Health Policy and Technology 8 (2019) 349–355

Contents lists available at ScienceDirect

Health Policy and Technology

journal homepage: www.elsevier.com/locate/hlpt

Taking the CON out of Pennsylvania: Did hip/knee replacement patients benefit? A retrospective analysis

Susan L. Averett[a,*], Sabrina Terrizzi[b], Yang Wang[c]

[a] Department of Economics, Lafayette College, 216 Simon Center, 30 Quad Drive, Easton, PA 18042, United States, IZA, Bonn Germany
[b] Department of Economics and Business, Moravian College, 1200 Main Street, Bethlehem, PA 18018, United States
[c] La Follette School of Public Affairs, University of Wisconsin–Madison, 1225 Observatory Drive, Madison, WI 53706, United States

ARTICLE INFO

Article history:
Available online 10 October 2019

Keywords:
Certificate of need
Hip and knee replacement
Health care
Cost
Quality

ABSTRACT

We analyze the effects of Certificate of Need (CON) laws on outcomes for hip and knee replacement procedures. Federal CON programs began in 1974 to stem rising health care costs by limiting hospital expansion and acquisition of equipment. The federal requirement for CON programs ended in 1987; however, 36 states and DC still maintain various forms of CON programs.

In 1996, Pennsylvania (PA) let its CON law expire. We use data from the National Inpatient Survey from HCUP for the years 1993–1999 and examine four outcomes: hospital acquired infections, mortality, length of stay, and total charges. We use a difference-in-differences estimation method leveraging the expiration of PA's law to compare outcomes between patients in PA with patients in states that continued to have a CON law. We control for a number of covariates and pre-treatment trends in our analysis.

We focus on hip and knee replacement surgeries — two procedures that have expanded greatly, have contributed increasingly to growing health care costs, and have not been well studied in the literature —for a population that includes Medicare beneficiaries and patients with other payment methods.

Our results provide new evidence of the effects of CON (de)regulation. We find that the expiration of CON laws in PA increased length of stay within the patient population and reduced the probability of dying. The CON laws did not have statistically significant effects on hospital acquired infections or total charges.

Introduction

Health care costs and quality remain pressing issues for American policymakers and the general public. The US spends more on health care per capita (and as a percentage of GDP) than any other OECD country [1]. Beginning in 1974, as a response to growing concerns about health care costs, many Certificate-of-Need (CON) laws were enacted across the nation as part of the federal "Health Planning Resources Development Act". A CON is a legal document that is required before any acquisition, expansion, or creation of facilities are permitted. Originally, CON laws regulated the purchase of new equipment as well as the number of beds in hospitals and nursing homes. More recently, some states' CON laws regulate outpatient facilities, ambulatory surgical centers (ASC), and long term care facilities. As of 2018, despite numerous changes in the past 30 years, 36 states (and the District of Columbia) retain some type of CON program, law, or agency.

In the post-Affordable Care Act environment, CON laws remain controversial [2,3]. Despite a wide variety of studies assessing the effects of CON regulation on costs, quality, and the number of procedures, the evidence regarding these effects is mixed [4]. Those in favor of CON laws note that CON regulation increases access to care by making existing hospitals more profitable through decreased competition, thus, assuring hospitals remain financially solvent, specifically in rural areas that may not be able to support multiple health care service providers. Further, a proliferation of competing hospitals that locate to serve well-insured, healthier patients may mean that rural, less wealthy populations lose their access to care. Subsequently, the most profitable services (cardiac care, orthopedics and diagnostic imaging) subsidize the use of less profitable, but necessary services, such as emergency room care, mental health services, or chemical dependency provisions

* Corresponding author.
E-mail addresses: averetts@lafayette.edu (S.L. Averett), terrizzis@moravian.edu (S. Terrizzi), yang.wang@lafollette.wisc.edu (Y. Wang).

https://doi.org/10.1016/j.hlpt.2019.09.006
2211-8837/

[3,5]. However, those opposed to CON laws believe that limiting competition increases costs and decreases quality for patients [3].

In this analysis, we examine the effect of the expiration of Pennsylvania's (PA's) CON law on four outcomes related to hip and knee replacement surgeries using data from the Healthcare Cost and Utilization Project (HCUP) National Inpatient Survey (NIS) for the years 1993 through 1999. The CON laws in PA were intended to regulate a variety of procedures within acute care and long-term care settings including hospitals, ambulatory centers, and nursing homes. The goals of the CON program with respect to acute care were threefold: control costs; maintain high-quality service; and expand access to these services [6]. In December of 1996, PA's CON law expired as its lawmakers failed to act by a certain deadline [7,8]; that is, this policy change was not the result of an affirmative decision based on cost or quality concerns. This arguably exogenous policy change provides a natural experiment that allows us to identify the effect of the CON expiration in PA on quality and costs of health care. While it is possible that permitting the law to expire was itself a deliberate act (and hence arguably not exogenous), we found no such evidence in our research. Furthermore, the CON laws in PA were reauthorized four years earlier in 1992 by General Assembly [6].

