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REFERENCE PRICING WITH ENDOGENOUS OR EXOGENOUS PAYMENT LIMITS: IMPACTS ON INSURER AND CONSUMER SPENDING

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ABSTRACT

Reference pricing (RP) theories predict different outcomes when reference prices are fixed (exogenous) versus being a function of market prices (MPs) (endogenous). Exogenous RP results in MPs at both high-price and low-price firms converging towards the reference price from above and below, respectively. Endogenous RP results in MPs at both high-price and low-price firms decreasing, with low-price firms acting strategically to decrease the reference price in order to gain market share. We extend these models to a hospital context focusing on insurer and consumer payments. Under exogenous RP, insurer and consumer payments to low-price hospitals increase, and insurer payments to high-price hospitals decrease, but predictions regarding consumer payments are ambiguous for high-price hospitals. Under endogenous RP, insurer payments to high-price and low-price hospitals decrease, and consumer payments to low-price hospitals decrease, but predictions regarding consumer payments are ambiguous for high-price hospitals. We test these predictions with difference-in-differences specifications using 2008–2013 data on patients undergoing joint replacement. For 2 years following RP implementation, insurer payments to high-price and low-price hospitals moved downward, consistent with endogenous RP. However, when the reference price was not reset to account for changes in MPs, insurer payments to low-price hospitals reverted to pre-implementation levels, consistent with exogenous RP. Copyright © 2015 John Wiley & Sons, Ltd.

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KEY WORDS: reference pricing; hip replacement; knee replacement; difference in differences; consumer cost sharing; insurer expenditures

1. INTRODUCTION

Reference pricing is widely applied to pharmaceutical markets across Europe, including Belgium, Germany, Hungary, Italy, Norway, Spain, and Sweden, and outside of Europe in New Zealand and Canada but has not been widely used in the USA (Galizzi *et al*., 2011). In pharmaceutical markets, a reference price is a reimbursement limit that is set for a group of drugs that are therapeutically interchangeable.

A reference price represents the maximum amount that an insurer will cover, with the consumer being responsible for any difference between the actual market price and this reimbursement limit. Thus, the reference price influences the out-of-pocket payment of consumers, with consumers having the ability to reduce these payments by favoring low-price providers.

The reference price is not a pricing policy but a reimbursement policy that sets payment limits. It is consistent with market prices being freely negotiated by market participants. Payments are determined in a two-step process. In the first step, the insurer or employer negotiates a market price with the provider. In the second step, the insurer or employer establishes a reimbursement limit, the maximum amount it will contribute towards that

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negotiated market price, with the consumer being responsible for the balance. A similar concept from managed competition is used by many employers who offer health insurance, where a fixed-dollar contribution is provided to employees who then may choose from an array of health plans, with some choices requiring employees to pay the difference between the employer fixed-dollar contribution and the insurance premium (Enthoven, 1993; Enthoven and Talbott, 2004). Benefits that are reimbursed using reference pricing in the USA can be referred to as 'reference-based benefits' (RBBs). RBBs can be combined with other cost control schemes (Galizzi *et al*., 2011).

Reference-based benefit design is potentially applicable to any group of medical goods or services that are therapeutically interchangeable but which vary in market price (Lee *et al*., 2012). In the USA, RBB design has taken a different trajectory than in other Organization for Economic Cooperation and Development countries, with RBB being applied primarily to non-pharmaceutical medical tests and procedures, including laboratory tests, imaging, colonoscopy, cataract surgery, arthroscopy, and joint replacement. Only limited evaluation has been published to date (Robinson and MacPherson, 2012; Robinson and Brown, 2013; Robinson *et al*., 2015). A critical question is the extent to which the theoretical findings of RBB as applied to pharmaceuticals have application to non-pharmaceuticals.

