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This is the author's manuscript

Original Citation:

Availability:

This version is available http://hdl.handle.net/2318/1649995 since 2017-10-19T15:36:44Z

Published version:

DOI:10.1002/hec.3541

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03 February 2025

UNIVERSITÀ DEGLI STUDI DI TORINO

This is an author version of the contribution published on:
Questa è la versione dell'autore dell'opera:

M. Di Giacomo, M. Piacenza, L. Siciliani, G. Turati, "Do Public Hospitals Respond to Changes in DRG Price Regulation? The Case of Birth Deliveries in the Italian NHS", ***Health Economics****, vol. 26(S2), September 2017, pp. 23-37.*

The definitive version is available at:
La versione definitiva è disponibile alla URL:
http://onlinelibrary.wiley.com/doi/10.1002/hec.3541/epdf

Do Public Hospitals Respond to Changes in DRG Price Regulation?
The Case of Birth Deliveries in the Italian NHS

Abstract

We study how changes in DRG price regulation affect hospital behaviour in quasi-markets with exclusive provision by public hospitals. Exploiting a quasi-natural experiment, we use a difference-in-differences approach to test whether public hospitals respond to an exogenous change in DRG tariffs by increasing C-section rates and/or by upcoding. Controlling for a detailed set of mother characteristics, we find that price changes did not affect the probability of a C-section. We do however find evidence of upcoding: conditional on the birth delivery method (either a C-section or a vaginal delivery), public hospitals experiencing the largest price change exhibit a higher probability of treating patients coded as complicated. This finding suggests that even public hospitals may be sensitive to market incentives.

Keywords: DRG price regulation, public hospitals, birth deliveries, inappropriateness, upcoding.

JEL: H75, I11, I18, L32, L50.

1. Introduction

Most developed countries face increasing pressure for both improving health care quality and controlling spending growth. One common answer has been the use of market mechanisms: while universal and comprehensive coverage is still ensured, quasi-markets – coupled with yardstick competition and prospective reimbursement systems by diagnostic categories – have been introduced since the 90's in the UK, the Netherlands, France, Sweden, and Italy. The idea is to (re)introduce market incentives in a highly regulated sector, where publicly-owned providers often prevail. It is claimed that competition can increase efficiency and improve quality (e.g., Gaynor et al., 2012, Gaynor and Town, 2012). However, side effects may also arise, in particular hospitals' opportunistic behaviours, such as inappropriateness and upcoding, aimed to maximize reimbursements (e.g., Dranove, 2012).

In an effort to increase the efficiency of public spending and contain public debt, the Italian government adopted the quasi-markets model in 1992. As in other countries, the national framework legislation required the separation of providers from purchasers of health services. The latter was then expected to contract with different providers (ideally, public and also private hospitals) the services for all the residents in its jurisdiction. A prospective payment system (PPS) based on Diagnosis Related Groups (DRG) was introduced. A fixed price payment mechanism replaced a cost reimbursement one for public hospitals and a fee-for-service one for private hospitals (which paid a fee for each day spent in the hospital). Lump sum payments were instead used for emergency and other specialised services. Differently from other countries, the quasi-market model in Italy resulted in large institutional differences. Given that provision of services is decentralized to regional governments, each of the twenty regions defined its own quasi-market model. Regions differ in the extent to which they separate third-party payers from providers, in the degree of involvement of private providers, but also in the prices paid for the services. A national listing of tariffs was proposed by the Central Government in 1994, but – coherently with the regional nature of the NHS – an opportunity was given to regional governments to adopt their own set of tariffs, tailored to the actual costs of their local providers. The new PPS started in 1997, and regions not setting their own prices had to adopt the national tariff.

Piedmont, a large industrial region in the North-West of Italy, is an interesting example of this institutional diversity. Piedmont set its own tariffs in 2002. The regional government decided to only partly separate the providers from the public funder: some large independent public hospitals co-exist with public hospitals that are still integrated with the public purchaser. Most importantly, although private hospitals supply about 20% of total beds in the regional healthcare system, as birth deliveries are concerned, the regional government allows only public hospitals to offer this service. This means that all deliveries funded by the public insurance scheme are within public hospitals. These characteristics make Piedmont an ideal setting for assessing how public hospitals respond to variations in DRG price regulation, even in a context characterized by weak market incentives, due to potentially soft budget constraints and the lack of competition with private providers (e.g., Duggan, 2000).

Our analysis is based on a large micro dataset covering all birth deliveries between 2007 and 2012. The data contains detailed clinical and socio-demographic information of women giving birth. We supplement data on birth deliveries with information on DRG tariffs. The analysis exploits a quasi-natural experiment: during our sample period, the regional tariffs changed only once, in 2010. This policy change was related to a set of hospital characteristics which directly affect hospital costs (like the presence of an emergency unit, research centres, or teaching units). In particular, the agreed price change was a percentage change applied to all DRG tariffs contracted with that hospital, and it was not related to birth deliveries or maternity units. This makes price changes exogenous to childbirth treatments. Our identification strategy exploits the fact that a group of hospitals were not affected by the increase in prices (our control group), a second group was affected by a smaller increase in prices, and a third group by a larger increase in prices (our treatment groups).

We consider two possible behavioural hospital responses. We identify the impact of the price change on: i) the probability of women having a C-section instead of a natural birth; ii) upcoding, as measured by the proportion of patients with complications. Using a difference-in-differences (DiD) strategy, our key results are as follows. We do not find that price changes affect the probability of a C-section. We do however find evidence of upcoding. Conditional on birth delivery method (either a C-section or a vaginal delivery), public hospitals experiencing the largest price increase exhibit a higher probability of treating patients coded as complicated. As a result of a price increase by four percent, the probability of a C-section with complications is higher than the probability of a C-section without complications by five percentage points; the probability of a vaginal delivery with complications is higher than a vaginal delivery without complications by two percentage points.

The paper relates to two strands of literature: (1) the incentive literature testing the effect of changes in DRG prices on diagnosis choice, including upcoding; (2) the health economics literature on the clinical appropriateness of healthcare treatments, looking in particular at C-sections. Within the first strand, Dafny (2005) provides evidence of upcoding when US hospitals experienced an increase in diagnosis-specific prices and this response was stronger among for-profit hospitals compared to non-profit and public hospitals, confirming a previous result by Silverman and Skinner (2004). More recently, Januleviciute et al. (2016) find that an increase in prices may trigger hospital response in medical (as opposed to surgical) DRGs in Norway, also reporting evidence of upcoding. Our paper also contributes to the extensive literature on the determinants of treatment choices (e.g., Chandra et al., 2012) and, specifically, of C-section deliveries. This literature has investigated several explicative factors (see, e.g., the recent survey in Francese et al., 2014), and the role played by reimbursement mechanisms is our main focus here. Each hospital is responsible for the choice of the appropriate treatment for delivery. Besides clinical conditions, the choice of C-sections is then influenced by differences in both medical and managerial practices across hospitals. As for medical practices, different physicians can simply evaluate clinical conditions in different ways. For instance, even a small 'degree' of malposition (one of the fetus' characteristics which make the use of C-section necessary according to clinical guidelines) can lead a risk-averse physician to recur to a caesarean delivery to avoid the risk of a lawsuit (e.g., Shurtz, 2013). Managerial practices can differ, for instance, in terms of incentives given to physicians. Doctors' wage can include also a (small) variable part related to i) the containment of the proportion of caesarean sections within the limits regionally defined; or ii) the effort put forward to control costs to avoid a deficit and therefore to help the regional government to stay within the budget assigned by the Central government. Gruber et al. (1999), Grant (2009) and Allin et al. (2015) find that an increase in price differentials between cesarean and vaginal deliveries, all else equal, enhances the rate of C-sections, thus presumably reducing the clinical appropriateness of the treatment. Our contribution to the literature is, differently from previous works, a study of hospitals' responses to price changes in markets with exclusive provision by public providers, where financial incentives are expected to play a minor role.

