointed by the scientific societies and professional associations in Denmark. Commonly used outcome measures such as mortality or readmission rates may be too crude to pick up smaller changes in quality that are important for long term outcomes but do not lead to death or re-hospitalisation. For example, early initiation of rehabilitation has been shown to be associated with better outcomes in functional performance after a stroke (Ottenbacher and Jannell, 1993), but a delayed rehabilitation effort is unlikely to manifest in 30-day mortality rates. Our detailed data on processes of care allow us to detect minor changes in processes that may lead to important but difficult-to-

measure differences in outcome. It is mandatory for all clinical departments in Denmark, treating patients with stroke, to report data to the database, the database completeness is high (approximately 90 %) and hospitals cannot reject to treat stroke patients, so selection bias is not a concern.

Our findings suggest that hospitals do not seem to respond to tariff reductions of 50-86%. However, for hospitals for which the marginal tariff for treating patients above the production target falls to zero, we do find some evidence of minor reductions in the process quality of care. The results are robust to inclusion of patient characteristics and choice of bandwidth and when examining the effect of the tariff increase that occurs at the start of a new financial year we find a corresponding increase in the level of quality provided.

2. Previous research on quality and ABR

When ABR was introduced, a substantial body of research compared the effects of fixed, prospectively set, per admission tariffs with the cost reimbursement or global budget schemes that ABR replaced, on a range of crude measures of quality. These studies found strong evidence to suggest that the introduction of ABR led to decreasing length of stay (e.g. Giammanco, 1999; Gilman, 2000; Sood et al., 2008). A number of studies found no significant effect on readmission rates (DesHarnais et al., 1987; Kahn et al., 1990; Farrar et al., 2009) while some studies found an increase in readmissions (Giammanco, 1999; Shmueli et al., 2002) and others (Cutler, 1995) found a decline in readmissions following average price reductions but an increase associated with the elimination of marginal reimbursement. A few studies have found an increase in mortality after the introduction of ABR (Cutler, 1995; Shen, 2003; Qian et al., 2007) some found no effect (DesHarnais et al., 1987, 1988; Shmueli et al., 2002; Picone et al., 2003; Sood et al., 2008; Kuwabara and Fushimi, 2009) and some found a reduction in mortality (Long et al., 1987; DesHarnais et al., 1990; Kahn et al., 1990; Farrar et al., 2009).

This paper is concerned with the effect of changes to the internal incentives in ABR schemes instead of the effect of shifts in reimbursement scheme addressed by the literature cited above. Our paper is thus closer related to the few studies (Seshamani et al., 2006b,a; Lindrooth et al., 2006; Wu and Shen, 2011) that have previously examined the effect of the U.S. Balanced Budget Act (BBA) of 1997 which substantially reduced Medicare payments. Lindrooth et al. (2007) found that price cuts in Medicare payments intro-

duced by the BBA led not-for-profit hospitals to decrease treatment intensity for profitable treatments in 50th 75th and 95th quantiles of treatment intensity. They found no statistically significant effect of the price cut in public and for-profit hospitals. Wu and Shen (2011) studied the impact of the same reform focusing on the long term effects on structure, process and outcome quality. They found no effects on in-hospital acute myocardial infarction (AMI) mortality Outcomes were found not to be affected in the early years after the reform, but the study identified an increase in 7- 30- and 90-day and 1 year AMI mortality rates from 2001-2005 in hospitals that experienced large and medium price cuts. Wu and Shen found evidence that this effect was explained by reductions in staffing levels and operating costs. But the BBA did not change marginal reimbursement per se, but eliminated the remaining cost reimbursement components of the Medicare ABR schemes. Furthermore, since Medicare is not the only payer at U.S. hospitals, payment reductions such as those introduced by the BBA can be passed on to other payers. Such cost-shifting was indeed found to follow the BBA reimbursement reform (Wu, 2010).

3. Volume dependent prices in Danish hospital reimbursement

Danish public hospitals account for approximately 97% of total hospital activity in Denmark and are the only providers of stroke treatment (Christiansen and Bech, 2013). The public hospitals are owned and reimbursed for their services by five regions, each serving a population of between 0.6 and 1.7 million inhabitants. The regions cannot levy taxes but are financed by government grants and activity dependent payments from the local governments within the regions' geographical boundaries (Christiansen, 2012). Each region is free to design its own hospital reimbursement scheme, but at least 50% of the total hospital funding must be distributed on the basis of activity as measured by the Danish version of the diagnosis related groups (DRG) system for inpatients and the outpatient equivalent, the Danish ambulatory grouping system (DAGS) .

All regions have chosen some form of volume dependent price setting in which, for a specific diagnosis group, k, a hospital's revenue function at time t is given by

$$R_{k,t} = \begin{cases} p^0_{k,t} q_{k,t} & t < t^* \\ p^0_{k,t} q_{k,t^*} + p^1_{k,t}(q_{k,t} - q_{k,t^*}) & t \geq t^*. \end{cases} \tag{1}$$

Region	2007	2008	2009	2010
Northern Jutland	.20	.20	.20	.20
Central Denmark	0	0	0	0
Southern Denmark	.14	.14	0	0
Zealand	.55	.55	.55	.55
Capital	.50	.50	.50	.50

Table 1: Proportion of national tariff paid for production beyond the baseline, by region and year.
Note: The table displays the proportion of the nation DRG tariff paid for acute stroke patients treated after hospitals reached the production target (baseline).

In the above equation $q_{k,t}$ is the accumulated level of production in group k at time t, p_k^0 is the corresponding reimbursement rate for production below a prospective activity target (known as the *baseline* and expressed in the monetary value of production at the national tariff) $\bar{r}$ and p_k^1 is the tariff for production above the target. Here, t^* denotes the time period when $\sum_k p_{k,t}^0 q_{k,t} = \bar{r}$. The baseline is usually set on the basis of previous years' production or last years' baseline plus a required productivity increase of 2–6 percent.

The regional reimbursement schemes and the share of the national tariff paid to the hospital for production above the baseline are summarised in Table 1. For example, hospitals in the Capital Region were paid 50 % of the national tariff for production above the hospital baseline in all years included in the study, while hospitals in Southern Denmark were paid 14 % of the national tariff in 2007 and 2008 and were not reimbursed for acute patients in 2009 and 2010[1].

4. Data and methods

4.1. Measuring the quality of acute stroke care

Our measure of quality is an index based on 9 process indicators recorded at individual level for 46,145 acute stroke patients treated at Danish hospitals

[1]To illustrate, in 2009 the national tariff for thrombolysis treatment of acute stroke care was DKK 82,452, but if the patient was treated at a hospital in the Region of Northern Jutland after the hospital had crossed the baseline, according to the reimbursement scheme the hospital would receive DKK 16,490 for treating the patient.

between 1 January 2007 and 31 December 2010. Of these, 17,806 observations were dropped due to missing or inaccurate information (detailed in the next section). The data was collected by the Danish National Indicator Project (DNIP). It is mandatory for all clinical departments in Denmark treating patients with stroke to participate in the project, and the database completeness is high at approximately 90%.

The DNIP quality indicators have been developed according to national clinical practice guidelines by an interdisciplinary national panel of physicians, nurses, physiotherapists and occupational therapists appointed by the scientific societies and professional associations (See Mainz et al., 2004, for a decription of indicator selection process and Appendix A.4 for a full description of the indicators). Hospital level performance on the indicators is made publicly available on the internet as the percentage of patients receiving the different processes at each hospital, but hospital reimbursement is not linked to performance on the indicators.

Each indicator reflects an intervention, and the interventions can be thought of as dimensions of the quality of stroke care. As the indicators reflect national clinical practice guidelines, it is expected that all patients receive all the interventions reflected by the indicators. For each indicator, hospitals report their successfulness in delivering the intervention to each patient, or that the indicator is not clinically relevant to the specific patient according to criteria set out by the indicator panel. In addition, a date variable specifies which date the indicator was achieved. The latter variable is used for assessing whether performance is within targets specified in the indicator guidelines from DNIP.