The effects of reference pricing have been extensively studied with regard to pharmaceuticals in European markets, providing analysts an array of models (Lòpez-Casasnovas and Puig-Junoy, 2000; Acosta *et al*., 2014; Galizzi *et al*., 2011; Lee *et al*., 2012). In this study, we extend a recent model of endogenous and exogenous pharmaceutical reference pricing to the market for high-priced orthopedic procedures. We compare the predictions of the extended model with results from an analysis of RBB applied to joint replacement surgery. We find that the market for high-price orthopedic surgery behaves consistently with this extended model. In particular, we find that when the way that reference prices will be set in the future is not unambiguous, hospital behavior is initially consistent with endogenous reference pricing. Hospital behavior then switches to behavior consistent with exogenous reference pricing after it becomes clear that the reference price is not endogenous.

2. METHODS

2.1. Model

We follow a model of reference pricing developed by Brekke *et al*. (2011), which describes the impact of RBB in a pharmaceutical market where brand-name drugs are competing against generics. We extend this model to describe the introduction of RBB for hip and knee replacement surgery. See the online appendix.

In the model presented by Brekke *et al*. (2011), the prices of drugs are transparent to consumers, and the out-of-pocket payments of consumers are determined by the market-determined prices charged by the pharmaceutical firms relative to the reference price and the levels of the relevant coinsurance and deductible in health insurance coverage. In this model, consumers are choosing between identical molecules (branded versus generic). Consumers may perceive the quality of brand-name drugs to be higher than their generic equivalents, based on marketing by brand-name drug manufacturers. Market prices are determined via a two-firm Bertrand game (a brand-name provider with higher-perceived quality and a generic provider with lower-perceived quality) in which the two firms simultaneously choose market prices to maximize profits under two possible reference pricing regimes.

Under the first regime, the reference price is fixed (exogenous) and not a function of market prices. Under the second regime, the reference price is a function of market prices (endogenous), being reset when market prices change. Under the fixed reference pricing regime, the model predicts (1) a reduction in the market price of the high-price brand-name drug and (2) an increase in the market price of the low-price generic drug: market prices converge towards the reference price from above and below, respectively. Under the floating reference pricing regime, however, market prices fall for both the brand-name and generic drugs, with market prices falling by a larger amount for the brand-name drug. Market prices do not converge towards the reference price.

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The fundamental reason for the difference in the two outcomes is a strategic move on the part of generic drug firms to gain market share via the influence of their behavior on the reference price. By setting a lower market price, the generic drug firms indirectly reduce the reference price, which is a function of market prices. This increases the relative size of the coinsurance portion of the out-of-pocket payment that consumers must pay for the brand-name drug, resulting in a higher market share for generic drug firms. This can be shown to be a profit maximizing strategy (Brekke *et al*., 2011). See also Miraldo (2009).

This model can be directly applied to the market for joint replacement. In January 2011, the California Public Employees' Retirement System (CalPERS) introduced reference pricing for unilateral total joint replacement surgery of the knee or hip in its self-insured preferred provider organization (PPO) product, managed by Anthem Blue Cross. The model of Brekke *et al.* (2011) appropriately characterizes price transparency in the CalPERS reference pricing initiative. Hospital market prices for knee and hip replacement surgery were made transparent by means of the Anthem Care Comparison Tool, an Internet-based comparison tool that allowed consumers to compare average hospital market prices across California for various procedures including hip and knee replacement surgery. In addition, CalPERS provided its PPO enrollees with a list of hospitals, termed value-based purchasing design (VBPD) facilities, which would provide hip and knee replacement surgery at or below the reference price. The two classes of hospitals, VBPD and non-VBPD, are appropriately characterized by the model of Brekke *et al*. (2011).

In order for non-VBPD hospitals to gain the business of any given CalPERS enrollee, they must provide a perception of quality over and above that of VBPD hospitals. The perception of quality may come from many sources: orthopedists, friends, past experience, the market price, etc. This perception need not correspond with actual quality differences (it does not correspond to actual quality with regard to brand-name and generic drugs in the Brekke *et al*. (2011) model). Note that systematic quality information on hip and knee replacement was not publicly available during this period.[1] However, in a recent study of the quality of outcomes in the CalPERS program examined here, no quality difference was found between VBPD and non-VBPD hospitals (Chi *et al*., 2014), mirroring the actual brand-name/generic quality difference in the Brekke *et al*. (2011) model.