The remainder of the paper is organized as follows. The next section describes the data. Section 3 introduces the estimation strategy, and discusses our results. Section 4 concludes.

2. Data

2.1. Sources and variables

The data source is the CeDAP (*Certificato di Assistenza al Parto*), literally the 'birth aid certificate' issued by the hospital where the delivery occurs. The certificate provides a rich source of information. These include:

i) the identity of the hospital, the admission date, the delivery date, and the discharge date of the woman giving birth;
ii) birth outcome: method of delivery (C-section or vaginal delivery), infant general conditions immediately after birth (Apgar score), and the possible most dramatic health outcome, i.e., infant death at birth[1];
iii) detailed information on medical conditions of the mother during pregnancy, labour and at delivery: number of previous births and number of previous C-sections, number of previous miscarriages, weight gain during pregnancy, twin births, Robson classification[2], breech births, Rh sensitivity[3], whether the woman experienced hospital

[1] Information about mother post partum conditions and puerperium is available only for births occurring from 2010.

[2] The Robson Classification (Robson, 2001) aims at giving a comparable framework for classifying pregnant women. The classification consists of ten mutually exclusive groups, where the following obstetric conditions are considered: presentation (cephalic, breech, other), parity (number of previous deliveries), labour (spontaneous, induced, or past C-Sections), delivery week, single or multiple pregnancy. Low risk birthing women (single child, cephalic presentation, spontaneous labor and delivery week greater than 37)

admissions during pregnancy and the presence of diseases in pregnancy (pathological pregnancy, i.e., presence of diabetes, eclampsia, hypertension, preterm labour, placental defects, mental health condition), delivery week[4], whether the woman chose a gynaecologist/obstetrician working in a public hospital (or a private practice) for prenatal care;

iv) other pathologies (asthma and allergies), and alcohol consumption and smoking during pregnancy;

v) demographic data on the mother: age, nationality, residence, education and employment status.

We supplemented these data on births' outcomes and mothers' attributes, with information on DRG tariffs. These data were supplied by the Piedmont regional government, which is responsible for setting all the DRG tariffs for public hospitals within the administrative regional borders. During our observed period (2007-2012) the base regional reimbursement tariff changed only once, in 2010.

Price variation is hospital specific and exogeneity is assured by the fact that the agreed tariff change is a percent change applied to *all* DRGs occurring in that hospital, in order to remunerate higher average costs for some categories of hospitals with four specific functions identified:

(a) presence of an emergency department;

(b) presence of research centres;

(c) teaching hospital;

(d) specialized (vs. general) hospital.

The hospitals obtaining the highest price increase (a four percent increase) are those scoring four points in the four factors above. Hospitals scoring zero, did not receive any price increase. Hospitals scoring in the interval one to three, obtain their price update

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are in Robson class 1, while high-risk pregnancies are grouped in subsequent classes (e.g., women experiencing pre-term births and previous C-sections are in class 10).

[3] Rh sensitivity occurs when a woman has Rh-negative blood group, while the baby has Rh-positive blood. In these cases, at delivery, when mother's blood and baby's blood mix, the mother body could trigger an immune reaction that may cause serious problems to the child, especially in subsequent pregnancies, because of the presence of antibodies in the mother blood. Continuing medical care is necessary during the whole pregnancy.

[4] A preterm (or premature) birth occurs before the 37th pregnancy week. A term birth is between 37th and 41st week. A post-term (prolonged) pregnancy occurs when delivery is on or after 41 pregnancy weeks.

accordingly. Clearly, the price change experienced by each hospital is linked to these functions and not to its childbirth activity.

Our final sample includes 216,760 deliveries occurred in 31 public hospitals. They represent around 95% of all deliveries occurred in Piedmont between 2007 and 2012.[5] We deal with three broad groups of hospitals. The first group (Group 1) includes two large hospitals (on average 4,600 deliveries per year) within the metropolitan area of Torino that experienced the largest tariff increases. The second group (Group 2) includes twenty-five hospitals (on average 1,000 deliveries per year), whose price changes were positive but smaller over the period considered. The third group (Group 3) is a set of four small hospitals (with on average 500 deliveries per year) whose reimbursement tariffs did not change over time. We will refer to Group 3 as our 'untreated' (or control) group, i.e., the group of hospitals not affected by the tariff change in 2010.

We exploit information for four relevant DRGs: vaginal deliveries with (DRG 372) and without complications (DRG 373), C-section with (DRG 370) and without complications (DRG 371). Figure 1 shows the dynamics over time of the spread between the reimbursement tariffs for C-sections and vaginal deliveries (without and with complications), for the three groups of hospitals. For hospitals in Group 1, the difference in the reimbursement tariffs between a C-section and a vaginal delivery increases from Euro 960 to Euro 1000. For hospitals in Group 2, the spread changes from Euro 915 to Euro 924. In the case of complications, the C-section/vaginal delivery spread for hospitals in Group 1 shifts from Euro 1420 to Euro 1480, while for Group 2 from Euro 1350 to Euro 1364. A similar dynamics over time by hospital groups is observed for the spread between the tariffs for C-sections with and without complications and for the spread between the tariffs for vaginal deliveries with and without complications. In particular, the spread between C-sections with complications and C-section without complications increases from Euro 1260 to Euro 1312 (+4.1%) in Group 1, and from Euro 1198 to Euro 1210 (+1%) for Group 2. The differential increase for natural birth deliveries with and without complications is from Euro 802 to Euro 834 (+4%) for hospitals in Group 1, and from Euro 762 to Euro 769 (+0.9%) in Group 2.

[5] Source: Istat, the Italian National Institute of Statistics. Our sample does not cover home births, private hospitals and two small public hospitals whose information was incomplete for the relevant years (the public hospitals in Ceva and Ivrea).

2.2. Descriptive statistics

Our main dependent variable is the delivery method coupled with the presence of complications. We deal with four possible outcomes: a vaginal birth without complications, a vaginal birth with complications, a C-section without complications and a C-section with complications. A different DRG (and reimbursement tariff) is attached to each possible birth outcome. An assisted birth (use of forceps or ventouse) typically represents a complicated case for vaginal deliveries, while most emergency C-sections are among the complicated events.