We focus our analysis on an index measure of quality, intended to measure the average level of quality provided at hospital h at time (day) t:

$$Y_{ht} = \frac{\sum_{ht}(D_{iht}/A_{ikt})}{\sum_{ht} N_{ht}} \tag{2}$$

with A_{iht} bthe sum of all clinically relevant binary process indicators related to quality for patient i, D being the sum of processes delivered to the patient and N being the number of patients. [2] Summary statistics for each of the indicators are presented in Table A.5.

[2]As shown by Gravelle et al. (2010), indicators that allow hospitals to report certain processes as irrelevant can be gamed by increasing the number of process deemed clinically irrelevant. We have examined whether changes in the reimbursement was associated with

4.2. Hospital production and baseline

To identify the time when the hospitals in our sample cross their individual baselines $\sum_k q_{k,t} = \bar{q}$ and marginal tariffs are reduced, we calculate the accumulated revenue measured by the DRG/DAGS-value of production by hospital by day in the financial year that runs from January 1st to December 31st. As a new baseline is set for each hospital each year, on the 1st of January, the variable is reset to zero. To construct this variable we obtained data from administrative datasets on all somatic inpatients and outpatients treated at all Danish hospitals treating acute stroke patients from January 2007 to December 2010. In total this corresponds to more than 40 million observations[3] from patients treated at 33 hospitals for which we could obtain a baseline for at least one year of 2007-2010[4]

For each patient we obtained information on DRG/DAGS-price, discharge date for inpatients, and date of visit for outpatients. We accumulated the DRG/DAGS-value for each patient by hospital by day. When multi-site hospitals operated under a collective baseline, observations were merged accordingly. We could thus trace hospital revenue over time and determine at which date the hospital crossed the baseline. This enabled us to assign the information on quality through each patients admission date in the DNIP data set.

For a given patient we know on which side of the baseline the patient was treated and thus whether the hospital was reimbursed for that patient at full p_k^0 or the reduced p_k^1 tariff. Where possible, we validated our computation of

a change in the exception reporting or missingness of individual indicators but did not find that to be the case. The results are available from the authors on request.

[3]The large number of records is due to the structure of the administrative data set in which one hospital visit may be recorded as more than one observation

[4]Adjustments of the baseline may occur during the year if departments are moved between hospitals, or large unexpected changes in production occur. In macroeconomics, the impact of data revisions have been discussed under the heading of real-time data analysis (Croushore, 2011). When analysing data available at present, correct inference about past time behaviour may be incorrect, if the data available today is different from the data available at the when the decision was made. In our context, the relevant baseline is the baseline available to the hospital decision makers when the baseline is crossed. Information about the updated baseline will be available to the hospital during the year as they are calculated by the region. It was not possible to obtain information on adjustments of hospital baselines over time. Instead we use the final baseline that is used in the annual accounts. As the baseline is typically crossed near the end of the year, we believe this to be a fair approximation.

the accumulated hospital production on the regions' own annual accounts. We drop 31 "hospital years" for where there was a $> 2\%$ discrepancy between the region's statement in the annual budget and our estimates.[5] For the remaining observations the mean deviance between our calculation and the annual accounts is 1%. 8 "hospital years" were dropped because of a national hospital worker strike that led to a suspension of the reimbursement scheme in two regions.

4.3. Identification and estimation

The goal of this paper is to estimate the effect of changes in tariffs on quality of medical care. In an ideal experimental setting, payment schemes would be randomly allocated across hospitals and a comparison of average quality achievement among groups would have a causal interpretation. This type of designs are rare in practice and in general a comparison of mean quality levels across tariff groups is likely to yield biased estimates due to selection bias.

The scheme introduces a discontinuity in the per-case revenue function since, for a given DRG at time t, $r_{kt} = (p_k^0 + \mathbb{I}(t \geq t^*)(p_k^1 - p_k^0))$ where $\mathbb{I}(\cdot)$ is an indicator function equal to 1 if the statement within the brackets is true and 0 otherwise. Specifically, note that the price decrease is determined deterministically by the level of production, so that $p_k = p_k^0$ whenever $r_t \leq \bar{r}$ and $p_k = p_k^1$ whenever $r_t > \bar{r}$ for all $k = 1, \ldots, K$. In a regression discontinuity (RD) setting it is implicit that, if a change in tariff has a causal effect, average quality levels will exhibit a discontinuity at the baseline level of activity.

However, the quality of care might not exactly mirror changes in tariffs even when the level of reimbursement has a causal effect on the level of quality. Hospital management may have imprecise information about the hospital's output level, so that information about the current applicable reimbursement rate is imperfect around the date when the threshold is actually crossed. Recent evidence (KREVI, 2012) suggest that advanced management information systems at Danish hospitals can provide detailed production information even department level. However, even if perfect knowledge of output is available, Harris (1977) has suggested that the internal organisation of hospitals and the potential difference between management decisions

[5] Due to organisational changes at hospital level which it has not been possible to correct for in the data.

and behavioural changes from the medical staff might can down the hospital's response to prices. This suggests that one would instead expect a discontinuity in the first derivatives of the conditional mean of quality at the threshold (that is, a kink).

In this paper we thus follow Card et al. (2009) and Simonsen et al. (2010) and, instead of trying to unveil the whole functional relationship between prices and quality, we exploit the volume dependent price setting of the Danish regions to estimate a local causal effect. In particular, we note that the reimbursement schemes described in Equation 1 introduces a kink in the hospital's revenue function. This kink can be used as a source of exogenous variation to estimate the response of quality of care to changes in prices. If reimbursement rates affects the quality of care, we expect to find a matching kink in the conditional mean of quality at the threshold level of activity that triggers the reduction in reimbursement tariffs.

As kinks are discontinuities in the first derivative of a function, a type of RD approach can be devised that relies on the derivatives of the conditional means (although, the conditions for identification are stronger in kink designs than in RD designs). Borrowing from Card et al. (2009), consider the following general model for quality of care with unrestricted heterogeneity in the relationship between revenue and quality of care,

$$Y = y(R, T, \varepsilon)$$

where Y is our measure of quality, $R = R(t)$ denotes accumulated revenue, T denotes time, ε is an unobservable, no-additive error term and $y(\cdot)$ is an unspecified mapping of quality to revenue. The parameter of interest is the local average treatment effect on the treated, which is defined as

$$ATT_{T=t^*} = E\left(\frac{\partial Y}{\partial R}|T = t^*\right) \tag{3}$$

Under the regularity conditions detailed in Card et al. (2009)[6], $P(\varepsilon \leq \epsilon|T = t)$ and, more importantly, $P(X \leq x|T = t)$, are continuously differentiable

[6]The required regularity conditions are: (i) $y(\cdot)$ has continuous partial derivatives with respect to revenue and time, so that the effect of these variables on quality must be smooth, (ii) the kink exists in the sense that $R = R(t)$ is continuously differentiable everywhere, except at t^*, where $lim_{t \to t^*_+} R'(t) \neq lim_{t \to t^*_-} R'(t)$ -this is equivalent to the existence of a jump in a regression discontinuity design, and that (iii) the distribution of production levels be continuously differentiable in observables and unobservables.

in T at t^*. The implication of the latter result is that the validity of the kink design can be tested by ruling out kinks in the distribution of observable variables, X, at t^*. Under the regularity conditions in Card et al. (2009),

$$E\left(\frac{\partial Y}{\partial R}|T=t^*\right)=\frac{\lim_{t\to t_*^+}\frac{\partial E(Y|T=t)}{\partial t}-\lim_{t\to t_*^-}\frac{\partial E(Y|T=t)}{\partial t}}{\lim_{t\to t_*^+}\frac{\partial R(t)}{\partial t}-\lim_{t\to t_*^-}\frac{\partial R(t)}{\partial t}}, \tag{4}$$

which is non parametrically identified.