CalPERS set a reference price of $30,000, which was chosen by examining the past pattern of market prices and choosing a reference price level that would ensure adequate geographical availability of hospitals as well as include selected hospitals that have a reputation for quality. Forty-one hospitals were identified whose average market price for knee and hip replacement was $30,000 or less.[2]

Thus, the CalPERS reference price was a function of the geographic distribution of market prices. While CalPERS did not announce that it would alter the reference price in the future, it was reasonable for hospitals to expect that the reference price could be changed depending on the future geographic distribution of prices. It is common for reference prices in Europe to be altered in this way (Kaiser *et al*., 2014). Hospitals could thus reasonably expect to be able to influence future reference pricing decisions.

In order to determine the effect of reference pricing on insurer payments to hospitals, the reduction of which is the primary goal of the CalPERS reference pricing initiative, we extend the Brekke *et al.* (2011) reference pricing model to include insurer payments and consumer cost sharing. Details are provided in the online appendix using the same notation as Brekke *et al*. (2011). Under endogenous reference pricing, these extensions predict that insurer expenditures at both VBPD and non-VBPD facilities will decline, with expenditures being reduced by a larger amount for non-VBPD facilities than for VBPD facilities. The extension also predicts that out-of-pocket coinsurance payments for consumers will decline in VBPD facilities but yields ambiguous predictions about these expenditures at non-VBPD facilities. Under exogenous reference pricing, these extensions predict that insurer expenditures at VBPD facilities will increase and that insurer expenditure to non-VBPD facilities will decline, with coinsurance payments at VBPD hospitals mirroring these changes (predictions regarding coinsurance payments are again ambiguous for non-VBPD facilities). We suggest that,

[1]For example, the Center for Medicare and Medicaid had suppressed information on complications from hip and knee replacement on their website: http://www.medicare.gov/hospitalcompare/

[2]The number of hospitals on this list was later increased as additional hospitals sought inclusion on this list by reducing their market price.

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under ambiguity regarding the future status of the reference price, low-price hospitals will behave consistently with the assumption that their behavior may impact the reference price (endogenous reference pricing) but will revert to behavior consistent with exogenous reference pricing if it becomes clear that their behavior does not influence the reference price.

2.2. Data

We obtained claims data on hip and knee replacement surgery from CalPERS for all enrollees covered by its PPO products from January 2008 to December 2013. All enrollees in CalPERS PPO products were subject to reference pricing for single knee and hip replacement beginning in January of 2011. We also constructed a comparison group that had similar PPO coverage, with the exception of reference pricing, by obtaining non-CalPERS claims on hip and knee replacement surgery from the same health insurer in California that administered the CalPERS PPO program (Anthem Blue Cross). We restricted our sample to only include hospital referral regions within California that contain both VBPD and non-VBPD hospitals: 22 of the 24 hospital referral regions. This approach allows us to avoid issues related to horizontal hospital differentiation based on significant differences in hospital location.

The market price for orthopedic surgery is identical within each hospital across both the treatment and comparison groups, because CalPERS used the market price negotiated by Anthem for its membership. We also had data on insurer payments (e.g., the market price actually paid by CalPERS and Anthem, as distinct from the amount paid by the consumer), consumer cost sharing (deductibles, coinsurance, and copayments, including the difference between reference price and the market price), age, sex, International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) diagnosis and procedure codes, source of insurance, insurance characteristics, hospital discharge destination, hospital referral region, and year. Hospital referral region information comes from the Dartmouth Atlas of Health Care.

Other inclusion criteria were as follows: patients must have been in the 18–64 years age range, received a single knee or hip replacement (bilateral procedures and combination knee/hip procedures were omitted because they were not subject to reference pricing), resided in and had surgery performed in California, and received surgery sometime from January 2008 to December 2013. This study was approved by the Committee for the Protection of Human Subjects at the University of California, Berkeley.