Identification of the effects of the price increase requires that trends in C-section and vaginal deliveries (with and without complications) do not differ across the three groups of hospitals before the policy change, i.e. when the reimbursement tariffs were constant. Figure 2 sheds some light on the issue. The two top panels of the figure show the dynamics over time of C-section rates (number of all C-sections out of total deliveries), and complication rates (number of vaginal and C-section births with complications out of total deliveries). C-sections slightly decrease over time, especially in Group 2 and Group 3 (the untreated one). C-sections rates are always above 28%, and for hospitals in Group 1, the C-section rate is above 35% in all years. The complication rate shows a sharp increase in all groups of hospitals, especially after 2009. While the average pre-policy complication rate is 3.9% for Group 1, 8.7% for Group 2 and 4.6% for the untreated group, after 2010 the three average rates jump to 9.9%, 9.8%, and 7% respectively. Such increases are large, both in absolute and relative terms. Relative differences within and across groups are also large (e.g., for Group 1 the relative increase is +157%, while for the Untreated the increase is only +52%). In our evaluation design, we are primarily interested in absolute differences in complication rates since they represent a direct measure of the impact on revenues and, hence, on spending for the regional government.

Moreover, unlike the C-section rates, the pre-policy trends for complications look very similar for the three groups of hospitals. This supports the validity of the assumption of parallel trends across groups, absent the treatment, at least when complications are considered. To further explore the issue, the two bottom panels of figure 2 split the ratio of complicated deliveries distinguishing C-sections from vaginal deliveries. The three groups of hospital show similar trends in the pre-policy period, especially for complicated C-section rates.

Following Silverman and Skinner (2004), we couple this evidence on complication rates with information on risky pregnancies. Table 1 reports two possible indicators of complicated cases: the Robson Classification and a risk factors index, based on a number of clinical conditions of the mother (see Table 1 for definitions). We compute the average of the two indicators over time and by hospital group. Higher indexes indicate riskier pregnancies, with higher expected probabilities for a C-section delivery or a delivery with complications. Focusing on the pre-treatment period, hospitals in Group 1 systematically deal with a larger number of high-risk pregnancies, while Group 2 and the Untreated have statistically undistinguishable risk factors. In principle, however, the difference-in-difference strategy is robust to endogenous health conditions, as long as the expected trends for complications (conditional on observables) are parallel in the absence of the policy change (Beatty and Shimshack, 2011). We statistically test this assumption in our empirical model.[6]

Table 2 provides descriptive statistics for mothers' characteristics. In terms of demographics, about 60% of mothers are between 30 and 39 years old, 67% are married, 49% have a high school degree, and 67% are employed. In relation to the clinical conditions, about 55% of deliveries are first births, 18% of mothers experienced a high risk (pathological) pregnancy, 11% had a previous C-section, and 17% of deliveries were overdue, i.e., after the 40th week of pregnancy. The average weight gain during pregnancy is 10.8 Kg. The average number of previous miscarriages and pregnancy hospital admissions are 0.2 and 0.1 respectively. The distribution of mothers' characteristics shows some differences across groups of hospitals. With regard to demographic information, mothers in Group 1 are more likely to work (71% in Group 1, 66% in Group 2, and 63% in the Untreated group). They are more likely to have the lowest levels of education: the rates of women with no education are 7% in Group 1, 5% in Group 2 and 2% in the Untreated group. They are also more likely to have the highest level of education with graduated women being 20%, 18% and 15% respectively. Information about medical conditions also

[6] In particular, we allow for leads and lags of the treatment (Autor, 2003), and linear hospital specific time trends among the regressors (Besley and Burgess, 2004).

differ across groups, reflecting the evidence (as from Table 1) that hospitals in Group 1 deal with riskier pregnancies: women are older and more likely to have experienced past C-sections, weight gain, miscarriages and past hospital admissions. The proportion of pathological pregnancies, twin and breech deliveries, allergies, alcohol consumption, pre-term births are also higher for Group 1. In order to capture different casemix across hospitals, all these observable characteristics for the mother are controlled for in our regression model. Moreover, we control for time-invariant differences in casemix and treatment complexity across hospitals through hospital fixed effects.

3. Empirical strategy and results

We investigate whether a variation of financial incentives induced by a change in DRG price regulation triggers a response by hospitals, even in a system where all providers are publicly-owned.[7] In particular, we want to test the following two hypotheses:

1. Inappropriateness: when tariffs change, hospitals shift patients to higher paid diagnoses, by changing the treatment from vaginal to C-sections.
2. Upcoding: when tariffs change, hospitals shift patients to higher paid DRGs, without changing any aspect of care but simply coding additional complications.

3.1. Inappropriateness

The empirical strategy is based on the estimation of a binomial regression model. The birth delivery type is modelled as a latent variable *y**, with *y* being the observed outcome equal to one when a C-section is performed, and to zero for a natural birth. Our first main empirical specification is:

$$\begin{aligned} y_i^* &= \alpha_0 + \delta_1 (G_1 \times post_{2010}) + \delta_2 (G_2 \times post_{2010}) + X_i^M{}'\beta + X_i^D{}'\gamma + \mu_t + \mu_m + \mu_w + \mu_h + \varepsilon_i \\ y_i &= 1 \text{ if } y_i^* > 0 \qquad (1) \\ y_i &= 0 \text{ if } y_i^* \leq 0 \end{aligned}$$

[7] A similar analysis for a different Italian region and a different set of treatments can be found in Verzulli et al. (2016). Although the regional framework is comparable, the authors exploit a different administrative dataset which does not allow to control for a number of individual characteristics; additionally, they do not consider the case of upcoding.

where the type of birth delivery for woman i is a function of individual characteristics related to medical conditions X^{M}_{i} (age, pathologies, allergies, weight gain, hospital admissions, number of children, previous C-sections, etc.) and socio-demographic information X^{D}_{i} (education level, marital status, working condition). We include a set of dummies for each year (μ_t), month (μ_m), and day of the week (μ_w). The hospital fixed effects (μ_h) capture time-invariant hospital characteristics, including the availability of a neonatal intensive care unit or a paediatric emergency department.

G_1 and G_2 are two dummy variables for hospitals in Group 1 (larger price increase) and Group 2 (smaller price increase), respectively. $post_{2010}$ is a dummy variable equal to one for birth deliveries in the post-policy period (from 2010 to 2012), and zero otherwise. δ_1 and δ_2 are the parameters of interest, measuring the change in the probability of having a C-section in Group 1 or Group 2 hospitals (when compared to the 'untreated' Group 3) after the change in prices.

One possible concern with equation (1) is that any effect on C-section rates induced by a price change may be due to changes in classifying patients with and without complications (a form of upcoding). We therefore estimate equation (1), first without controlling for complications and then compare these estimates with those obtained once a control for patients being classified as having complications is added to the model. If the results are robust with and without inclusion of the complication dummy, then we should be able to rule out that the effect on C-sections is due to upcoding.

Second, we estimate equation (1) separately for the two sub-samples of births with and without complications. We may expect the price change to differently affect the probability of a C-section for women with and without complications.

In Table 3 we present estimation results (linear probability models) for equation (1). Columns (1) and (2) only differ for the inclusion of a dummy variable that controls for those deliveries coded as complicated (either vaginal or C-section). While the dummy for complications is positive and significant, implying that, all else equal, we may expect a higher probability of C-section when a case is coded as complicated, the two interaction terms for Group 1 and Group 2 are not significantly different from zero. After the policy change in 2010, hospitals do not display any difference in their C-section probabilities.