The denominator in (4) is the change in the reimbursement rate at the baseline. The numerator can be estimated in a variety of ways. For instance, non-parametric estimators of the derivatives of conditional moments can be employed. These can be obtained indirectly, from local polynomial regressions, or directly as devised in Pagan and Ullah (1999). However, the rate of convergence of these estimators is even slower than the rate of linear smoothers for conditional means. Therefore, as in Simonsen et al. (2010), we define a parametric model for our quality indicator and a bandwidth parameter h is used to restrict data to a sensible neighbourhood around the baseline. Because our measure of quality is a continuously distributed index, bounded between 0 and 1, the effect of the change of reimbursement can be captured by a dummy variable in the conditional mean of a fractional data model (Papke and Wooldridge, 1996). More precisely, the log-likelihood of the sample in a neighbourhood of x_o for any given hospital is,

$$\ell=\sum_{t=1}^{T}\left(Y_t\log[\Phi(\mathbf{x}_t'\theta)]+(1-Y_t)\log[1-\Phi(\mathbf{x}_t'\theta)]\right)\mathbb{I}(|T-t^*|<h) \tag{5}$$

As highlighted by Papke and Wooldridge (1996), the quasi-maximum likelihood estimator (QMLE) of the parameter θ are consistent, $\sqrt{N}$-asymptotically normal and efficient. Additionally, this approach ensures predictions within the [0,1] range and allows for the inclusion of fractions of zero and one without manipulation of data. The linear index in (5) equals,

$$\mathbf{x}_t'\theta=\alpha+(T-t^*)\beta_1+\mathbb{I}\left((T-t^*)\geq 0\right)\gamma+\mathbb{I}\left((T-t^*)\geq 0\right)\times T\tau. \tag{6}$$

As in Simonsen et al. (2010), our parameter of interest is τ, which captures the change in the slope of the conditional mean of Y. That is, the QMLE of τ estimates the numerator of 4. We evaluate the robustness of our results by estimating at different values of p and h. In addition we test for kinks

in the distribution of patient characteristics variable and re-estimate our model conditioning on these characteristics. We also test for a kink in the reimbursement–quality relationship at the start of a new financial year when the marginal tariffs again is increased. In all models we include regional fixed effects and report cluster-robust standard errors at hospital level.

5. Results

5.1. Descriptive analysis

5.1.1. Patient characteristics

Controlling for case mix is important in the comparison of (outcome) quality between hospitals. However, the DNIP indicators used for measuring the process quality of acute stroke care are not contingent on patient characteristics other than those related to stroke type and as such can be expected to be delivered to all patients. Still, as detailed in the previous section, in a kinked regression framework, observable patient characteristics may serve as a means for testing the validity of our design.

The observable patient characteristics available to our analysis are the patients' age, gender, housing status (living with others or in an assisted living facility), hypertension, previous stroke or acute myocardial infarction (AMI), alcohol consumption above national guidelines and smoking status. Descriptive statistics for patients characteristics on either side of the baseline for different bandwidths are presented in Table B.6

The distribution of variables appear to be similar on both sides of the threshold with respect to most patient characteristics. Exceptions are the proportion of patients living with others which is somewhat lower above the baseline for all bandwidths, the number of patients with hypertension which is higher above the baseline for all bandwidths and the proportion of patients with alcohol consumption above national guidelines which is lower above the baseline for a bandwidth of 7 days.

The distribution of patient characteristics around the baseline are plotted in Figures C.4–C.6. The figures indicate a difference in the distribution of patients with respect to smoking status, hypertension and living status for patients at hospitals that were not reimbursed for stroke patients after crossing the baseline. The formal tests for kinks in the covariates around the baseline (not shown, but available from the authors on request) only reveal occasional violations of the assumptions which are sensitive to bandwidth and model choice but most prominent for smoking status, patients

with hypertension and gender. It seems unlikely that differences in these characteristics should affect the hospitals' provision of quality, and we find it reasonable to proceed with our analysis maintaining the necessary assumptions of continuous and continuous differentiable potential outcomes in our sample.

5.1.2. The quality of care around the baseline

We begin by plotting the value of the quality index defined in Equation 2 against time using a bandwidth of 20 days before and after the baseline was crossed, grouping our analysis by the percentage size of the tariff reduction when crossing the baseline (as detailed in Table 1) in Figures 1–3.

Each dot represents the daily hospital level of quality in acute stroke care, expressed as the mean proportion of relevant processes delivered to the stroke patients admitted to a given hospital on a given day. The fitted lines represents a smoothed local polynomial regression of the quality index on days to baseline. While there is no visible sign of a response in quality to tariff reductions of around 50% and 80%, Figure 3 does give the impression of a minor response in quality when hospitals are not reimbursed at all for stroke patients treated after the hospital has crossed the baseline.

5.2. Regression Kink estimates

Table 2 presents our estimates of the local average treatment effect of reductions in the marginal tariff on the process quality of acute stroke care. Again we split our analysis by the size of tariff reduction and, as a robustness test at bandwidths of 7–28 days. Our central estimate is the local average treatment effect on the treated (ATT) defined in Equation 4 as the derivative of quality with respect to income. Thus, while the estimates of dy/dx depend on the size of the reduction in the marginal tariff, the ATT estimate is comparable across reimbursement regimes. We also display p-values, sample sizes and upper and lower confidence intervals for the ATT at a 95% level.

The regression estimates corresponds to the expectations from the graphical analysis: No statistically significant change in the level of quality at reductions in the marginal tariff of 45–86%, but some evidence of a small reduction in quality when the marginal tariff is reduced to 0 for patients treated above the baseline. The effect is minor at about 1 percentage point. However, while only statistically significant at a 100% reduction, the estimates of the ATT are relatively robust, displaying similar sign and magnitude at at different bandwidths.

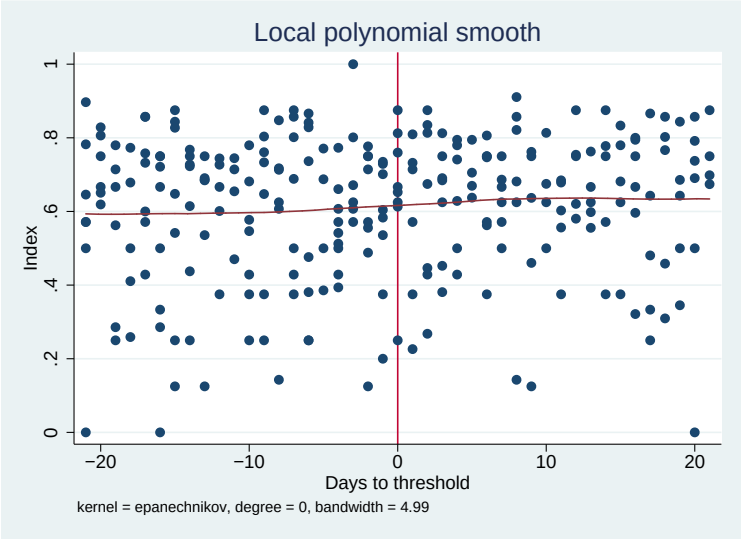

Figure 1: Mean level of quality by hospital and day 20 days before and after a 45–50 % decrease in the marginal tariff for stroke treatment.

Note: Each dot represents the daily hospital level of quality in acute stroke care, expressed as the mean proportion of relevant processes delivered to the stroke patients admitted to a given hospital on a given day. The fitted line represents a smoothed local polynomial regression of the quality index on days to baseline. The vertical line represents the day the baseline was crossed.