2.3. Econometrics

We estimate two difference-in-differences models. Our first model examines the effect of reference pricing on insurer payments, while the second examines the effect of reference pricing on consumer cost sharing related to coinsurance[3]:

$$IP = \beta_0 + \beta_1 D + \beta_2 C + \beta_3 V + \beta_4 Y + \beta_5 C\times V + \beta_6 C\times Y + \beta_7 V\times Y + \beta_8 C\times V\times Y + \beta_9 DI + \beta_{10} H + \varepsilon \quad (1)$$

$$CI = \alpha_0 + \alpha_1 D + \alpha_2 C + \alpha_3 V + \alpha_4 Y + \alpha_5 C\times V + \alpha_6 C\times Y + \alpha_7 V\times Y + \alpha_8 C\times V\times Y + \alpha_9 DI + \alpha_{10} H + \upsilon \quad (2)$$

where *IP* refers to insurer payments, *CI* refers to coinsurance, *D* refers to a vector of demographics, comorbidities, insurance plan characteristics, hospital discharge status indicators, and measures of competition including age (18–24, 25–34, 35–44, 45–54, and 55–64 years), sex (male or female), insurance market (large firm, small firm, and individual plan), whether a firm participates in the financial results of the group benefit plan (refunding or non-refunding), comorbidity status (Charlson comorbidity index), patient discharge status (home, readmission, and other), and a Herfindahl–Hirschman Index (HHI) based on hospital beds, computed at the hospital referral region level and scaled from 0 to 1 (Charlson *et al*., 1987; Stagg, 2006). The scalar *C* refers to CalPERS enrollees, the scalar *V* refers to whether a hospital is a VBPD facility, *Y* is a vector of dummy variables indicating years (2008, 2009, 2011, 2012, and 2013), and *DI* is a vector of interaction terms including $D\times C$ and $D\times V$,

[3]The second model only includes coinsurance as the dependent variable because, as shown in the online appendix, the only portion of consumer cost sharing that is expected to vary because of the introduction of reference pricing is coinsurance.

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which are included so that the equations mimic the estimation of separate equations for VBPD and non-VBPD hospitals but retain the sample size of the combined group in order to maintain statistical precision. Finally, H is a vector of month indicators and hospital-specific fixed effects.

The insurance market variables are designed to pick up the effect of unobserved individual heterogeneity that may be related to whether an individual received insurance because of being employed in a small or large firm, or purchased insurance directly in the individual market. Whether a firm participates in the financial results of the group benefits plan will account for any internal pressure faced by individuals working in such firms to select lower-priced hospitals. The HHI is included to account for the level of hospital concentration in each HRR, which may impact market prices (and thus insurer payments and consumer cost sharing) for knee and hip replacement surgery. Month indicators remove seasonal effects. Hospital-specific fixed effects are included to account for unobserved hospital-level heterogeneity. Year fixed effects are included to account for state-level changes that may affect the prices of knee and hip replacement surgery and also indicate the periods during which reference pricing was in force.

The vectors β and α are parameters to be estimated and ε and υ are error terms. The constant term (reference group) represents men who are aged 18–24 years, have no comorbidities, received treatment at a non-VBPD facility, were not discharged home nor were readmitted to the hospital, are Anthem Blue Cross PPO enrollees, are employed by large firms with a non-refunding group benefits plan, received care in the year prior to the implementation of reference pricing, and received care in a market area characterized by competition (zero HHI).

We test the validity of the parallel trends assumption for each difference-in-differences model. This is performed by modeling differential trends using both treatment and comparison group-specific pre-implementation dummies. If any of the estimated coefficients for the interaction of the treatment group and the pre-implementation year dummies, β_6, β_8, α_6, or α_8, are statistically significant, this would indicate a violation of the parallel trends assumption (Ryan *et al*., 2015).

The parameters of interest in each equation are β_6 and β_8, and α_6 and α_8, for the post-implementation period. The effect of reference pricing on insurer payments and consumer cost sharing for those receiving care from a non-VBPD facility is described by the following second partial derivatives where V is set to zero: $\frac{\partial^2 IP}{\partial C \partial Y}\Big|_{V=0}$ and $\frac{\partial^2 CI}{\partial C \partial Y}\Big|_{V=0}$. Specifically, we are interested in the difference between the base year, 2010, and the years during which reference pricing occurred for CalPERS enrollees: 2011, 2012, and 2013. These derivatives indicate the difference between being a CalPERS enrollee (the treatment group) and being a non-CalPERS enrollee (the comparison group) for those who received their joint replacement surgery in a non-VBPD facility and are estimated, respectively, by the parameters β_6 and α_6.