We examine hip and knee replacement surgeries because of their increasing importance to the US population and economy. Osteoarthritis is one of the ten most disabling diseases in developed countries ("Chronic Diseases and Health Promotion", n.d.). In the US, expenditures related to osteoarthritis and other non-traumatic joint disorders totaled $80.3 billion [9] and affected 40 million people in 2014 [10]. Total knee arthroplasty is also one of the most common and costly surgical procedures performed [11]. In addition, there has been a 161% increase in knee replacement surgeries among Medicare participants in the past 20 years [12]. Total annual costs are approximately $5 billion and rising due to an increased demand primarily from the Medicare-eligible population [12]. Hip replacement surgery has also increased in popularity in the US, and the US conducts more knee replacement surgeries per capita than any other OECD country [13]. Surgeons perform approximately 280,000 hip replacement surgeries annually, at a cost of approximately $12 billion [14]. Recent estimates suggest that more than one million total hip and total knee replacements are performed each year in the US, and as the population continues to age, these are expected to be the most common elective surgical procedures in the coming years [15].

Much of the previous research related to CON laws has focused on the Medicare population affected by Acute Myocardial Infarction (AMI) because demand for AMI procedures is largely price inelastic, and it is one of the most profitable areas in medicine with costly expansions/duplications of its facilities [16,17]. To our knowledge, there are only a few existing studies that analyze a procedure or area of medicine other than cardiovascular-related procedures, and they have shown that effects of (expiration of) CON regulations vary across procedures [17–21].

In addition to contributing to the literature on CON laws by providing the first empirical evidence on the effects of the expiration of CON laws on costs and quality of health care for patients undergoing hip and knee replacement surgeries, we also expand the patient population of interest to a wider age range. Further, we examine all potential insurance types including uninsured and self-pay patients, as these patient populations could be affected differently than the Medicare population. We find that the expiration of CON laws in PA increased length of stay and decreased mortality, but it did not affect cost (as measured by total charges), or the probability of developing hospital-acquired conditions for the patient population.

Methods

We use a difference-in-differences (DD) estimator, which is widely used in the literature to exploit a natural experiment [22], as follows:

$$\gamma_{ihst} = \alpha + Post_t\gamma_1 + CON_s\gamma_2 + (Post_t * CON_s)\gamma_3 + Z_{hst}\gamma_4 + X_{ihst}\gamma_5 + \delta_s + \theta_t + \varepsilon_{ihst} \quad (1)$$

where y_{ihts} indicates the outcome variables for individual i at hospital h in state s in year t. $Post_t$ is a binary variable indicating whether the CON law has expired; thus, it takes the value of one in the years after the CON expired in PA (1996). CON_s is a binary variable equal to one if the individual was observed in PA and zero if they were observed in a control state. Z_{hst} and X_{ihst} describe hospital and individual characteristics, respectively. Finally, δ_s is a time-invariant state fixed effect and θ_t is a year fixed effect. Because the expiration of the CON law only affects those patients in PA, γ_3 is the main parameter of interest and captures the effect of the CON expiration on patient-level outcomes in this framework. All standard errors are clustered by state.

We choose Pennsylvania (PA) to be our treatment state and focus on the CON law expiration in the mid-1990s in PA for two reasons. First, the expiration of CON law in PA is arguably exogenous, as described above. Second, most states without a CON law repealed their CON laws in the 1970s or 1980s, a period not covered in the NIS data that we use. The only two states that repealed their CON laws (or allowed them to expire) in the 1990s are Pennsylvania and North Dakota, and the latter is not in the NIS data during our sample period. Our control states are those that had a CON law specifically regulating acute care services, as these represent facilities in which individuals would have surgery requiring an overnight stay. Moreover, our control states did not change their CON laws/regulations during the period of our study, and participated in the NIS in each of the years of our analysis providing a balanced panel. These control states are Connecticut, Florida, Iowa, Illinois, Massachusetts, Maryland, New Jersey, New York, Oregon, South Carolina, and Washington.

CON regulations provide expansive coverage over a variety of treatments and procedures conducted in both inpatient and outpatient settings, and regulate the number of hospitals and hospital beds. The CON programs that regulate acute hospital beds are relevant to our research question, and we have taken care to review the details regarding the existing CON legislation in each state to ensure the regulation is relevant to the population studied. Details on these regulations are available in the Appendix.

Data

To conduct the analyses described above, we use data from the NIS, which is part of a family of databases developed for the HCUP. The NIS is particularly well-suited for our research because it is the largest all-payer inpatient health care database in the United States, and it is often used to obtain national estimates of hospital inpatient stays. The NIS contains all discharge data from more than 1000 short-term and non-Federal hospitals each year, which approximates a 20 percent stratified sample of US community hospitals. The NIS contains charge information on all patients, including individuals covered by Medicare, Medicaid, or private insurance, as well as those who are uninsured. It also contains information on the hospitals including their size, ownership, and the income level of the patient's zip code. Our use of inpatient data for this analysis is appropriate because hip and knee replacements were inpatient procedures during the time period of our study. Further, as recently as 2014, US Centers for Medicaid and Medicare Services (CMS) did not fund hip and knee replacement surgeries at outpatient facili-

Table 1
Means of outcome variables by treatment status, Traditional DD.