In columns (3) and (4) of Table 3, we consider the common trend assumption implied by equation (1). We thus re-estimate the specifications from columns (1) and (2) by including interaction terms between the two hospitals' groups dummy variables (G_1 and G_2) and all year dummies, which corresponds to consider a full set of leads and lags of our treatment (i.e., the price change occurred in 2010).[8] This augmented specification allows us to test whether: 1) a common trend in our dependent variable existed before the policy change; 2) the new prices exerted an impact already in the first year after their introduction, or dispatched their effects in the following years. In column (4) we also include the dummy for complicated cases, which is again positive and statistically significant. Interestingly, for hospitals in Group 1 only, all interacted terms before 2011 are positive and significant. Given that the reference year is 2007, the probability of a C-section is higher in all years, except for 2012, for hospitals in Group 1. The policy change seems not to affect the hospital behaviour as for the choice of the delivery procedure. Finally, in column (5) we include a linear time trend interacted with hospital specific dummy variables, which allows for differential time trends in C-sections across hospitals. The results are unaltered as no reaction after the policy change is again found.

3.2. Upcoding

It may be that the observed higher probability of C-sections when a case is coded as complicated (Table 3, columns (2)-(4)-(5)) hides a possible upcoding behaviour by hospitals. Indeed, in the actual practice for birth deliveries, the clinical staff usually upcode to the presence of complications after the choice of the delivery method (C-section vs. vaginal birth). Therefore, the result in Table 3 may be due to the provider upcoding more severe patients who are more likely to have a C-section.

We start exploring the determinants of complications in Table 4, where we report estimates of a linear probability model where the dependent variable is now equal to one for complicated deliveries (C-sections and vaginal) and zero for non-complicated cases.

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[8] A well-known example of this DiD approach is the paper by Autor (2003), that includes both leads and lags in a model analyzing the effect of increased employment protection on the firm's use of temporary help workers in US.

The set of independent variables is the usual one (see equation (1)), including interaction terms between groups of hospitals and post 2010 dummy, mothers' characteristics, and the full set of year, month, weekday and hospital fixed effects. As expected the R^2 from this regression (0.08) is lower than in Table 3 (0.40), reflecting that complications are not well explained by our observables. The key finding from Table 4 is that the policy change produced some response from hospitals in Group 1. After the policy change, the probability of observing complicated cases increased in hospitals where the price change was larger. We also include in all specifications a dummy for C-sections, which is always positive – as expected – and statistically different from zero.

Finally, we investigate upcoding behaviour in more detail, by testing whether the price change in 2010 affects the probability of complications separately for C-section and natural births. We therefore run two regressions, one for C-section patients, and one for natural births. In order to account for possible "selection effect" through the type of procedure (C-section vs. vaginal delivery), since prices changes can increase the probability of a C-section, we introduce a Heckman selection type model (Heckman, 1979). The specification is a bivariate sample selection model[9]:

$$y_i^* = \alpha_0 + \delta_1(G_1 \times post_{2010}) + \delta_2(G_2 \times post_{2010}) + X_i^{M}{}'\beta_0 + X_i^{D}{}'\gamma + \mu_t + \mu_m + \mu_w + \mu_h + \varepsilon_i \qquad (2)$$

$$w_i^* = \alpha_1 + \delta_3(G_1 \times post_{2010}) + \delta_4(G_2 \times post_{2010}) + X_i^{M}{}'\beta_1 + \lambda_t + \lambda_m + \lambda_w + \lambda_h + u_i \qquad (3)$$

$$y_i = 1 \text{ if } y_i^* > 0$$

$$y_i = 0 \text{ if } y_i^* \leq 0$$

$$w_i = 1 \text{ if } w_i^* > 0 \text{ and } y_i^* > 0$$

$$w_i = 0 \text{ if } w_i^* \leq 0$$

where equation (2) is the participation equation, and equation (3) is the upcoding equation; they are simultaneously estimated by maximum likelihood, after assuming the error terms ε and u are jointly normally distributed.

We estimate equations (2) and (3) for the two subsamples of C-sections and natural births. When estimating the model on the patients that underwent a C-section, the binary

[9] The notation for equations (2) and (3) is similar to that for equation (1): X^M_i collects medical conditions (see Table 2), X^D_i socio-demographic information (see Table 2). μ_t and λ_t represent sets of dummies for year, μ_m and λ_m dummies for month, and μ_w and λ_w dummies for the day of the week. The hospital fixed effects are μ_h and λ_h. G_1 and G_2 are two dummy variables for hospitals in Group 1 and Group 2, respectively; $post_{2010}$ is a dummy variable equal to one for deliveries in the post-policy period (from 2010 to 2012), and zero otherwise.

variable y equals one when a C-section occurred, and zero for vaginal deliveries. The binary variable w controls for complications: it equals one for women who underwent a C-section with complications, and zero for C-section deliveries without any complications. Similarly, for the subsample of women delivering by natural birth, y is equal to one for vaginal deliveries, and zero for C-sections, while w is equal to one if a vaginal delivery with complications is observed, and zero for natural birth with no complications.

Identification of the bivariate sample selection model is achieved by an exclusion restriction: while the full set of medical and socio-demographic information (X^M and X^D) may affect the participation, i.e., the choice of a C-section instead of a vaginal delivery, it is reasonable to assume that only medical conditions (X^M) play a role in the decision to classify a birth as a complicated case. To support this exclusion restriction, we refer to some evidence in the medical literature on the link between delivery methods (C-section vs. natural birth) and maternal preferences, which strongly depend on socio-demographic factors like education and occupational status of the mother (see, e.g., Charles et al., 1999, Coulter, 1999, Donati et al., 2003). Indeed, the decision process about the delivery method with an active involvement of the patient has become increasingly acceptable; on the contrary, the decision to code the patient as complicated totally rests on physicians and only depends on mother’s medical conditions (e.g., Kalish et al., 2006).

From a statistical point of view, the demographic variables that we exclude (the dummies for married women, working women and education level) are neither individually nor jointly significant at conventional statistical levels in the upcoding equation, while they are all significant in the C-section equation, and with the expected sign. We also implement some additional Likelihood Ratio (LR) tests on the validity of our exclusion restriction. We estimate equations (2) and (3) in the perfectly identified version (where the same set of covariates enter both the participation and the upcoding equations) and compare it to the model where the exclusion restriction is introduced. The exclusion restriction is never rejected, at any conventional significance level.

Tables 5 and 6 report results from the Heckman type model in equations (2) and (3): while Table 5 considers the coding decision within C-section births, Table 6 considers the coding decision within vaginal deliveries. In columns (1) of Tables 5 and 6, the main finding is that the policy change did not affect the delivery method (participation equation), which is in line with Table 3, but it triggered some response in the coding practice (upcoding equation). All else equal, hospitals in Group 1 (experiencing larger price changes) show a higher probability of complicated cases (upcoding), both in the case of vaginal and C-section deliveries, and the effect is stronger for C-sections. Surprisingly, hospitals in Group 2 have a reduced probability of complicated C-sections after the policy change, which is even lower than for the 'untreated' group of hospitals (Table 5, column (1)). All else equal, for hospitals in Group 1, the probability of a C-section with complications is higher than the probability of a C-section without complications by five percentage points (Table 5, column (1)), while the probability of a vaginal delivery with complications is higher than a vaginal delivery without complications by two percentage points (Table 6, column (1)).