The effect of reference pricing on insurer payments and consumer cost sharing with respect to coinsurance for those patronizing a VBPD facility is described by the same second partial derivatives, where V is set to 1: $\frac{\partial^2 IP}{\partial C \partial Y}\Big|_{V=1}$ and $\frac{\partial^2 CI}{\partial C \partial Y}\Big|_{V=1}$. These derivatives are estimated, respectively, by the parameter sums $\beta_6+\beta_8$ and $\alpha_6+\alpha_8$.

In estimating these equations, we followed Manning and Mullahy (2001) and employed generalized linear models. We determined the appropriate distributional family for each equation using a Park test and found that, with respect to insurer payments, a gamma distribution was indicated, while a Poisson distribution was indicated for the coinsurance model. In each model, standard errors are clustered at the hospital level and are corrected for heteroscedasticity. All analyses were performed using Stata 11.2 (StataCorp. College Station, TX, USA).

3. RESULTS

Tests of the parallel trends assumption found that the hypothesis of parallel trends could not be rejected. None of the relevant pre-implementation coefficients or sums of coefficients were statistically significant at $p < 0.10$.

Although the trends are statistically parallel, there are large unadjusted differences between the VBPD and non-VBPD categories across the treatment and comparison groups with regard to insurer payments. Table I

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Table I. Insurer payment and consumer coinsurance payment (2011 dollars)

	2008	2009	2010	2011	2012	2013
Insurer payment						
CalPERS non-VBPD facilities	31343	37642	39226	26088	26022	27896
Non-CalPERS non-VBPD facilities	28796	35141	37214	33390	31351	34347
Difference	2547	2501	2012	−7302	−5329	−6451
p-value	0.12	0.22	0.29	<0.01	<0.01	<0.01
CalPERS VBPD facilities	21122	25261	24196	22514	23373	25143
Non-CalPERS VBPD facilities	18204	19747	21874	23419	24143	23942
Difference	2918	5514	2322	−905	−770	1201
p-value	<0.01	<0.01	0.08	0.40	0.35	0.15
Consumer coinsurance payment						
CalPERS non-VBPD facilities	1735	2373	2682	1460	1173	854
Non-CalPERS non-VBPD facilities	1483	1576	1527	1444	1548	1564
Difference	252	797	1155	16	−375	−710
p-value	0.27	0.07	<0.01	0.96	0.04	<0.01
CalPERS VBPD facilities	586	778	749	510	534	708
Non-CalPERS VBPD facilities	1697	1710	1656	1534	1544	1453
Difference	−1111	−932	−907	−1024	−1010	−745
p-value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

The *p*-value is for the simple two-sample *t*-test, not fully adjusted regression analysis. VBPD: Value-based purchasing design. CalPERS, California Public Employees' Retirement System.

shows that prior to the intervention, the annual differences in mean insurer payments between VBPDs and non-VBPD hospitals for CalPERS members ranged from $10,221 to $15,030. The corresponding figures for non-CalPERS Anthem members ranged from $10,592 to $15,394.

Table II presents descriptive statistics. CalPERS and non-CalPERS patients patronized VBPD facilities in the same proportions. CalPERS patients are older, more likely to be female, have more comorbidities, and are less likely to be discharged to home. Hospital readmissions were not different across the groups.

While CalPERS is a large self-funded employer where the insurance carrier only administrates the group benefits program, the comparison group was a mix of individuals from large firms, small firms, and those with individual policies, and included both refunding and non-refunding group benefits programs. In addition, CalPERS enrollees were more likely to receive care in less competitive hospital referral regions. These differences underscore the importance of our statistical controls.