Variable	Treated, Before	Treated, After	Control, Before	Control, After
Hospital acquired condition	.1194	.1106	.1513	.1247
	(0.3243)	(0.3137)	(0.3583)	(0.3304)
Died in hospital	.0092	.0065	.0125	.0072
	(0.0957)	(0.0806)	(0.1112)	(0.0845)
Length of Stay (days)	6.7454	4.8965	7.7476	5.0291
	(4.3362)	(2.9776)	(5.3857)	(3.2706)
Log total charges	9.8227	9.8384	9.8711	9.8808
	(0.7353)	(0.451)	(0.4403)	(0.4377)
Total Charges ($)	22,148.69	20,977.62	21,518.49	21,529.67
	(13,581.01)	(13,079.66)	(12,946.34)	(11,502.05)
Observations	36,441	21,439	306,337	159,397

Hospital acquired condition takes the value of 1 if the patients has any of the recognized complications associated with hip or knee replacement as determined by CMS. Died in hospital takes the value of 1 if the patients died while admitted for the surgery. Length of stay is measured in days. Total charges are measured in dollars and we use the logged form in our models. Standard deviations in parentheses. Pennsylvania is the treatment state. Control states include Connecticut, Florida, Iowa, Illinois, Massachusetts, Maryland, New Jersey, New York, Oregon, South Carolina and Washington. Before refers to 1993, 1994, 1995 and 1996. After refers to 1997, 1998 and 1999.

Table 2
Means of control variables by treatment status.

Variable	Treated, Before	Treated, After	Control, Before	Control, After
Charlson Index	.4518	.5409	.5333	.5195
	(0.8563)	(0.9048)	(0.9737)	(0.9125)
Male	.3552	.5376	.352	.5419
	(0.4786)	(0.4986)	(0.4776)	(0.4982)
Age years	71.4369	71.342	72.3609	71.958
	(8.8118)	(9.3465)	(8.9968)	(9.3958)
Small hospital	.1696	.1976	.1024	.1444
	(0.3753)	(0.3982)	(0.3032)	(0.3515)
Medium hospital	.4412	.4263	.2912	.2691
	(0.4965)	(0.4945)	(0.4543)	(0.4435)
Large hospital	.3892	.3761	.6064	.5865
	(0.4876)	(0.4844)	(0.4885)	(0.4925)
Log of real income	9.7675	9.8084	9.776	9.8507
	(0.5173)	(0.389)	(0.4948)	(0.3764)
Income missing	.0254	.0271	.0493	.0469
	(0.1574)	(0.1625)	(0.2165)	(0.2114)
Teaching hospital	.5179	.5263	.305	.4001
	(0.4997)	(0.4993)	(0.4604)	(0.4899)
Medicare	.7265	.6503	.774	.7321
	(0.4457)	(0.4769)	(0.4183)	(0.4429)
Medicaid	.0154	.0123	.0145	.0154
	(0.1233)	(0.1103)	(0.1197)	(0.1232)
Private insurance	.2081	.2889	.1795	.2232
	(0.4059)	(0.4532)	(0.3838)	(0.4164)
Self pay	.0047	.0035	.0098	.0076
	(0.0685)	(0.0587)	(0.0986)	(0.0868)
Other payer	.0448	.0444	.0221	.0217
	(0.2068)	(0.2059)	(0.1471)	(0.1457)
Observations	36,441	21,439	306,337	159,397

Standard deviations in parentheses. The Charlson index is an index of comorbidities; we calculate this using the diagnostic codes and software provided by HCUP. Higher values indicate more comorbid conditions. In the NIS, income is reported categorically as the quartile classification of the estimated median household income of residents in the patient's zip code (based on 1999 demographics). We create the log of income following the procedures in Hout (37). If income is not reported, we set income equal to the mean income across all years for that zip code and control for missing income in our models. Age measured in years. Hospital size is determined by the NIS based on location and teaching status. Details are available here: https://www.hcup-us.ahrq.gov/db/vars/h_bedsz/nisnote.jsp. All other variables take the value of 1 if the patient (or hospital) exhibits that characteristic.

ties [23,24], providing additional support for our use of inpatient data for this analysis.

As explained earlier, we exploit the expiration of the CON laws in PA in 1996 to identify the effects of CON laws on patient-level outcomes for those patients undergoing knee or hip replacement surgery. To create the analysis sample, we start with all patients in 1993, 1994, 1995, 1996, 1997, 1998 and 1999, which provides us with four years of data before (1993–1996) and three years of data after (1997–1999) the policy change. During this time frame, PA was the only state within our dataset that repealed their CON law. We limit our sample to people age 50 or older because they are most likely to obtain a total hip or knee replacement [15]. We focus our analysis on those patients who had a hip or knee replacement as coded according to the HCUP clinical classification software as "152″ or "153″. This age range also allows us to examine a population outside of Medicare recipients, which has been the main population of interest in the literature.