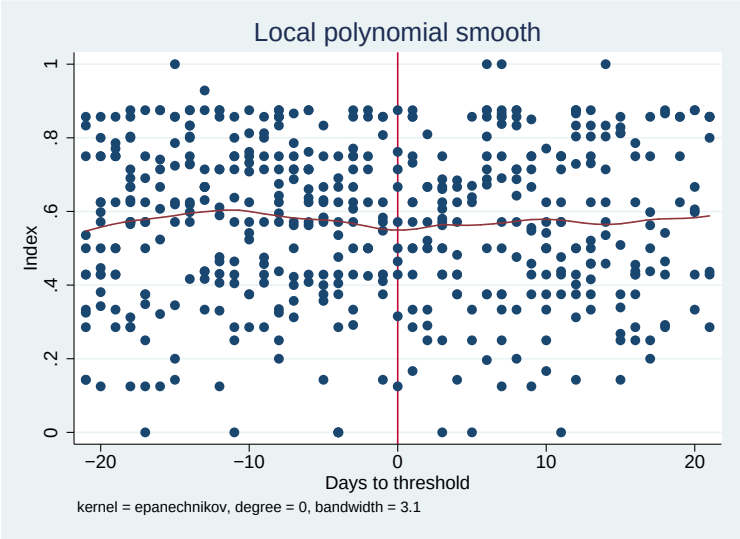

Figure 2: Mean level of quality by hospital and day 20 days before and after a 80–86 % decrease in the marginal tariff for stroke treatment.

Note: Each dot represents the daily hospital level of quality in acute stroke care, expressed as the mean proportion of relevant processes delivered to the stroke patients admitted to a given hospital on a given day. The fitted line represents a smoothed local polynomial regression of the quality index on days to baseline. The vertical line represents the day the baseline was crossed.

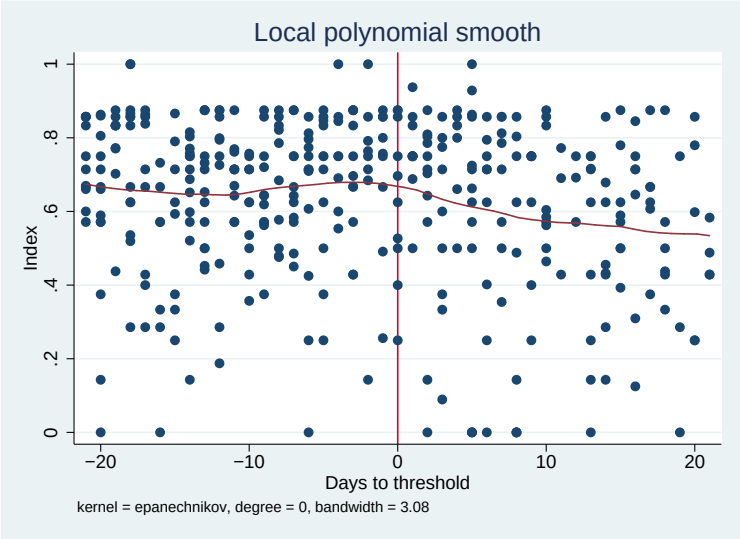

Figure 3: Mean level of quality by hospital and day 20 days before and after hospitals no longer are reimbursed for treating additional stroke patients.

Note: Each dot represents the daily hospital level of quality in acute stroke care, expressed as the mean proportion of relevant processes delivered to the stroke patients admitted to a given hospital on a given day. The fitted line represents a smoothed local polynomial regression of the quality index on days to baseline. The vertical line represents the day the baseline was crossed.

Table 2: Local Average Treatment Effect estimated at the baseline

Bandwidth	dy/dx	p	ATT	CI_L	CI_U	N
Marginal decrease in tariffs at baseline: 50-55%						
$h = 28$	0.0035	0.1538	-0.0070	-0.0013	0.0083	335
$h = 21$	-0.0000	0.9914	0.0001	-0.0051	0.0051	260
$h = 14$	0.0026	0.6584	-0.0051	-0.0088	0.0139	178
$h = 7$	0.0094	0.3475	-0.0188	-0.0102	0.0291	101
Marginal decrease in tariffs at baseline: 80-86%						
$h = 28$	-0.0004	0.8598	0.0005	-0.0046	0.0038	645
$h = 21$	0.0016	0.6382	-0.0019	-0.0049	0.0080	502
$h = 14$	0.0117	0.0674	-0.0146	-0.0008	0.0243	358
$h = 7$	0.0155	0.1187	-0.0193	-0.0040	0.0349	182
Marginal decrease in tariffs at baseline: 100%						
$h = 28$	-0.0096	0.0037	0.0096	-0.0161	-0.0031	480
$h = 21$	-0.0080	0.0758	0.0080	-0.0168	0.0008	381
$h = 14$	-0.0145	0.0184	0.0145	-0.0265	-0.0024	271
$h = 7$	-0.0218	0.3184	0.0218	-0.0645	0.0210	146

Note: The table reports estimates of the local average treatment effect on the treated (ATT) of a change in the marginal tariffs for stroke patients estimated when hospitals' production exceed the baseline and the tariffs decrease. The analysis is split by the size of the tariff reduction: 50-55%, 80-86 % or 100%. h is the bandwidth used when estimating the treatment effect and N is the sample size in hospital-days. CI_L and CI_U are lower and upper confidence intervals for the ATT at a 95% level with clustering at hospital level

5.3. Robustness analysis

As test of the validity of our results we estimate the effect on quality of the increase in the marginal tariff that occurs at the beginning of a new financial year. If hospitals respond in quality to marginal changes in the admission tariff, our estimate of ATT should remain of similar sign and magnitude. This corresponds to estimating a positive coefficient on the dy/dx where we estimated a negative sign on dy/dx around the baseline crossing.

The results displayed in table 3 confirm our expectations. For the hospitals that were exposed to less than 100% reductions in the marginal tariffs when crossing the baseline and did not respond in quality then, we find no change in the level of quality at the start of a new financial year. However, for the hospitals that did not receive reimbursement for acute stroke patients admitted after crossing the baseline, we estimate an average treatment effect of same sign and similar magnitude as in table 2 when using the tariff increase at the start of a new financial year as the basis for estimation. This finding reassures us that the effect we identified in the first part of the analysis is unlikely to be spurious.

As a final sensitivity test we re-estimate the effect of tariff reductions on the quality of care, this time conditioning on the observable patient characteristics. As expected, the sign and magnitude of the estimated treatment effects remain stable from the inclusion of the covariates in the analysis with an increased statistical significance of the results for the group of hospitals that had the marginal reimbursement removed after crossing the baseline. This reassure us that our design is valid. The full set of results is reported in the Appendix Table C.7.

6. Discussion and concluding remarks

In this paper we have estimated the price sensitivity of the quality of acute stroke care. The identification problems related to estimating causal effects using conventional methods such as difference-in-differences were overcome by using a regression kink design. This approach was possible due to the volume-dependent pricing schemes used for reimbursing Danish hospitals. When hospitals reach a prospectively set hospital wide production target (the baseline), marginal tariffs for treating acute stroke patients are reduced by 50%–100%. This reimbursement scheme allow us to identify local average treatment effects of prices on the quality of acute stroke care. A rich data set of the process quality of stroke care allowed us to detect minor changes

Table 3: Local Average Treatment Effect estimated at New Financial Year (FIY)

Bandwidth	dy/dx	p	ATT	CI_L	CI_U	N
Marginal increase in tariffs at new FIY: 50-55%						
$h = 28$	0.0005	0.8561	0.0010	-0.0050	0.0060	258
$h = 21$	0.0058	0.2391	0.0115	-0.0038	0.0153	188
$h = 14$	0.0048	0.5445	0.0097	-0.0108	0.0205	126
$h = 7$	0.0186	0.2423	0.0372	-0.0126	0.0497	64
Marginal increase in tariffs at new FIY: 80-86%						
$h = 28$	0.0038	0.1235	0.0047	-0.0010	0.0085	575
$h = 21$	0.0063	0.1418	0.0079	-0.0021	0.0147	433
$h = 14$	0.0137	0.1432	0.0171	-0.0046	0.0321	289
$h = 7\ 8$	0.0245	0.3546	0.0306	-0.0273	0.0762	150
Marginal increase in tariffs at new FIY: 100%						
$h = 28$	0.0065	0.0002	0.0065	0.0031	0.0099	454
$h = 21$	0.0078	0.0039	0.0078	0.0025	0.0132	346
$h = 14$	0.0103	0.3084	0.0103	-0.0095	0.0301	234
$h = 7$	0.0301	0.4392	0.0301	-0.0462	0.1065	115

Note: The table reports estimates of the local average treatment effect on the treated (ATT) of a change in the marginal tariffs for stroke patients estimated when hospitals' enter a new financial year and the tariffs increase. The analysis is split by the size of the tariff increase: 50-55%, 80-86 % or 100%. h is the bandwidth used when estimating the treatment effect and N is the sample size in hospital-days. CI_L and CI_U are lower and upper confidence intervals for the ATT at a 95% level with clustering at hospital level

in the quality of care that can be important for the long term rehabilitation outcomes other than mortality and readmission.