In columns (2) of Tables 5 and 6 we include a full set of leads and lags of our treatment. As with respect to the participation equation, we confirm results from Table 3: for hospitals in Group 1, almost all interactions are significantly different from zero, and no response after the policy change is actually detected. In the upcoding equation for C-sections (Table 5, col. (2)), point estimates for Group 2 are decreasing over time, even if never significant. Instead for Group 1, coefficients are zero in the years before the price change, then they are positive in 2010 (marginally significant at the 11% level) and in 2011 (significant at conventional level) and finally they come back to the pre-policy level in 2012. For natural births (Table 6, col. (2)), coefficients for Group 2 in the upcoding equation are always zero, while coefficients for Group 1 are increasing in the post policy years 2011 and 2012. Overall, the policy triggered some reaction in hospitals that experienced high price changes (Group 1), although its effect seems limited to the first two years after the change.

Finally, columns (3) from Tables 5 and 6 report results when we include the interaction between a linear trend and the full set of hospital dummies. While the upcoding effect disappears for vaginal deliveries, upcoding is still present and even larger when compared to column (1) for C-sections. The probability of observing a complicated C-section is higher by 6.7 percentage points in public hospitals where the price change was larger (Group 1 in Table 5, column (3))[10].

[10] The degree of correlation (ρ) between the error terms in the participation and the upcoding equations presented in Table 6 is not significantly different from zero in all specifications, pointing to absence of

We are aware that our results could be affected by ecological fallacy, due to inference about the individuals' behaviour drawn from aggregate data (Freedman, 2004). However, ecological fallacy is substantially reduced in our estimated model, as the observational unit is a single childbirth, and we are able to include a large number of observable demographic and medical conditions of the mother. Still, ecological fallacy may arise from aggregating hospitals in three groups. For this reason, we experiment with alternative groupings, in particular splitting Group 1, since this is the group mostly affected by the price increase. Results are almost unchanged and evidence of upcoding is still found in all hospitals that experienced the highest tariff change.

4. Conclusions

This paper investigates the response of hospitals to exogenous changes in DRG price regulation, focusing on health care markets with exclusive provision of birth deliveries by public producers. We identify three groups of hospitals according to the observed degree of price variation. We then use medical and socio-demographic data on all women giving birth in one Italian region over a six year time span, three years before and three years after the policy change. We focus on four DRGs – vaginal deliveries with and without complications, and C-section deliveries with and without complications – and test whether in response to a relative price increase hospitals are more likely (i) to provide a C-section and (ii) to shift patients to higher paid DRGs to increase their reimbursements.

Consistently with previous literature (e.g., Silverman and Skinner, 2004, Dafny, 2005, Januleviciute et al., 2016), our analysis suggests that changes in DRG prices have an impact on hospital behaviour and influence the choice of DRG. Compared to existing studies, we find a price response even in a market where all hospitals are public. This is to some extent surprising since *a priori* financial incentives are expected to play a minor role for public providers, due to possible soft budget constraints and the lack of competition with private hospitals. We find evidence of upcoding for hospitals that experienced the largest price change: these show a higher probability of reporting patients with complications, both for vaginal and C-section deliveries, with a larger magnitude for the

selection. We use ordinary least squares to fit the upcoding equation for natural births (complicated vs non-complicated) and we obtain results similar to those displayed in Table 6.

latter. Instead changes in DRG prices do not affect the probability of having a C-section. Hence the variation in price regulation does not seem to exert any impact on the inappropriateness of health care treatments.

It is worth highlighting that the presence of upcoding as a response to changes in price regulation is detected despite observed price increases being relatively small (4 percent for the group subject to the highest increase in price). This finding suggests that even public hospitals may be sensitive to market incentives and take care of balancing the budget. This is even more plausible within a context, such as the Italian NHS, where external audits are virtually absent [11]. In the period analysed here this behaviour is likely to be due to the more austere financial climate triggered by the worldwide crisis since 2008 and the tighter constraints on public finances imposed at the European level.

Acknowledgements: We wish to thank two anonymous referees for their careful review, and the Editor Giorgio Vittadini for his advices. Thanks are also due to Veronica Grembi, Paolo Li Donni, Klenio Barbosa and all seminar participants at the XXVIII SIEP Conference (Lecce), the V Health Econometrics Workshop (Bari), the VII NERI Meeting (Torino), and the XII Annual IIOC (Chicago), for their insightful comments. We are grateful to Mirko Pia at Regione Piemonte, Assessorato alla Sanità, for kindly supplying the data. Usual disclaimers apply.

Declaration of interests

We declare no competing interests.

Original publication

We declare that no prior or duplicate publication or submission elsewhere of any part of the work has been included in the manuscript.

Ethics

We declare that no ethical issues are involved in the production of this manuscript.

[11] Indeed, one can think that, due to reputational reasons, small price increases are not enough to justify any change in professional standards (e.g., Pongpirul and Robinson, 2013, Pongpirul et al., 2011). However, absent external audits, such reputational concerns are unlikely to be effective.

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Table 1. Average Robson class and average risk factor index over time and by hospital groups

	Robson Class			Risk Factors		
Year	*Group 1*	*Group 2*	*Untreated*	*Group 1*	*Group 2*	*Untreated*
2007	3.286	2.924	2.919	1.554	0.637	0.604
2008	3.269	2.918	2.858	1.261	0.647	0.578
2009	3.359	2.942	2.804	1.210	0.699	0.610
2010	3.378	3.047	2.927	1.009	1.490	1.370
2011	3.352	3.079	2.905	1.118	1.552	1.427
2012	3.608	3.087	3.014	1.181	1.552	1.458

Notes: The risk factor index is computed as the sum of the following binary variables: Pathological pregnancy, Twin birth, Breech birth, Asthma in pregnancy, Allergy in pregnancy, Alcohol in pregnancy, Smoke in pregnancy, RH sensitivity, Delivery week below 36, Delivery week above 40, mother age above 40. Higher Robson class and risk factors signal high-risk deliveries.