We examine four outcome variables. Three of our outcome variables are indicators of quality: Hospital Acquired Condition (HAC), a binary variable indicating whether the patient experienced any complications from their surgery as identified by the CMS (these complications apply to any patient undergoing the procedure); mortality, a binary indicator for whether the patient died in the hospital; and Length of Stay (LOS) in days. The fourth outcome

Table 3
Difference-in-differences estimates of con repeal.

Variables	Hospital acquired condition	Died	Length of Stay	Log of total charges
PA x Post 1996	0.0021	0.0010	0.7380**	0.0134
	(0.0041)	(0.0005)	(0.2961)	(0.0131)
PA	−0.0068**	−0.0002	−1.7607***	−0.0386**
	(0.0027)	(0.0004)	(0.1090)	(0.0175)
post 1996	−0.0210***	−0.0043***	−3.7969***	0.0393
	(0.0054)	(0.0010)	(0.3639)	(0.0240)
Charlson Index	0.0472***	0.0130***	0.8942***	0.0491***
	(0.0030)	(0.0016)	(0.1132)	(0.0054)
Male	−0.0352***	0.0027***	−0.1090	0.0193***
	(0.0041)	(0.0005)	(0.0536)	(0.0021)
Age years	0.0130***	0.0009***	0.0670***	−0.0017
	(0.0008)	(0.0001)	(0.0113)	(0.0008)
Small hospital	0.0295**	0.0002	−0.1776	−0.0121
	(0.0100)	(0.0003)	(0.1989)	(0.0347)
Medium hospital	0.0197**	0.0006	−0.0773	0.0318
	(0.0078)	(0.0004)	(0.1938)	(0.0444)
Log of real income	−0.0025	−0.0012	−0.2455***	0.0030
	(0.0048)	(0.0006)	(0.0569)	(0.0168)
Income missing	−0.0041	0.0016	0.0811	−0.0346
	(0.0039)	(0.0011)	(0.0957)	(0.0172)
Teaching hospital	−0.0458***	−0.0006	0.1986	0.1292**
	(0.0053)	(0.0005)	(0.2221)	(0.0425)
Medicare	−0.0875**	0.0097**	0.9728**	0.2660**
	(0.0345)	(0.0043)	(0.4006)	(0.0874)
Medicaid	0.0359	0.0158***	2.8655***	0.3445***
	(0.0331)	(0.0046)	(0.5154)	(0.0850)
Private insurance	−0.0168	0.0153***	1.0758**	0.2699**
	(0.0344)	(0.0042)	(0.3556)	(0.0895)
Self pay	0.0153	0.0130**	1.4241**	0.2582**
	(0.0463)	(0.0057)	(0.5723)	(0.0928)
Other payer	−0.0113	0.0134***	1.0839**	0.2680**
	(0.0290)	(0.0039)	(0.4116)	(0.0932)
Constant	−0.6965***	−0.0617***	5.7556***	9.5648***
	(0.0784)	(0.0034)	(1.0733)	(0.2267)
Observations	522,148	520,525	521,612	521,129
R-squared	0.1335	0.0240	0.2104	0.1630

Standard errors clustered by state in parentheses.
*** $p < 0.01$,
** $p < 0.05$. Reference categories are individuals who are females admitted to a large non-teaching hospital whose primary payer was unknown. Definitions of hospital size vary by hospital location and teaching status; e.g. in an urban area a large nonteaching hospital is one with 200 plus beds.

variable, (the log of) the total charge for the hospitalization, is a measure of cost. Because we use the log of the total charge and we control for year fixed effects in our model, we do not index the total charges to inflation. We recognize that these total charges do not necessarily indicate what a patient actually paid. Each outcome has a slightly different sample size due to missing information for some patients. To account for the effects of other explanatory variables on the outcomes of interest, we also include two sets of covariates (Z_{hst} and X_{ihst} in Eq. (1)) that describe the hospitals and the individuals, respectively.

Results

The four outcome variables are summarized in Table 1. LOS ranged from 0 to 3029 days; only one percent of observations in the data had a LOS in excess of 64 days, so we trimmed our sample at that number. This yields a mean LOS of 7.75 days, consistent with those reported by other researchers using data over the same time frame [25]. Both HAC and LOS have a downward trend across treatment and control states, which is consistent with the national trend for these procedures [11]. The log of total charges has an upward and similar trend across both treatment and control states. Finally, the probability of dying in the hospital is decreasing in both PA and the control states.