For hospitals that were exposed to reductions in marginal tariff of acute stroke admissions of less than 100% we did not find any significant effect of tariff changes on the level of quality provided. Hospital for which the marginal tariff for acute stroke patients dropped to 0 responded to tariff reductions by slightly decreasing the level of quality for acute stroke care patients. The estimated size of the effect was minor at about 1 percentage point, but the results were robust to different bandwidth choice and to the inclusion of patient characteristics. In addition, when the marginal tariff increased again at the beginning of a new financial year, the hospitals that reduced the level of quality when the marginal tariff was decreased, responded with an increase in quality of similar magnitude, indicating that the estimated effect is not spurious.

It is possible that the marginal costs of treating acute stroke patients at an unchanged level of quality is in fact covered by the lower tariffs for the production levels around the baseline, but that the effect would be different in the case of a permanent decrease in tariffs. This can also explain the lack of response in quality for hospitals exposed to less than 100% tariff reductions. It is equally possible that hospitals reacted to the changes in marginal tariffs by cross-substitution from other areas of care where the quality of care is less closely measured to avoid poor ranking results being publicised, but this will be difficult to pick up until good measures of quality exist for all areas of care. Finally, imperfect hospital information systems, or medical ethics may explain the limited response in quality to changes in the marginal tariff.

The regression kink design we have employed in this analysis is characterised by having a high internal validity (if it is valid to apply in the given context), whereas the external validity is generally thought to be limited, because the effect we identify is local (Hahn et al., 2001; Imbens and Lemieux, 2008). Although we only found minor reactions to the the quality of acute stroke to substantial changes in the marginal tariff, we cannot conclude that the quality of acute stroke care is in general insensitive to price changes, or that evaluating other areas of care would yield the same result.

7. Acknowledgements

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Appendix A. The DNIP indicators

Table A.4: The DNIP indicators for acute stroke care quality

Indicator	Indicator domain	Description	Target	Evidence strength
1	Treatment, care and rehabilitation in a stroke unit	Admission to a stroke unit no later than the 2nd day of hospitalisation	>= 90%	A
2	Secondary prophylactic medical treatment	Treatment with antiplatelet inhibitor initiated no later than the 2nd day of hospitalization for acute ischemic stroke patients without atrial fibrilation	>= 95%	A
3	Secondary prophylactic medical treatment	Treatment with oral anticoagulants initiated no later than the 14th day of hospitalisation for acute ischemic stroke patients with atrial fibrillation	>= 95%	A
4	Diagnostics with CT/MR scan	Examiniation/diagnostics with CT/MR scan on the first day of hospitalisation	>= 80%	B
5	Assessment by physiotherapist	Assessment by a physiotherapist no later than the 2nd of hospitalisation in order to clarify the extent and type of rehabilitation needed and time for initiation of physiotherapy	>= 90%	D
6	Assessment by occupational therapist	Assessment by a occupational therapist no later than the 2nd day of hospitalisation in order to clarify the extent and type of rehabilitation needed and time for initiation of occupational therapy	>= 90%	B
7	Assessment of nutritional risk	Assessment of nutritional risk no later than the 2nd day of hospitalisation	>= 90%	D
8	Dysphagia screening	Assessment by bedside screening in order to determine the extent of aspiration and the severity of swallow dyfunction no later than the 1st day of hospitalisation	>= 90%	D
9	Ultrasound/CT angiography	Ultrasound/CT angiography of the carotid ateries no later than the 4th day of hospitalisation	>= 90%	B

Note: Evidence grading as judged by the national indicator panel and the Danish Health and Medicines Authority. Key: A: Evidence from meta-analyses, systematic reviews or randomised controlled trials, B: controlled non randomised studies, cohort studies or direct diagnostic tests, C: case-control studies, diagnostic tests (indirect nosographic), Decision analyses, Decsriptive studies, D: case series, reviews, expert opinion

Table A.5: Summary statistics for DNIP indicators for acute stroke care quality

	year				
	2007	2008	2009	2010	Total
	%	%	%	%	%
Indicator 1: Treatment at a stroke unit					
Yes	70.2	77.2	75.0	79.8	75.2
No	29.4	22.3	24.6	20.1	24.4
Missing	0.4	0.5	0.4	0.2	0.4
Total	100.0	100.0	100.0	100.0	100.0
Indicator 2: Treatment with antiplatelet inhibitor					
Yes	2.4	3.1	5.4	7.4	4.7
No (other)	9.9	20.8	24.8	10.8	15.5
No (contraindicated)	36.4	66.8	67.9	80.8	61.6
Missing	51.3	9.2	1.9	1.0	18.1
Total	100.0	100.0	100.0	100.0	100.0
Indicator 3: Treatment with oral anticoagulants					
Yes	6.2	6.2	8.7	9.6	7.8
No (other)	1.4	2.1	12.8	7.0	6.0
No (contraindicated)	7.0	6.9	50.2	81.0	39.4
Missing	85.3	84.8	28.4	2.4	46.8
Total	100.0	100.0	100.0	100.0	100.0
Indicator 4: CT/MR scan					
Yes	98.6	95.6	99.1	99.5	98.5
No	0.4	0.4	0.2	0.1	0.2
Not clinically relevant	0.5	0.4	0.3	0.3	0.4
Missing	0.6	3.7	0.4	0.2	0.9
Total	100.0	100.0	100.0	100.0	100.0
Indicator 5: Assessment by a physiotherapist					
Yes	80.6	77.7	80.3	81.2	80.3
No	2.4	1.9	1.8	0.7	1.7
Not clinically relevant	14.4	15.3	15.2	17.1	15.5
Missing	2.6	5.2	2.6	1.0	2.5
Total	100.0	100.0	100.0	100.0	100.0
Indicator 6: Assessment by an occupational therapist					
Yes	81.5	80.5	81.5	82.2	81.6
No	2.4	1.8	2.1	0.9	1.8
Not clinically relevant	13.2	13.1	13.8	15.9	14.1
Missing	2.9	4.6	2.6	0.9	2.5
Total	100.0	100.0	100.0	100.0	100.0
Indicator 7: Assessment of nutritional risk					
Yes	69.1	68.6	78.7	83.4	75.6
No	7.0	6.0	7.0	4.0	6.0
Not clinically relevant	12.5	13.6	10.1	9.7	11.2
Missing	11.4	11.8	4.2	2.9	7.2
Total	100.0	100.0	100.0	100.0	100.0
Indicator 8: Dysphagia screening					
Yes	35.0	64.8	78.5	80.7	63.6
No	3.1	4.3	5.5	3.3	3.9
Not clinically relevant	7.5	14.0	11.7	13.7	11.3
Missing	54.4	16.8	4.2	2.3	21.1
Total	100.0	100.0	100.0	100.0	100.0
Indicator 9: Ultrasound/CT-angiography of the carotid arteries					
Yes	14.3	38.9	45.1	52.9	36.9
No	6.7	12.4	14.1	4.5	8.8
Not clinically relevant	15.9	42.0	38.7	41.5	32.9
Missing	63.1	6.7	2.1	1.1	21.5
Total	100.0	100.0	100.0	100.0	100.0

Appendix B. Descriptive statistics: Patient charachteristics

Table B.6: Descriptive statistics for patient characteristics above and below the baseline at different bandwidths