Table III presents the difference-in-differences estimates. Table IV provides a summary of the relevant second partial derivatives. The second partial derivatives for insurer payments to non-VBPD hospitals, after transformation into percentages, are -19.2% ($p < 0.01$) for 2011, -14.1% ($p < 0.05$) for 2012, and -13.7% ($p = 0.05$) for 2013 (Halvorsen and Palmquist, 1980). The second partial derivatives for insurer payments to VBPD hospitals, after transformation into percentages, are -9.2% ($p < 0.05$) for 2011, -10.0% ($p = 0.08$) for 2012, and -5.3% ($p = 0.38$) for 2013 (Halvorsen and Palmquist, 1980). During 2011–2012, the decline in insurer payments to non-VBPD hospitals is larger than the decline in insurer payments to VBPD hospitals.

The average change in insurer payments is negative and statistically significant for non-VBPD facilities for each year from 2011 to 2013. The average change in coinsurance payments is also negative and statistically significant in 2011 and 2013 and marginally statistically significant in 2012. However, for VBPD facilities, the average change in insurer payments is negative in 2011 but then goes through a transition, first retaining the same sign and magnitude while losing some precision in 2012 and then falling in magnitude and no longer being statistically different from zero in 2013. This pattern of change is largely mirrored in the average change in coinsurance payments to VBPD facilities from 2011 to 2013, although the magnitude of the changes, as shown in Tables I and IV, is too small to be precisely measured by the regression analysis.

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Table II. Descriptive statistics: total joint replacement surgery (knee/hip)

	CalPERS		Non-CalPERS comparison group		
	Mean	Std. Dev.	Mean	Std. Dev.	*p*
Insurer payment (2011 dollars)	27442.69	17194.13	27112.16	17907.35	0.42
Consumer coinsurance payment (2011 dollars)	1158.85	5068.90	1566.21	1502.24	<0.01
VBPD facilities	0.56	—	0.54	—	0.02
Age (years)					
25–34	0.01	—	0.01	—	0.48
35–44	0.03	—	0.04	—	<0.01
45–54	0.18	—	0.25	—	<0.01
55–64	0.78	—	0.70	—	<0.01
Female	0.59	—	0.53	—	<0.01
Charlson comorbidity index	0.33	0.57	0.25	0.52	<0.01
Discharged to home	0.90	—	0.93	—	<0.01
Readmitted to hospital	0.003	—	0.002	—	0.54
Insurance policy characteristics					
Small firm group policy	0.00	—	0.31	—	<0.01
Individual policy	0.00	—	0.39	—	<0.01
Refunding	0.00	—	0.09	—	<0.01
Year					
2008	0.15	—	0.18	—	<0.01
2009	0.16	—	0.16	—	0.74
2011	0.17	—	0.16	—	0.30
2012	0.18	—	0.16	—	0.02
2013	0.16	—	0.17	—	0.21
Herfindahl–Hirschman Index	0.13	0.09	0.11	0.09	<0.01
Number of patients	2389		8914		

Months included, but not reported. Std. Dev., standard deviation; VBPD, value-based purchasing design; CalPERS, California Public Employees' Retirement System.

What was the impact on CalPERS of the re-establishment of the pre-implementation level of insurer payment by VBPD hospitals? The average CalPERS payment at VBPD facilities was $22,514 in 2011 and $23,373 in 2012. Average savings per patient were $2071 ($0.092 \times \$22{,}514$) in 2011 and $2337 ($0.100 \times \$23{,}373$) in 2012. The total number of CalPERS employees receiving care from a VBPD facility was 256 in 2011 and 285 in 2012. Thus, the total estimated savings that was lost by CalPERS when VBPD facilities returned to their original price trajectory is approximately $1.2 million [$(256 \times \$2071) + (285 \times \$2337)$].

4. DISCUSSION

This study analyzed the application of RBBs to high-price orthopedic procedures examining insurer and consumer payments under two scenarios: exogenous and endogenous reference pricing. Under exogenous reference pricing, insurer expenditures to low-price VBPD hospitals are predicted to increase but are predicted to decrease to non-VBPD hospitals, with coinsurance payments to VBPD hospitals mirroring these changes. There is no unambiguous prediction about changes in consumer expenditures to non-VBPD hospitals.