These unadjusted means in Table 1 can also be used to calculate non-parametric DD estimates, which preview some of our parametric DD estimation results below. For example, though LOS declined over the same period for both treatment and control groups, the CON expiration was associated with an average of 0.8696 days increase in LOS for the patients in the treatment state after the treatment (post period) ((4.8965 – 6.7454) – (5.0291 – 7.7476) = 0.8696) compared to the control states in the post period. This simple, unadjusted difference-in-differences calculation, though interesting and informative, does not give us an indication of statistical significance.

Table 2 presents the means of the control variables in the same format as Table 1. Many of the control variables are self-explanatory, but a few merit a more detailed explanation. The Charlson index is an index of comorbidities; we calculate this using the diagnostic codes and software provided by HCUP. Higher values indicate more comorbid conditions. In the NIS, income is reported categorically as the quartile classification of the estimated median household income of residents in the patient's zip code (based on 1999 demographics). We follow the procedures in Hout [26] to create a log of real income for each patient. If income is not reported, we set income equal to the mean income across all years for that zip code and control for missing income in our models. We also control for type of payment. Because of the age of our sample, Medicare is the dominant payment method, but we also find a sizeable patient population using private insurance. Medicaid, self-pay, and other payers together account for less than 7% of the sample. Our benchmark category is the uninsured. Payment types are mutually exclusive in NIS. For hospitals, consistent with the literature, we control for their sizes and their teaching status.

Table 4
Difference-in-differences estimates of con repeal controlling for pre-trends.

Variables	Hospital acquired condition	Died	Length of stay	Log of total charges
PA × Post 1996	−0.0050	−0.0015***	0.3065**	−0.0134
	(0.0033)	(0.0004)	(0.1332)	(0.0101)
PA	0.0003	0.0024***	−1.3223***	−0.0110
	(0.0034)	(0.0004)	(0.0820)	(0.0224)
Post 1996	−0.0210***	−0.0041***	−3.7762***	0.0462**
	(0.0055)	(0.0010)	(0.3623)	(0.0199)
Charlson Index	0.0472***	0.0130***	0.8925***	0.0494***
	(0.0030)	(0.0016)	(0.1128)	(0.0054)
Male	−0.0352***	0.0027***	−0.1086	0.0192***
	(0.0041)	(0.0005)	(0.0535)	(0.0021)
Age years	0.0130***	0.0009***	0.0670***	−0.0017
	(0.0008)	(0.0001)	(0.0113)	(0.0008)
Small hospital	0.0295**	0.0002	−0.1804	−0.0114
	(0.0100)	(0.0003)	(0.1978)	(0.0350)
Medium hospital	0.0198**	0.0007	−0.0677	0.0309
	(0.0078)	(0.0004)	(0.1943)	(0.0440)
Log of real income	−0.0025	−0.0011	−0.2430***	0.0034
	(0.0048)	(0.0006)	(0.0570)	(0.0170)
Income missing	−0.0041	0.0016	0.0818	−0.0342
	(0.0039)	(0.0011)	(0.0961)	(0.0172)
Teaching hospital	−0.0458***	−0.0005	0.2108	0.1291**
	(0.0053)	(0.0005)	(0.2208)	(0.0427)
Medicare	−0.0878**	0.0093**	0.9220	0.2511***
	(0.0343)	(0.0042)	(0.4253)	(0.0718)
Medicaid	0.0355	0.0154***	2.8048***	0.3282***
	(0.0329)	(0.0045)	(0.5429)	(0.0686)
Private insurance	−0.0171	0.0150***	1.0246**	0.2548***
	(0.0341)	(0.0041)	(0.3803)	(0.0738)
Self pay	0.0150	0.0126**	1.3710**	0.2427***
	(0.0460)	(0.0056)	(0.5894)	(0.0779)
Other payer	−0.0116	0.0131***	1.0363**	0.2514***
	(0.0288)	(0.0038)	(0.4361)	(0.0770)
PA x 1993	−0.0074	−0.0008	−0.1969	0.0463***
	(0.0037)	(0.0008)	(0.2257)	(0.0123)
PA x 1994	−0.0112**	−0.0067***	−0.9616***	0.0126
	(0.0036)	(0.0010)	(0.2898)	(0.0222)
PA x 1995	−0.0064***	−0.0005	−0.3407***	−0.2469***
	(0.0015)	(0.0004)	(0.0994)	(0.0105)
Constant	−0.6963***	−0.0618***	5.7448***	9.5691***
	(0.0785)	(0.0033)	(1.0650)	(0.2252)
Observations	522,148	520,525	521,612	521,129
R-squared	0.1335	0.0240	0.2108	0.1662

Standard errors clustered by state in parentheses.
*** $p < 0.01$,
** $p < 0.05$. Benchmark categories are individuals who are females admitted to a large non-teaching hospital whose primary payer was unknown. PA = Pennsylvania (treated state).