	Age	Male	Previous stroke	Ex-smoker	Occasional smoker	Daily smoker	Hypertension	Cohabiting	Assisted Living facility	AMI	Alchohol
Sample for k=7											
Below baseline											
Mean	72.486	.552	.245	.245	.003	.295	.512	.549	.081	.093	.081
SD	12.981	.497	.430	.430	.055	.456	.500	.498	.272	.291	.272
N	322	322	322	322	322	322	322	322	322	322	322
Above baseline											
Mean	72.644	.545	.291	.247	.005	.306	.562	.495	.078	.075	.058
SD	13.400	.498	.455	.432	.076	.461	.496	.5007	.269	.265	.234
N	343	343	343	343	343	343	343	343	343	343	343
Full sample											
Mean	72.567	.548	.269	.246	.004	.300	.538	.521	.079	.084	.069
SD	13.189	.497	.443	.431	.067	.458	.498	.499	.271	.277	.253
N	665	665	665	665	665	665	665	665	665	665	665
Sample for k=14											
Below baseline											
Mean	72.233	.544	.237	.229	.004	.299	.518	.554	.073	.092	.078
SD	13.242	.498	.426	.421	.063	.458	.499	.497	.261	.289	.269
N	748	748	748	748	748	748	748	748	748	748	748
Above baseline											
Mean	72.298	.552	.272	.253	.004	.295	.558	.507	.078	.072	.072
SD	12.943	.497	.445	.435	.067	.456	.496	.500	.269	.259	.259
N	650	650	650	650	650	650	650	650	650	650	650
Full sample											
Mean	72.263	.547	.253	.241	.004	.297	.537	.532	.075	.082	.075
SD	13.099	.497	.435	.427	.065	.457	.498	.499	.264	.275	.264
N	1398	1398	1398	1398	1398	1398	1398	1398	1398	1398	1398
Sample for k=21											
Below baseline											
Mean	72.236	.534	.250	.228	.003	.304	.521	.548	.080	.089	.084
SD	13.263	.499	.433	.420	.059	.460	.499	.497	.272	.285	.277
N	1115	1115	1115	1115	1115	1115	1115	1115	1115	1115	1115
Above baseline											
Mean	71.978	.545	.251	.246	.004	.300	.552	.503	.074	.077	.073
SD	13.328	.498	.434	.430	.067	.458	.497	.500	.263	.266	.261
N	882	882	882	882	882	882	882	882	882	882	882
Full sample											
Mean	72.122	.539	.250	.236	.004	.302	.534	.528	.078	.084	.079
SD	13.289	.498	.433	.424	.063	.459	.498	.499	.268	.277	.270
N	1997	1997	1997	1997	1997	1997	1997	1997	1997	1997	1997

Chrachteritstics are the the patients age and the proportion of male patients, patients who previously had a stroke, who previously smoked, are daily smokers, has hypertension, are cohabiting, live in an assisted living facility (ALF), previously had acute myocardial infarction (AMI) and had a weekly alchohol intake above national recommendations. The fitted line represents a smoothed local polynomial regression of the proportion of patients with the charachteristic on days to baseline. The vertical line represents the day the baseline was crossed

Appendix C. Sensitivity analysis

Table C.7: Local Average Treatment Effect estimated at baseline with inclusion of patient characteristics

Bandwidth	dy/dx	p	ATT	CI_L	CI_U	N
Marginal decrease in tariffs at baseline: 50–55%						
$h = 28$	0.0036	0.1985	-0.0072	-0.0019	0.0091	335
$h = 21$	0.0009	0.7873	-0.0017	-0.0054	0.0072	260
$h = 14$	0.0029	0.5907	-0.0059	-0.0077	0.0136	178
$h = 7$	0.0104	0.3759	-0.0209	-0.0127	0.0336	101
Marginal decrease in tariffs at baseline: 80–86%						
$h = 28$	-0.0004	0.8479	0.0005	-0.0041	0.0034	645
$h = 21$	0.0015	0.6572	-0.0019	-0.0052	0.0082	502
$h = 14$	0.0121	0.0697	-0.0151	-0.0010	0.0251	358
$h = 7$	0.0143	0.1437	-0.0179	-0.0049	0.0335	182
Marginal decrease in tariffs at baseline: 100%						
$h = 28$	-0.0089	0.0123	0.0089	-0.0158	-0.0019	480
$h = 21$	-0.0076	0.1202	0.0076	-0.0173	0.0020	381
$h = 14$	-0.0131	0.0247	0.0131	-0.0245	-0.0017	271
$h = 7$	-0.0204	0.2773	0.0204	-0.0573	0.0164	146

Note: The table reports estimates of the local average treatment effect on the treated (ATT) of a change in the marginal tariffs for stroke patients estimated when hospitals' production exceed the baseline and the tariffs decrease with inclusion of patient characteristics. The analysis is split by the size of the tariff reduction: 50-55%, 80-86 % or 100%. h is the bandwidth used when estimating the treatment effect and N is the sample size in hospital-days. CI_L and CI_U are lower and upper confidence intervals for the ATT at a 95% level with clustering at hospital level

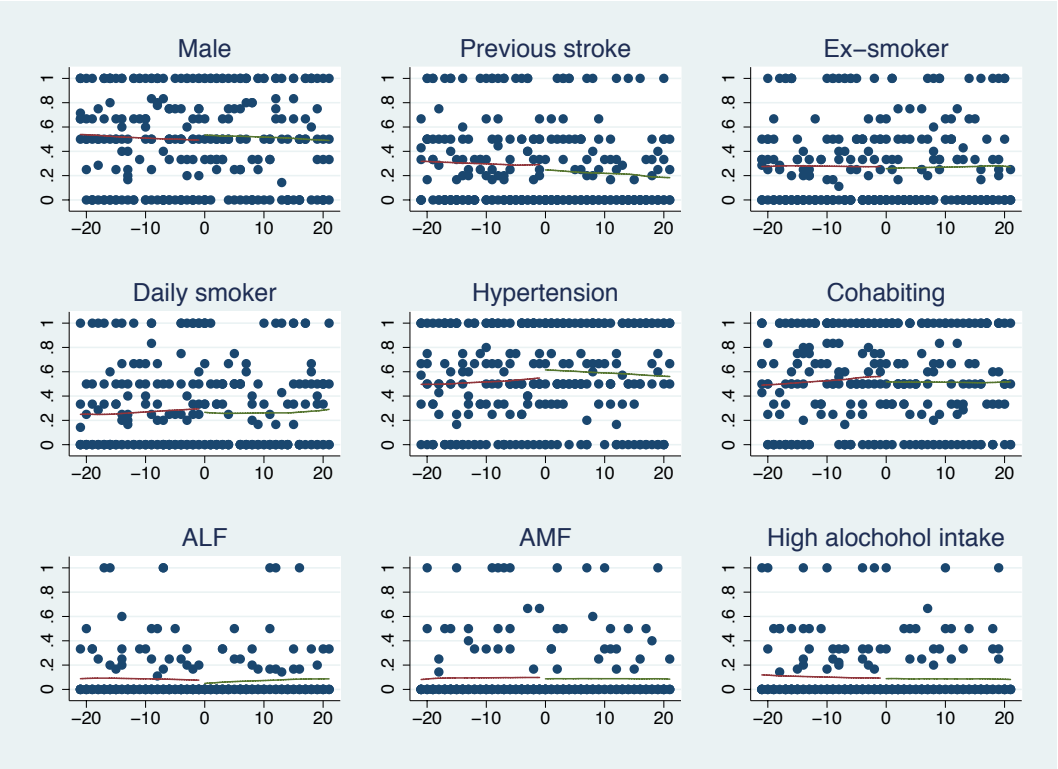

Figure C.4: Mean level of quality by hospital and day 20 days before and after a 45–50 % decrease in the marginal tariff for stroke treatment

Note: Each dot represents the the mean proportion of patients with a given charachteristic admitted on a given day. Chrachteritstics are the proportion of male patients, patients who previously had a stroke, who previously smoked, are daily smokers, has hypertension, are cohabiting, live in an assisted living facility (ALF), previously had acute myocardial infarction (AMI) and had a weekly alchohol intake above national recommendations. The fitted line represents a smoothed local polynomial regression of the proportion of patients with the charachteristic on days to baseline. The vertical line represents the day the baseline was crossed