Table 2. Descriptive statistics (mean and standard deviation) for the mothers' characteristics

	Group 1		Group 2		Untreated		Whole sample	
	Mean	Std.dev.	Mean	Std.dev.	Mean	Std.dev.	Mean	Std. dev.
Demographic Information								
Married	0.693	0.461	0.653	0.476	0.705	0.456	0.666	0.472
Working	0.707	0.455	0.656	0.475	0.634	0.482	0.668	0.471
Educ. None	0.067	0.25	0.047	0.212	0.024	0.154	0.051	0.22
Educ. Mandatory	0.217	0.412	0.296	0.456	0.324	0.468	0.277	0.448
Educ. High	0.52	0.5	0.478	0.499	0.506	0.5	0.49	0.5
Educ. graduate	0.196	0.397	0.18	0.384	0.146	0.353	0.182	0.386
Medical Conditions								
- Dichotomous variables								
Age <20	0.01	0.099	0.016	0.125	0.017	0.128	0.014	0.119
Age 20-25	0.092	0.289	0.137	0.344	0.154	0.361	0.127	0.333
Age 26-29	0.163	0.37	0.202	0.402	0.223	0.416	0.193	0.395
Age 30-35	0.438	0.496	0.414	0.493	0.412	0.492	0.42	0.494
Age 36-39	0.218	0.413	0.174	0.379	0.148	0.355	0.184	0.387
Age >39	0.079	0.27	0.057	0.231	0.046	0.21	0.062	0.241
Pathological	0.367	0.482	0.116	0.32	0.085	0.278	0.178	0.383
First birth	0.555	0.497	0.544	0.498	0.517	0.5	0.545	0.498
Second birth	0.345	0.475	0.347	0.476	0.367	0.482	0.348	0.476
Third birth	0.078	0.268	0.084	0.278	0.091	0.287	0.083	0.276
Fourth+ birth	0.022	0.147	0.025	0.155	0.026	0.159	0.024	0.153
Twin	0.038	0.192	0.012	0.108	0.006	0.074	0.018	0.134
Breech	0.062	0.242	0.045	0.208	0.043	0.204	0.049	0.217
Other C-section	0.125	0.331	0.101	0.301	0.104	0.305	0.107	0.31
Asthma	0.001	0.022	0.011	0.104	0.008	0.092	0.008	0.09
Allergy	0.099	0.299	0.051	0.219	0.051	0.221	0.063	0.243
Alcohol	0.162	0.368	0.006	0.078	0.003	0.053	0.046	0.209
Smoke	0.074	0.262	0.071	0.256	0.084	0.278	0.072	0.259
Rh-sensitivity	0.103	0.304	0.479	0.5	0.434	0.496	0.38	0.485
Public Gyn	0.326	0.469	0.386	0.487	0.403	0.49	0.371	0.483
Italian	0.76	0.427	0.742	0.438	0.796	0.403	0.749	0.433
Del. week <28	0.005	0.071	0.003	0.051	0.001	0.034	0.003	0.056
Del. week 28-31	0.012	0.109	0.005	0.072	0.001	0.036	0.007	0.082
Del. week 32-33	0.013	0.115	0.008	0.087	0.002	0.041	0.009	0.093
Del. week 34-36	0.073	0.26	0.049	0.215	0.039	0.193	0.054	0.226
Del. week 37-40	0.757	0.429	0.752	0.432	0.768	0.422	0.754	0.431
Del. week >40	0.14	0.347	0.184	0.388	0.189	0.392	0.173	0.378
- Continuous variables								
Weight gain (Kg)	12.099	6.551	10.397	6.315	9.52	7.04	10.785	6.468
Robson class (1-10)	3.374	2.57	2.999	2.314	2.903	2.121	3.09	2.378
Miscarriage (Num.)	0.254	0.603	0.189	0.514	0.188	0.506	0.206	0.539
Admissions (Num.)	0.161	0.519	0.056	0.29	0.034	0.232	0.082	0.363
N. obs.	55,592		149,112		12,056		216,760	

Table 3. Linear Probability models: dependent variable is 1 for a C-section and 0 for a vaginal delivery

	(1)	(2)	(3)	(4)	(5)
G1×post2010	0.024	0.015			0.005
	(0.02)	(0.02)			(0.03)
G2×post2010	0.005	0.008			-0.003
	(0.01)	(0.01)			(0.02)
CC dummy		0.263***		0.263***	0.263***
		(0.02)		(0.02)	(0.02)
G1×2008			0.050**	0.046**	
			(0.02)	(0.02)	
G2×2008			0.005	0.002	
			(0.02)	(0.02)	
G1×2009			0.046*	0.046**	
			(0.02)	(0.02)	
G2×2009			-0.003	-0.002	
			(0.02)	(0.02)	
G1×2010			0.079***	0.070***	
			(0.02)	(0.02)	
G2×2010			0.003	0.005	
			(0.02)	(0.02)	
G1×2011			0.038*	0.023	
			(0.02)	(0.02)	
G2×2011			-0.004	-0.003	
			(0.02)	(0.02)	
G1×2012			0.050	0.041	
			(0.03)	(0.03)	
G2×2012			0.018	0.022	
			(0.03)	(0.03)	
Mother demographic controls	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Mother medical controls	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Hospital fixed effects	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year fixed effects	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Month fixed effects	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Weekday fixed effects	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Hospital specific linear time trend	*No*	*No*	*No*	*No*	*Yes*
R^2	0.37	0.39	0.37	0.39	0.39

Notes: Mother controls (demographic information and medical conditions) are defined in Table 2. CC dummy is equal to one if the delivery is with complications. G1 is for hospitals in Group 1, G2 is for hospitals in Group 2. Standard errors are clustered at hospital-year level. The number of observations is 216,670.

* significant at 10% level; ** significant at 5% level and *** at 1% level.

Table 4. Linear Probability models: dependent variable is 1 for Complication and 0 otherwise

	(1)	(2)	(3)
G1×post2010	0.032***		0.032***
	(0.01)		(0.01)
G2×post2010	-0.012		-0.002
	(0.01)		(0.01)
G1×2008		0.007	
		(0.02)	
G2×2008		0.009	
		(0.02)	
G1×2009		-0.004	
		(0.02)	
G2×2009		-0.006	
		(0.02)	
G1×2010		0.024	
		(0.02)	
G2×2010		-0.009	
		(0.02)	
G1×2011		0.052***	
		(0.02)	
G2×2011		-0.006	
		(0.02)	
G1×2012		0.027	
		(0.02)	
G2×2012		-0.019	
		(0.02)	
C-Section dummy	0.144***	0.144***	0.144***
	(0.02)	(0.02)	(0.02)
Mother demographic controls	*Yes*	*Yes*	*Yes*
Mother medical controls	*Yes*	*Yes*	*Yes*
Hospital fixed effects	*Yes*	*Yes*	*Yes*
Year fixed effects	*Yes*	*Yes*	*Yes*
Month fixed effects	*Yes*	*Yes*	*Yes*
Weekday fixed effects	*Yes*	*Yes*	*Yes*
Hospital specific linear time trend	*No*	*No*	*Yes*
R^2	0.08	0.08	0.08

Notes: Mother controls (demographic information and medical conditions) are defined in Table 2. C-section dummy is equal to one if the delivery method was a C-section. G1 is for hospitals in Group 1, G2 is for hospitals in Group 2. Standard errors are clustered at hospital-year level. The number of observations is 216,670.

* significant at 10% level; ** significant at 5% level and *** at 1% level.