Examining the characteristics of the patients and the hospitals reported in Table 2, we observe that patients from the treatment and the control groups have very similar characteristics before and after the CON expiration. Specifically, they share a similar gender ratio, average age, real income, and payment methods. The only visible difference in patients' characteristics comes from the Charlson comorbidity index, which was relatively lower for patients in the treatment group as compared to those in the control group before the policy change. However, this index converged to approximately 0.5 after the policy change across groups. When considering the hospital characteristics, we find that most hospitals were of medium size in the treatment state, but of large size in the control states, both before and after the policy change. Hospitals in the treatment state are more likely to be teaching hospitals.

Table 3 presents an estimation of Equation [1) with the full set of covariates described in Table 2. We find that the estimated coefficients on our variable of interest (PAxPost 1996) are not statistically significant for HAC, dying, or log of total charges. However, the coefficient on LOS for this variable is significant at the 5 percent level.

The key assumption for any DD strategy is that the outcomes in the treatment and the control group would follow the same time trend in the absence of the treatment. There is no test for this assumption because we cannot observe the counterfactual for the treated state; however, we would be concerned if PA already displayed significantly different trends in quality or cost measures from the control states *prior* to the expiration of the CON law. In that instance, we would not be able to conclusively assign the observed changes in quality or cost to the expiration of the CON law itself unless we controlled for those pre-trends.

To check this pre-trend assumption, we estimate the DD model with interactions between our treatment group and each of the years before the policy change, while still including the full set of covariates previously described, plus year and state fixed effects. If those interaction terms between the treatment state and the pre-policy years are insignificant, then pre-treatment trends are unlikely to be driving our results and would not cause concern. However, if the difference in pre-policy trends indeed exists, then we would need to control for these pre-trends to avoid potentially biased results.

The results shown in Table 4 provide clear evidence of the existence of different pre-treatment trends in our outcome variables between the treatment and control groups. For all four outcome variables, at least one of the interaction terms is statistically sig-

nificant, and those statistically significant interaction terms tend to be of greater magnitude than the DD estimates of interest; thus, emphasizing the importance of controlling for these trends in our final specification. In this preferred specification, we find the CON expiration in PA had a statistically significant effect on LOS: the expiration increased LOS by 0.3065 days or 4.5 percent (0.3065/6.7325 where 6.7325 is the average LOS over the entire sample). We also find the probability of dying decreases by 0.15 percentage points. Given the low probability of dying in our sample of approximately 1%, this estimate is a 14.4 percent reduction (0.0015/0.0104) in the probability of death.

Conclusion and discussion

Our paper is the first to focus on hip and knee replacement surgeries — two procedures that have expanded greatly, have contributed increasingly to growing health care costs, and have not been well studied in the literature. We have also expanded the population from Medicare beneficiaries on whom the literature has mainly focused to those age 50+ to examine individuals with other payment methods. Increased competition introducted by the removal of the CON law may have implications for how individuals undergoing this surgery, which is increasingly likely after age 50, will fare. We therefore provide important new evidence on the effects of CON (de)regulation and on the generalizability of conclusions previously drawn across procedures and patient populations with regard to quality effects.

In summary, we find that the expiration of PA's CON program is associated with a longer hospital stay and a reduced probability of dying in PA compared to the control states. We do not find this repeal to have any significant effects on patients obtaining HACs or overall chargers. Our analysis provides critical insight into the relative effectiveness of the (expiration of the) CON program, and helps states make decisions to retain their CON laws or let them expire. We highlight these important policy implications below.

The existing evidence in the literature regarding the effects of CON laws on cost is mixed [4]. Some studies have indicated that CON regulations can lower costs through mechanisms such as higher occupancy rates, reduced expenditures, and reduced acute care spending [18,27–30], while others find neutral or negative associations with total per capita spending or procedural expenses [17,18,20,21,29,31]. Our study aligns with the latter in that we find no effect on costs, as measured by charges.

As for quality, the existing literature finds little to no association between CON regulation and quality of health care. While some researchers find that the expiration of CON regulation is associated with very small reductions in inpatient mortality [16], most of the current analyses find no measurable difference in mortality rates between states with and without CON regulations [17,19,32,33]. There is some evidence that patients in states that eliminated CON regulations experience lower Coronary Artery Bypass Graft (CABG) mortality rates (although this disappates over time) and also more hospital providers and lower hospital volume [17]. A similarly designed study [34] found that states that dropped CON experienced lower costs per patient for CABG but not for percutaneous coronary intervention, and the average Medicare reimbursement was lower for both procedures in states that dropped CON.

Our clear measures of quality are HAC and mortality. We find no significant effect on HAC, but we find a statistically significant effect on mortality. It is clear that a reduction in mortality is viewed as a measure of increased quality. This may seem to be a counter-intuitive result, as CON laws limit competition and centralize procedures in hospitals. A common argument is that this centralization improves outcomes as physicians improve their craft through "learning by doing" [35]. However, recent research suggests that this limiting of hospital beds impedes access for patients, and thus CON laws could have negative effects on mortality [35]. Our findings are consistent with this explanation.