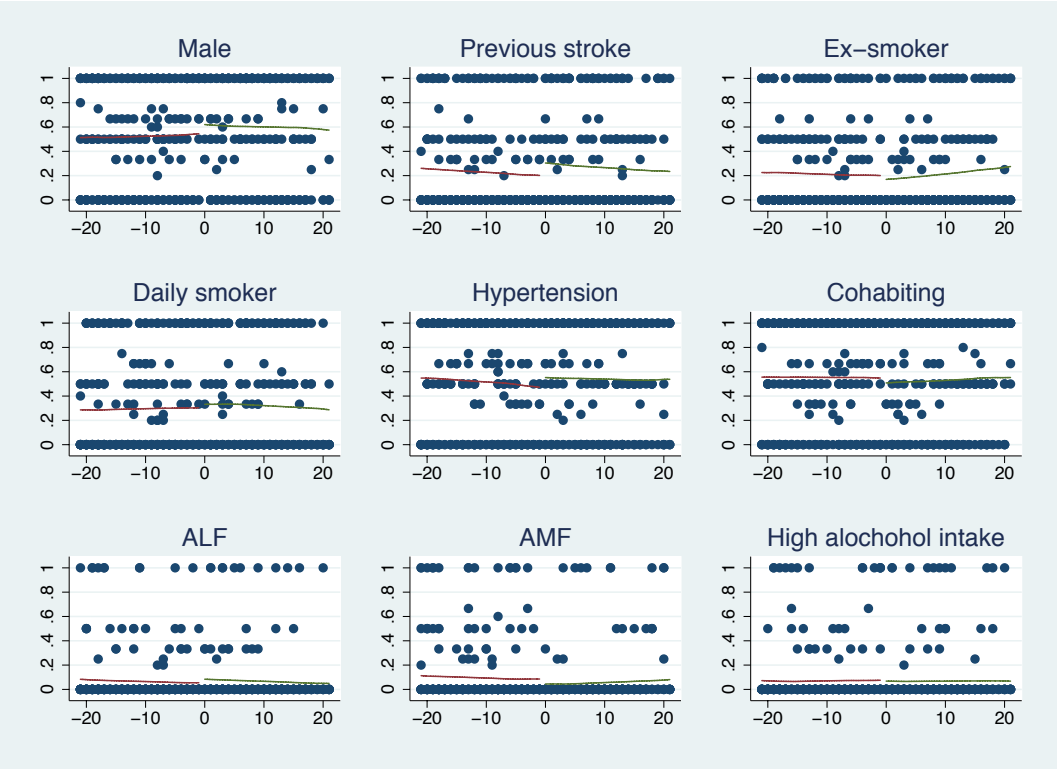

Figure C.5: Mean level of quality by hospital and day 20 days before and after a 80–86 % decrease in the marginal tariff for stroke treatment.

Note: Each dot represents the the mean proportion of patients with a given charachteristic admitted on a given day. Chrachteritstics are the proportion of male patients, patients who previously had a stroke, who previously smoked, are daily smokers, has hypertension, are cohabiting, live in an assisted living facility (ALF), previously had acute myocardial infarction (AMI) and had a weekly alchohol intake above national recommendations. The fitted line represents a smoothed local polynomial regression of the proportion of patients with the charachteristic on days to baseline. The vertical line represents the day the baseline was crossed

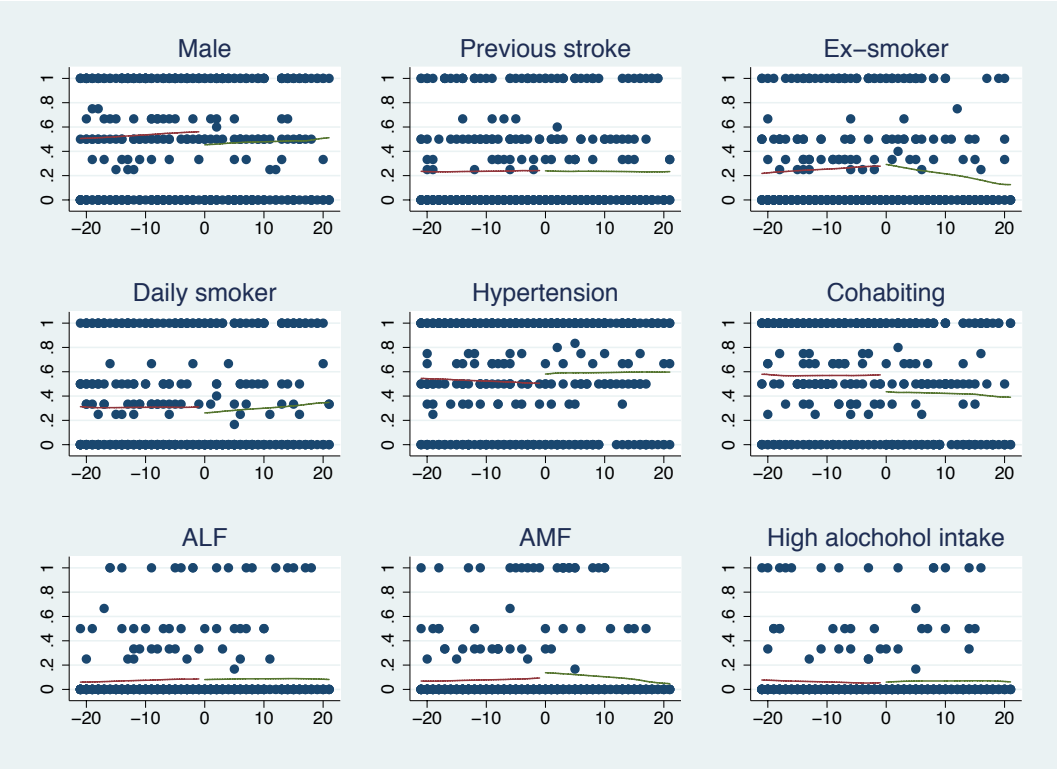

Figure C.6: Mean level of quality by hospital and day 20 days before and after a 45–50 % decrease in the marginal tariff for stroke treatment.

Note: Each dot represents the the mean proportion of patients with a given charachteristic admitted on a given day. Chrachteritstics are the proportion of male patients, patients who previously had a stroke, who previously smoked, are daily smokers, has hypertension, are cohabiting, live in an assisted living facility (ALF), previously had acute myocardial infarction (AMI) and had a weekly alchohol intake above national recommendations. The fitted line represents a smoothed local polynomial regression of the proportion of patients with the charachteristic on days to baseline. The vertical line represents the day the baseline was crossed

References

Allen, R., Gertler, P., 1991. Regulation and the provision of quality to heterogenous consumers: The case of prospective pricing of medical services. Journal of Regulatory Economics 3 (4), 361–375.

Arrow, K. J., Dec. 1963. Uncertainty and the welfare economics of medical care. The American Economic Review 53 (5), 941–973.

Card, D., Lee, D. S., Pei, Z., Nov. 2009. Quasi-experimental identification and estimation in the regression kink design. Tech. rep., Princeton University, Department of Economics, Industrial Relations Section.

Chalkley, M., Malcomson, J. M., Jan. 1998. Contracting for health services when patient demand does not reflect quality. Journal of Health Economics 17 (1), 1–19.

Christiansen, T., Jul. 2012. Ten years of structural reforms in danish healthcare. Health Policy 106 (2), 114–119.

Christiansen, T., Bech, M., Feb. 2013. Denmark. In: OECD Health Policy Studies. Organisation for Economic Co-operation and Development, pp. 115–131.

Croushore, D., 2011. Frontiers of real-time data analysis. Journal of Economic Literature 49 (1), 72–100.

Cutler, D. M., Jan. 1995. The incidence of adverse medical outcomes under prospective payment. Econometrica 63 (1), 29–50.

DesHarnais, S., Chesney, J., Fleming, S., 1988. Trends and regional variations in hospital utilization and quality during the first two years of the prospective payment system. Inquiry: A Journal of Medical Care Organization, Provision and Financing 25 (3), 374–382.