Under endogenous reference pricing, insurer expenditures to both VBPD and non-VBPD facilities are predicted to decline, with expenditures to non-VBPD hospitals decreasing by a larger amount than expenditures to VBPD hospitals. In addition, coinsurance payments to VBPD hospitals are predicted to decline, but there is no unambiguous prediction about changes in coinsurance payments to non-VBPD hospitals.

The theoretical reason that low-price (VBPD) hospitals reduce their market prices is a strategic attempt to indirectly reduce the reference price, where the intended result is a larger difference in the relative coinsurance levels that consumers must pay when choosing a high-price over a low-price hospital. This larger coinsurance differential would induce more consumers to choose low-price hospitals over high-price hospitals, increasing the market share of low-price VBPD hospitals.

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Table III. Difference-in-difference estimates

	Insurer payments		Consumer coinsurance	
	Parameter	Std. Err.	Parameter	Std. Err.
Age (years)				
25–34	0.095	0.357	−0.003	0.613
35–44	−0.054	0.289	−0.104	0.602
45–54	−0.075	0.278	−0.032	0.593
55–64	−0.071	0.279	−0.117	0.596
Female	0.006	0.010	0.001	0.028
Charlson comorbidity index	0.049*	0.011	−0.063*	0.026
Discharged to home	−0.105*	0.032	0.537*	0.107
Readmitted to hospital	−0.259*	0.084	−0.597	0.391
Insurance policy characteristics				
Small firm group policy	−0.035*	0.013	0.479*	0.101
Individual policy	−0.042*	0.016	0.716*	0.088
Refunding	0.012	0.022	0.078	0.110
VBPD	−0.026	0.359	−0.198	0.564
VBPD × 2008	0.043	0.050	0.044	0.098
VBPD × 2009	−0.024	0.032	−0.020	0.076
VBPD × 2011	0.043	0.046	−0.093	0.117
VBPD × 2012	0.059	0.055	−0.087	0.137
VBPD × 2013	0.026	0.065	−0.072	0.126
VBPD × CalPERS	0.003	0.048	−1.233*	0.441
VBPD × CalPERS × 2008	−0.037	0.061	0.121	0.507
VBPD × CalPERS × 2009	−0.015	0.051	0.163	0.253
VBPD × CalPERS × 2011	0.117	0.079	0.276	0.245
VBPD × CalPERS ×2012	0.047	0.091	0.626	0.568
VBPD × CalPERS × 2013	0.094	0.097	1.241*	0.556
CalPERS	−0.016	0.033	0.822*	0.397
CalPERS × 2008	0.013	0.047	−0.392	0.430
CalPERS × 2009	0.021	0.033	−0.120	0.141
CalPERS × 2011	−0.213*	0.063	−0.536*	0.147
CalPERS × 2012	−0.152*	0.070	−0.893	0.513
CalPERS × 2013	−0.147*	0.076	−1.222*	0.506
Year				
2008	−0.193*	0.039	−0.008	0.081
2009	−0.052*	0.025	0.065	0.064
2011	0.016	0.040	0.108	0.111
2012	−0.004	0.047	0.115	0.120
2013	0.054	0.054	0.031	0.111
Herfindahl–Hirschman Index	2.076	2.516	−12.437	6.846
Constant	9.875*	0.284	6.240*	0.597
Number of patients	11,303		11,303	

Generalized linear model with log link and gamma distribution for insurer payments; Poisson distribution for consumer coinsurance payment. Parameters must be transformed to obtain accurate percentages: 100(exp(parameter) − 1). Hospital fixed effects and month indicators included, but not reported. We fully interact VBPD with other covariates in this model in order to mimic the results of separate models for VBPD and non-VBPD hospitals and retain statistical power (not reported). CalPERS, California Public Employees' Retirement System; VBPD, value-based purchasing design; Std. Err., standard error clustered by hospital.
*$p \leq 0.05$ (two-tailed t-test).

A key assumption of this study is that when ambiguity regarding the future status of the reference price is present, low-price hospitals will initially behave as if reference pricing is endogenous but will revert to behavior consistent with exogenous reference pricing if it becomes clear that their behavior does not influence the reference price.