LOS is also one of the most commonly used measures of hospital quality [36]. However, it is not clear if increased or decreased LOS corresponds to an increase in quality. Again, we might anticipate CON laws improving quality due to increased concentration of procedures and "learning by doing," and increased LOS is generally viewed as an indicator of poor hospital quality [37]. However, a LOS that is too short can lead to hospital readmissions if patients are discharged before they are ready, which would be an indicator of poor quality. Specifically, in knee replacement surgery, one study reported that shorter LOS led to more readmissions; thus, being an indicator of decreased quality [11]. Therefore, our findings of longer LOS coupled with a lower probability of dying appear to indicate that replealing CON laws can increase quality.

Of course, no study is without limitiations. In order to obtain exogenous variation in CON laws, we used data from the 1990s. Thus, our results may not be generalizable to current time periods given that these surgeries are increasingly done at ambulatory surgery centers. However, the most difficult cases are still done in hospitals [25]. Furthermore, it is difficult to assess costs and our measure, total charges, is different from what patients actually pay. Still, ours is the first study to explore the effect of CON laws on outcoems for these increasingly popular surgeries, and our findings provide additional information for consideration by policymakers in states that still have, and might consider repealing, CON legislation.

Author statements

Funding: None.

Competing interests: None declared.

Ethical approval: Not required.

Appendix

CON Details by State in Data:

State	CON Details
Connecticut	New health care facility; Outpatient surgical facility; Increase in operating rooms by outpatient facility
Florida	Increase in acute hospital beds; New construction or establishment of additional health care facilities; Conversion from one type of care to another; Increase in total licensed bed capacity of a health care facility; Increase in comprehensive rehabilitation beds
Iowa	Hospitals; Outpatient surgical facilities
Illinois	Hospitals; Ambulatory surgery centers; Alternative health care delivery models
Massachusetts	Hospitals; Clinics; Freestanding ambulatory surgery center; Addition or expansion of non-acute care services or ambulatory surgery
Maryland	Hospitals; Ambulatory surgical facilities; Rehabilitation facilities
New Jersey	General, special, mental hospital; Outpatient clinics
New York	Hospitals; Ambulatory surgery centers
Oregon	Hospitals; Specialty inpatient care facilities in hospitals; Long-term care facilities
Pennsylvania	**Hospitals (acute care and long-term care); ambulatory facilities; nursing homes**
South Carolina	Acute care hospitals; ambulatory surgical facilities
Washington	Hospitals (certain procedures); Ambulatory surgical centers

References

[1] Health at a Glance 2015: OECD indicators. OECD. Available from: http://www.oecd.org/unitedstates/Health-at-a-Glance-2015-Key-Findings-UNITED-STATES.pdf [Accessed 14 January 2019].