Table 5. Heckman regressions: Upcoding equation and Participation equation results for C-Section

	(1)	(2)	(3)
Upcoding			
G1×post2010	0.049*		0.067**
	(0.03)		(0.03)
G2×post2010	-0.050**		-0.021
	(0.02)		(0.03)
G1×2008		0.037	
		(0.03)	
G2×2008		0.035	
		(0.04)	
G1×2009		-0.005	
		(0.04)	
G2×2009		0.006	
		(0.04)	
G1×2010		0.052	
		(0.03)	
G2×2010		-0.015	
		(0.04)	
G1×2011		0.097**	
		(0.04)	
G2×2011		-0.027	
		(0.04)	
G1×2012		0.027	
		(0.05)	
G2×2012		-0.074	
		(0.05)	
Mother demographic controls	*No*	*No*	*No*
Mother medical controls	*Yes*	*Yes*	*Yes*
Hospital fixed effects	*Yes*	*Yes*	*Yes*
Year fixed effects	*Yes*	*Yes*	*Yes*
Month fixed effects	*Yes*	*Yes*	*Yes*
Weekday fixed effects	*Yes*	*Yes*	*Yes*
Hospital specific linear time trend	*No*	*No*	*Yes*

Table 5. Heckman regressions: Upcoding equation and Participation equation results for C-Section - continued

	(1)	(2)	(3)
Participation			
G1×post2010	0.102		0.043
	(0.07)		(0.12)
G2×post2010	0.018		-0.028
	(0.05)		(0.08)
G1×2008		0.205**	
		(0.09)	
G2×2008		0.025	
		(0.09)	
G1×2009		0.189**	
		(0.09)	
G2×2009		-0.008	
		(0.09)	
G1×2010		0.327***	
		(0.08)	
G2×2010		0.011	
		(0.08)	
G1×2011		0.137	
		(0.08)	
G2×2011		-0.028	
		(0.08)	
G1×2012		0.226*	
		(0.13)	
G2×2012		0.086	
		(0.13)	
Mother demographic controls	*Yes*	*Yes*	*Yes*
Mother medical controls	*Yes*	*Yes*	*Yes*
Hospital fixed effects	*Yes*	*Yes*	*Yes*
Year fixed effects	*Yes*	*Yes*	*Yes*
Month fixed effects	*Yes*	*Yes*	*Yes*
Weekday fixed effects	*Yes*	*Yes*	*Yes*
Hospital specific linear time trend	*No*	*No*	*Yes*
N. observations	216,670	216,670	216,670
N. censored observations	149,245	149,245	149,245
ρ [p-val]	0.12 [0.00]	0.12 [0.00]	0.12 [0.00]

Notes: The dependent variable in the participation equation is 1 for a C-section, and 0 for a Vaginal delivery, while the dependent variable in the upcoding equation is 1 for a C-section with Complications, and 0 for a C-section without Complications. Mother controls (demographic information and medical conditions) are defined in Table 2. G1 is for hospitals in Group 1, G2 is for hospitals in Group 2. Participation and upcoding equations are jointly estimated using full maximum likelihood. ρ is an estimate of the correlation among the errors in the upcoding equation and the participation equation, while [p-val] is the p-value from a Wald test where the null is that the ρ correlation is actually zero. Standard errors are clustered at hospital-year level.

* significant at 10% level; ** significant at 5% level and *** at 1% level.

Table 6. Heckman regressions: Upcoding equation and Participation equation results for Vaginal deliveries

	(1)	(2)	(3)
Upcoding			
G1×post2010	0.019***		0.001
	(0.01)		(0.01)
G2×post2010	0.004		0.003
	(0.01)		(0.01)
G1×2008		0.006	
		(0.01)	
G2×2008		0.001	
		(0.01)	
G1×2009		0.008	
		(0.01)	
G2×2009		-0.011	
		(0.01)	
G1×2010		0.014	
		(0.01)	
G2×2010		-0.005	
		(0.01)	
G1×2011		0.027**	
		(0.01)	
G2×2011		0.001	
		(0.01)	
G1×2012		0.029***	
		(0.01)	
G2×2012		0.005	
		(0.01)	
Mother demographic controls	*No*	*No*	*No*
Mother medical controls	*Yes*	*Yes*	*Yes*
Hospital fixed effects	*Yes*	*Yes*	*Yes*
Year fixed effects	*Yes*	*Yes*	*Yes*
Month fixed effects	*Yes*	*Yes*	*Yes*
Weekday fixed effects	*Yes*	*Yes*	*Yes*
Hospital specific linear time trend	*No*	*No*	*Yes*

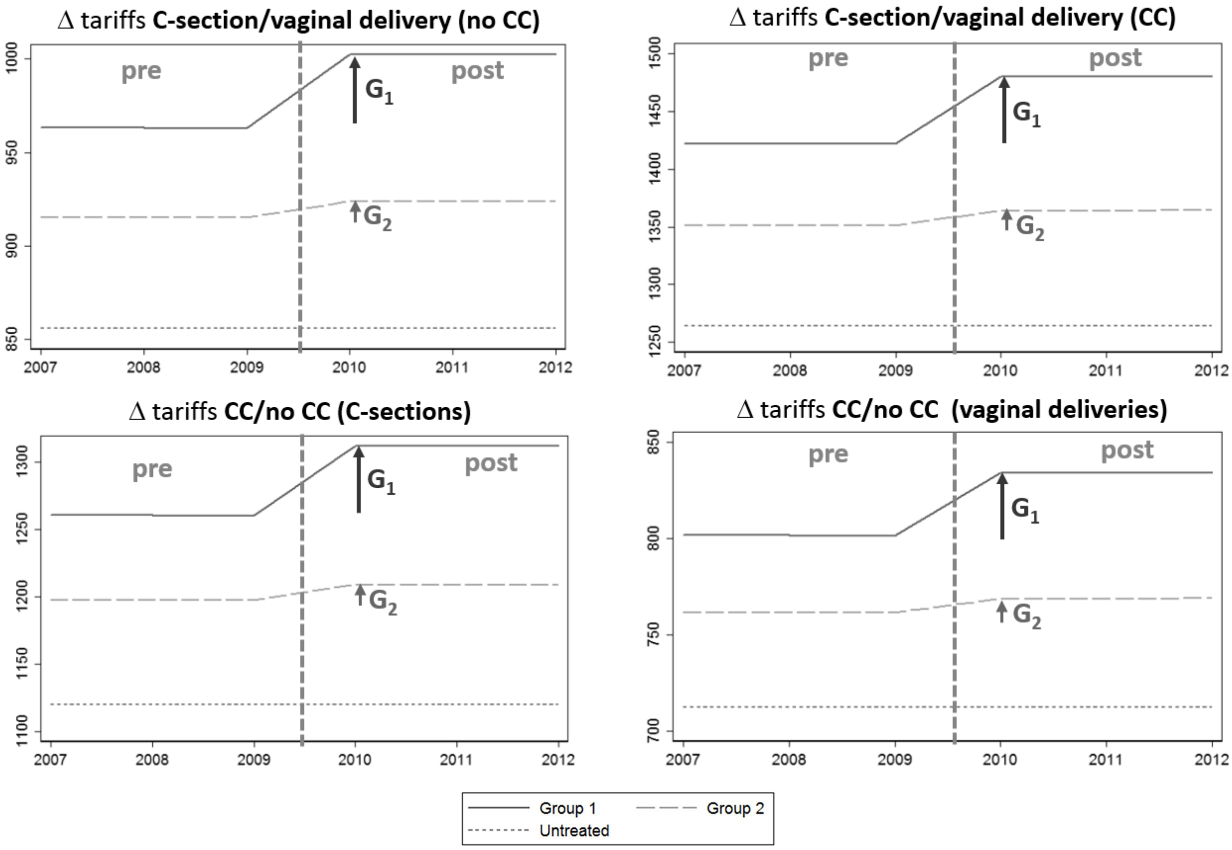
Table 6. Heckman regressions: Upcoding equation and Participation equation results for Vaginal deliveries - continued