DesHarnais, S., Kobrinski, E., Chesney, J., Long, M., Ament, R., Fleming, S., 1987. The early effects of the prospective payment system on inpatient utilization and the quality of care. Inquiry: A Journal of Medical Care Organization, Provision and Financing 24 (1), 7–16.

DesHarnais, S. I., McMahon, L. F., Wroblewski, R. T., Hogan, A. J., Dec. 1990. Measuring hospital performance: The development and validation of risk-adjusted indexes of mortality, readmissions, and complications. Medical Care 28 (12), 1127–1141.

Dong, Y., 2011. Jumpy or kinky? regression discontinuity without the discontinuity. Working Paper.

Donnan, G. A., Fisher, M., Macleod, M., Davis, S. M., May 2008. Stroke. Lancet 371 (9624), 1612–1623.

Farrar, S., Yi, D., Sutton, M., Chalkley, M., Sussex, J., Scott, A., 2009. Has payment by results affected the way that english hospitals provide care? difference-in-differences analysis. BMJ 339 (aug27_2), b3047–.

Giammanco, M. D., 1999. The short-term response of hospitals to the introduction of the DRG based prospective payment system: some evidence from italy. Giornale degli Economisti 58 (1), 27–62.

Gilman, B. H., 2000. Hospital response to DRG refinements: the impact of multiple reimbursement incentives on inpatient length of stay. Health Economics 9 (4), 277–294.

Gravelle, H., Sutton, M., Ma, A., Feb. 2010. Doctor behaviour under a pay for performance contract: Treating, cheating and case finding? The Economic Journal 120 (542), F129–F156.

Hahn, J., Todd, P., Van der Klaauw, W., Jan. 2001. Identification and estimation of treatment effects with a regression discontinuity design. Econometrica 69 (1), 201–209.

Harris, J. E., 1977. The internal organization of hospitals: Some economic implications. The Bell Journal of Economics 8 (2), 467–48.

Hodgkin, D., McGuire, T. G., Mar. 1994. Payment levels and hospital response to prospective payment. Journal of Health Economics 13 (1), 1–29.

Imbens, G. W., Lemieux, T., Feb. 2008. Regression discontinuity designs: A guide to practice. Journal of Econometrics 142 (2), 615–635.

Jegers, M., Kesteloot, K., De Graeve, D., Gilles, W., 2002. A typology for provider payment systems in health care. Health policy 60 (3), 255–273.

Kahn, K. L., Keeler, E. B., Sherwood, M. J., Rogers, W. H., Draper, D., Bentow, S. S., Reinisch, E. J., Rubenstein, L. V., Kosecoff, J., Brook, R. H., 1990. Comparing outcomes of care before and after implementation of the DRG-based prospective payment system. JAMA: the journal of the American Medical Association 264 (15), 1984–1988.

KREVI, 2012. Takster i faste rammer. Tech. rep.

Kuwabara, H., Fushimi, K., Sep. 2009. The impact of a new payment system with case-mix measurement on hospital practices for breast cancer patients in japan. Health Policy 92 (1), 65–72.

Lindrooth, R. C., Bazzoli, G. J., Clement, J., Jan. 2007. The effect of reimbursement on the intensity of hospital services. Southern Economic Journal 73 (3), 575–587.

Lindrooth, R. C., Bazzoli, G. J., Needleman, J., Hasnain-Wynia, R., Jun. 2006. The effect of changes in hospital reimbursement on nurse staffing decisions at safety net and nonsafety net hospitals. Health Services Research 41 (3 Pt 1), 701–720.

Long, M. J., Chesney, J. D., Ament, R. P., DesHarnais, S. I., Fleming, S. T., Kobrinski, E. J., Marshall, B. S., Jun. 1987. The effect of PPS on hospital product and productivity. Medical Care 25 (6), 528–538.

Ma, C.-t. A., 1994. Health care payment systems: Cost and quality incentives. Journal of Economics & Management Strategy 3 (1), 93–112.

Mainz, J., Krog, B. R., Bjornshave, B., Bartels, P., Apr. 2004. Nationwide continuous quality improvement using clinical indicators: the danish national indicator project. Int J Qual Health Care 16 (suppl_1), i45–50.

Maynard, A., Jan. 2012. The powers and pitfalls of payment for performance. Health Economics 21 (1), 3–12.

Newhouse, J. P., Jan. 1970. Toward a theory of nonprofit institutions: An economic model of a hospital. The American Economic Review 60 (1), 64–74.

Ottenbacher, K. J., Jannell, S., Jan. 1993. The results of clinical trials in stroke rehabilitation research. Arch Neurol 50 (1), 37–44.

Pagan, A., Ullah, A., 1999. Nonparametric econometrics. Cambridge University Press.

Papke, L. E., Wooldridge, J. M., 1996. Econometric methods for fractional response variables with an application to 401(k) plan participation rates. Journal of Applied Econometrics 11 (6), 619–32.

Paris, V., Devaux, M., Wei, L., 2010. Health systems institutional characteristics: A survey of 29 OECD countries (50).

Picone, G., Wilson, R. M., Chou, S.-Y., 2003. Analysis of hospital length of stay and discharge destination using hazard functions with unmeasured heterogeneity. Health Economics 12 (12), 1021–1034.

Pope, G. C., Jun. 1989. Hospital nonprice competition and medicare reimbursement policy. Journal of Health Economics 8 (2), 147–172.

Qian, X., Russell, L., Valiyeva, E., Miller, J., Oct. 2007. Medicare's prospective payment system for hospitals: New evidence on transitions among health care settings. Tech. rep., Rutgers University, Department of Economics.

Rogerson, W. P., 1994. Choice of treatment intensities by a nonprofit hospital under prospective pricing. Journal of Economics & Management Strategy 3 (1), 7–51.

Rosenthal, M. B., Frank, R. G., 2006. What is the empirical basis for paying for quality in health care? Medical Care Research and Review 63 (2), 135.

Saka, m., McGuire, A., Wolfe, C., Jan. 2009. Cost of stroke in the united kingdom. Age and Ageing 38 (1), 27–32.

Seshamani, M., Schwartz, J. S., Volpp, K. G., Jun. 2006a. The effect of cuts in medicare reimbursement on hospital mortality. Health Services Research 41 (3 Pt 1), 683–700.

Seshamani, M., Zhu, J., Volpp, K. G., Jun. 2006b. Did postoperative mortality increase after the implementation of the medicare balanced budget act? Medical Care 44 (6), 527–533.

Shen, Y.-C., Mar. 2003. The effect of financial pressure on the quality of care in hospitals. Journal of Health Economics 22 (2), 243–269.

Shmueli, A., Intrator, O., Israeli, A., Sep. 2002. The effects of introducing prospective payments to general hospitals on length of stay, quality of care, and hospitals' income: the early experience of israel. Social Science & Medicine 55 (6), 981–989.

Simonsen, M., Skipper, L., Skipper, N., 2010. Price sensitivity of demand for prescription drugs: Exploiting a regression kink design. Economics Working Papers.

Sood, N., Buntin, M. B., Escarce, J. J., Jul. 2008. Does how much and how you pay matter? evidence from the inpatient rehabilitation care prospective payment system. Journal of Health Economics 27 (4), 1046–1059.

Street, A., O'Reilly, J., Ward, P., Mason, A., 2011. DRG-based hospital payment and efficiency: Theory, evidence, and challanges. In: Busse, R., Geissler, A., Quentin, W., Wiley, M. (Eds.), Diagnosis-Related Groups in Europe: Moving towards transparency, efficiency and quality in hosiptals. Open University Press - McGraw-Hill Education.

Wu, V. Y., 2010. Hospital cost shifting revisited: new evidence from the balanced budget act of 1997. International Journal of Health Care Finance and Economics 10, 61–83.

Wu, V. Y., Shen, Y.-C., 2011. The long-term impact of medicare payment reductions on patient outcomes. National Bureau of Economic Research Working Paper Series No. 16859.