[2] Weight CJ, Elliott SP. The impotent certificate of need. J Urol 2013;189(1):12–13.
[3] Schencker L. State certificate-of-need laws weather persistent attacks. Mod Healthc 2016;46(4):12.
[4] Pacella SJ, Comstock M, Kuzon WM Jr. Certificate-of-need regulation in outpatient surgery and specialty care: implications for plastic surgeons. Plast Reconstr Surg 2005;116(4):1103–11.
[5] Moran P. Should minnesota reinstate a certificate of need program for health care capital expenditures? 2015, available at: https://mhcc.maryland.gov/mhcc/pages/home/workgroups/documents/CON_modernization_workgroup/Articles/Article%2015.pdf.
[6] Arnold J., Mendelson D. Evaluation of the Pennsylvania certificate of need program. LEWIN-ICF. 1992.
[7] Moore JD. Focus report: con survival struggle: certificate of need: gone in many states but not dead yet. Mod Healthc 1997;27(32):32–3 36.
[8] Longwell CB, Steele JT. The rise and fall of certificate of need in pennsylvania: an experiment in health care planning and the role of the commonwealth court. Widener LJ 2011;21:185.
[9] Medical Expenditures Panel Survey Custom Table. Total expenses and percent distribution for selected conditions by type of service. Agency for Healthcare Research and Quality; 2014. *Accessed from* https://meps.ahrq.gov/data_stats/quick_tables_results.jsp?component=1&subcomponent=0&tableSeries=2&year=-1&SearchMethod=1&Action=Search [Accessed 14 January 2019].
[10] Medical Expenditures Panel Survey Custom Table. Number of people with care for selected conditions by type of service. Agency for Healthcare Research and Quality; 2014.
[11] Cram P, Lu X, Kates SL, Singh JA, Li Y, Wolf BR. Total knee arthroplasty volume, utilization, and outcomes among medicare beneficiaries, 1991-2010. JAMA 2012;308(12):1227–36 2-12.
[12] Lloyd J. Knee replacements on the increase among older adults. usatoday.com. 2012. Available from: http://usatoday30.usatoday.com/news/nation/story/2012/09/25/knee-replacements-on-the-increase-among-older-adults/57841616/1. [Accessed 14 January 2019].
[13] Why is health spending in the United States so high?*OECD*. 2011. Available from: http://www.oecd.org/unitedstates/49084355.pdf [Accessed 14 January 2019].
[14] Ostrow N. Hip-Replacement patients' readmissions rise with shorter stays, study says. Bloomberg.com. 2011. Available from: http://www.bloomberg.com/news/2011-04-19/hip-replacements-spur-quicker-hospital-discharges-while-more-return-trips.html. [Accessed 14 January 2019].
[15] Kremers HM, Larson DR, Crowson CS, Kremers WK, Washington RE, Steiner CA, Berhry DJ. Prevalence of total hip and knee replacement in the United States. J Bone Joint Surg Am 2015;97(17):1386–97.
[16] Ho V. Does certificate of need affect cardiac outcomes and costs. Int J Health Care Finance Econ 2006;6(4):300–24.
[17] Ho V, Ku-Goto MH, Jollis JG. Certificate of need (CON) for cardiac care: controversy over the contributions of CON. Health Serv Res 2009;44(2p1):483–500.
[18] Conover CJ, Sloan F. Does removing certificate-of-need regulations lead to a surge in health care spending. J Health Polit Policy Law 1998;23(3):455–81.
[19] Lorch SA, Maheshwari P, Even-Shoshan O. The impact of certificate of need programs on neonatal intensive care units. J Perinatol 2012;32(1):39–44.
[20] Khanna A, Hu J, Xiangmei G, Nguyen P, Lipsitz S, Palapattu G. Certificate of need programs, intensity modulated radiation therapy use and the cost of prostate cancer care. J Urol 2013;189(1):75–9.
[21] Ross JS, Ho V, Wang Y, Cha SS, Epstein AJ, Masoudi FA, Nallamothu BK, Krumholz HM. Certificate of need regulation and cardiac catheterization appropriateness after acute myocardial infarction. Circulation 2007;115(8):1012–19.
[22] García-Cornejo B, Pérez-Méndez JA. Assessing the effect of standardized cost systems on financial performance. A difference-in-differences approach for hospitals according to their technological level. Health Policy (New York) 2018;122(4):396–403.
[23] Graham M. Are you prepared for the shift to outpatient total knee replacement. Health Care Intell Blog 2016. Available from https://www.sg2.com/health-care-intelligence-blog/2016/10/prepared-shift-outpatient-total-knee-replacement/.
[24] Meyer H. Replacing joints faster, cheaper, and better? Mod Health Care. Available from: http://www.modernhealthcare.com/article/20160604/MAGAZINE/306049986 [Accessed 10 January 2019].
[25] Cram P, Vaughan-Sarrazin MS, Wolf B, Katz JN, Rosenthal GE. A comparison of total hip and knee replacement in specialty and general hospitals. J Bone Joint Surg Am 2007;89(8):1675–84.
[26] Hout M. Getting the most out of the GSS income measures, GSS Methodological Report 101. Chicago: National Opinion Research Center; 2004.
[27] Devers KJ, Brewster LR, Casalino LP. Changes in hospital competitive strategy: a new medical arms race. Health Serv Res 2003;38(1p2):447–69.
[28] Hellinger FJ. The effect of certificate-of-need laws on hospital beds and healthcare expenditures: an empirical analysis. Am J Manag Care 2009;15(10):737–44.
[29] Yee T, Stark LB, Bond AM, Carrier E. Health care certificate-of-need laws: policy or politics? National Institute for Health Care Reform; 2011.
[30] Rosko MD, Mutter RL. The association of hospital cost-inefficiency with certificate-of-need regulation. Med Care Res Rev 2014;71(3):280–98 Available from:. doi:10.1177/1077558713519167.
[31] Grabowski DC, Ohsfeldt RL, Morrisey MA. The effects of CON repeal on medicaid nursing home and long-term care expenditures. Inquiry 2003;40(2):146–57.
[32] Popescu I, Vaughan-Sarrazin MS, Rosenthal GE. Certificate of need regulations and use of coronary revascularization after acute myocardial infarction. JAMA 2006;295(18):2141–7 m.
[33] Robinson J, Nash DB, Moxey E, O'Connor J. Certificate of need and the quality of cardiac surgery. Am J Med Qual 2001;16(5):155–60.
[34] Ho V, Ku-Goto M. State deregulation and medicare costs for acute cardiac care. Med Care Res Rev 2013;70(2):185–205.
[35] Bailey J. The effect of certificate of need laws on all-cause mortality. Health Serv Res 2018;53(1):49–62.
[36] Lingsma HF, Bottle A, Middleton S, Kievit J, Steyerberg EW, Marang-van de Mheen PJ. Evaluation of hospital outcomes: the relation between length-of-stay, readmission, and mortality in a large international administrative database. BMC Health Serv Res 2018;18(1):116.
[37] Thomas JW, Guire KE, Horvat GG. Is patient length of stay related to quality of care? J Healthc Manag 1997;42(4):489.