In our study, this behavioral switching pattern was clearly apparent. Following the introduction of reference pricing, both high-price non-VBPD and low-price VBPD hospitals initially accepted lower insurer payments (and non-VBPD hospitals accepted lower coinsurance payments), but the insurer, CalPERS, did not reset the reference price during the 3-year post-implementation period.

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Table IV. Effect of reference pricing on insurer payments and consumer coinsurance payment for those receiving care from VBPD and non-VBPD facilities

	Insurer payments		Consumer coinsurance payment	
	VBPD	Non-VBPD	VBPD	Non-VBPD
2011	−9.2% ($p = 0.04$)	−19.2% ($p < 0.01$)	−22.8% ($p = 0.18$)	−41.5% ($p < 0.01$)
2012	−10.0% ($p = 0.08$)	−14.1% ($p = 0.03$)	−23.4% ($p = 0.29$)	−59.1% ($p = 0.08$)
2013	−5.3% ($p = 0.38$)	−13.7% ($p = 0.05$)	2.0% ($p = 0.94$)	−70.5% ($p = 0.02$)

All percentages represent second partial derivatives derived from the equations presented in Table III and adjusted according to the procedure described in Halvorsen and Palmquist (1980). VBPD, value-based purchasing design.

Although CalPERS never specifically stated that the RBB payment limit would be reset over time, it was rational for VBPD hospitals to behave as if this were likely. The resetting of reference prices in response to changes in market prices is common in Europe, where reference prices are periodically reset as a function of either domestic market prices (internal reference pricing) or international market prices (external reference pricing) (Kaiser *et al*., 2014).

The results describe how, after 2 years, VBPD hospitals sharply raised the insurer payments they would accept, reverting to behavior consistent with exogenous reference pricing. This attenuated the previous levels of savings experienced by CalPERS.

Should CalPERS have therefore implemented endogenous reference pricing to maintain the additional $1.2 million in savings they had already experienced because of lower insurer payments to VBPD hospitals? There are important trade-offs to consider with regard to the choice between endogenous and exogenous reference pricing in this context. One the one hand, allowing the reference price to float based on the market prices of VBPD and non-VBPD hospitals would likely reduce the reference price over time, increasing the overall savings to CalPERS beyond the level of savings they experienced, other things equal. However, other things are unlikely to be equal. A reduced reference price may result in some VBPD hospitals no longer qualifying to be classified as VBPD facilities. This could result in there no longer being a choice between a VBPD and a non-VBPD hospital in some markets, which may result in less consumer acceptance of the RBB program. In this context, implementing endogenous reference pricing may create consumer and/or political opposition to RBB that may be sufficient to unravel RBB, erasing all savings due to the RBB program, while an exogenous reference price is unlikely to have any such effect. Future research should explore the general conditions under which the unraveling of RBB programs is likely or unlikely to occur.

The results of this study should be interpreted in light of its limitations. The model was adapted from a model of reference pricing applied to generic and brand-name drugs, where actual quality is identical, although perceived quality varies. In the case of hip and knee replacement, consumers did not have information on the actual quality of hip and knee replacement surgery across hospitals. However, the relative quality of the CalPERS VBPD hospitals has been statistically compared with the quality of CalPERS non-VBPD hospitals in a study by other authors. It was found that, relative to non-VBPD hospitals, the increase in the use of VBPD hospitals was not associated with any increase in surgical complications related to joint replacement, any increase in hospital readmission rates, and any increase in admissions to emergency departments (Chi *et al*., 2014).

The model used in this study does not take into account explicitly the fact that consumers likely take distance into account when choosing hospitals (we did not possess specific consumer addresses). Consumers are assumed to choose between a VBPD and a non-VBPD hospital within the region in which they live.

This study provides policy makers with additional evidence on the effectiveness of reference pricing. It also sheds light on potential trade-offs between endogenous and exogenous RBB limits. Policy makers would do well to carefully think through the implications of any RBB program in order to obtain their desired outcome.

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CONFLICT OF INTEREST

There are no conflicts of interest.

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