	(1)	(2)	(3)
Participation			
G1×post2010	-0.104		-0.050
	(0.07)		(0.12)
G2×post2010	-0.016		0.026
	(0.05)		(0.08)
G1×2008		-0.204**	
		(0.09)	
G2×2008		-0.024	
		(0.09)	
G1×2009		-0.186**	
		(0.09)	
G2×2009		0.010	
		(0.09)	
G1×2010		-0.329***	
		(0.08)	
G2×2010		-0.010	
		(0.08)	
G1×2011		-0.139*	
		(0.08)	
G2×2011		0.031	
		(0.08)	
G1×2012		-0.223*	
		(0.13)	
G2×2012		-0.082	
		(0.13)	
Mother demographic controls	*Yes*	*Yes*	*Yes*
Mother medical controls	*Yes*	*Yes*	*Yes*
Hospital fixed effects	*Yes*	*Yes*	*Yes*
Year fixed effects	*Yes*	*Yes*	*Yes*
Month fixed effects	*Yes*	*Yes*	*Yes*
Weekday fixed effects	*Yes*	*Yes*	*Yes*
Hospital specific linear time trend	*No*	*No*	*Yes*
N. observations	216,670	216,670	216,670
N. censored observations	67,425	67,425	67,425
ρ [p-val]	0.00 [0.29]	0.00 [0.30]	0.00 [0.31]

Notes: The dependent variable in the participation equation is 1 for a Vaginal delivery, and 0 for a C-section delivery, while the dependent variable in the upcoding equation is 1 for a Vaginal delivery with Complications, and 0 for a Vaginal delivery without Complications. Mother controls (demographic information and medical conditions) are defined in Table 2. G1 is for hospitals in Group 1, G2 is for hospitals in Group 2. Participation and upcoding equations are jointly estimated using full maximum likelihood. ρ is an estimate of the correlation among the errors in the upcoding equation and the participation equation, while [p-val] is the p-value from a Wald test where the null is that the ρ correlation is actually zero. Standard errors are clustered at hospital-year level.

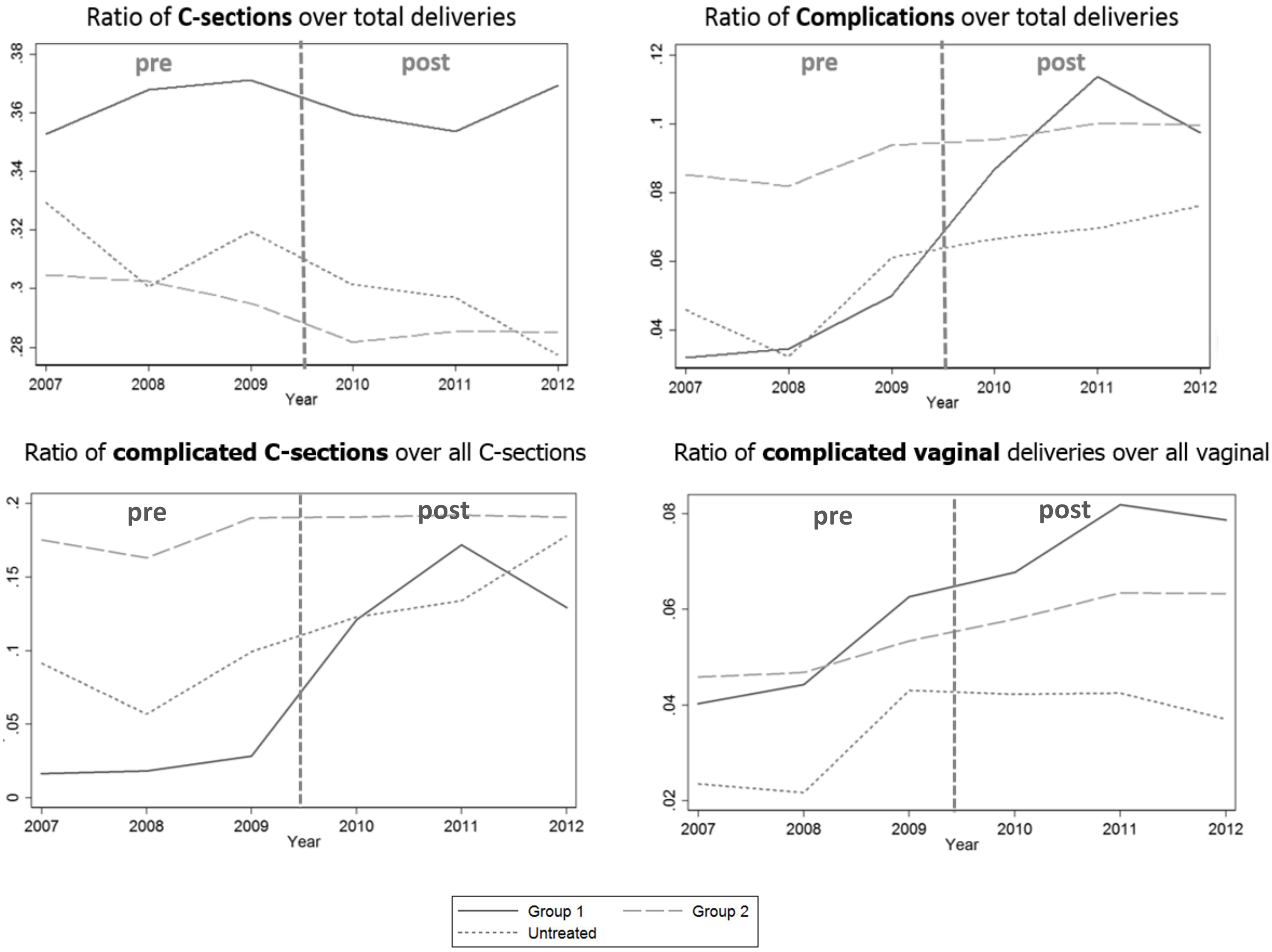
* significant at 10% level; ** significant at 5% level and *** at 1% level.

Figure 1. Dynamics over time of the spread between the tariffs for C-section and vaginal deliveries, without complications (no CC) and with complications (CC), by hospital Groups



Note: Years are on the horizontal axis, while Euros on the vertical axis. G_1 means Group 1, G_2 is for Group 2. Pre and post refer to the periods before and after the 2010 policy change. The figure shows the dynamics over time of the following four spreads: (1) absolute difference between the tariff for C-section without complications and vaginal delivery without complications (top-left panel); (2) absolute difference between the tariff for C-section with complications and vaginal delivery with complications (top-right panel); (3) absolute difference between the tariff for C-section with complications and C-section without complications (bottom-left panel); (4) absolute difference between the tariff for vaginal delivery with complications and vaginal delivery without complications (bottom-right panel)

Figure 2. Dynamics over time of the ratios of C-sections, vaginal deliveries, and complications by hospital groups.



Note: Years are on the horizontal axis, while percentage on the vertical axis. Pre and post refer to the periods before and after the 2010 policy change.