1 Severity-adjusted price

To account for differences in private payer prices across hospitals due to differences in patient mix and associated differences in necessary resources, we construct a private payer price index. We use a regression-based adjustment that is common in studies of hospital competition and prices (Cooper *et al.*, 2018; Gowrisankaran *et al.*, 2015; Gaynor & Vogt, 2003). We first adjust for resource use by dividing the allowed payment amount for each claim by the the MS-DRG weight corresponding to the MS-DRG assigned to the claim in a given year. We then estimate the following regression model and use the resulting coefficient estimates and average population characteristics to construct a severity-adjusted mean hospital price for each hospital-year observation in our data:

$$y_{hit} = \alpha + x'_{hit}\beta + \sum \gamma_{ht} + \epsilon_{hit}. \quad (1)$$

We regress y_{hit}, the resource adjusted payment for patient i at hospital h in year t on patient characteristics x_{hit}, which include age category, gender, age-gender interactions, and length of hospital stay; hospital fixed effects in year t, γ_{ht}, and a constant term α_{ht}. The error term ϵ_{hit} is assumed i.i.d. across hospitals, patients, and time. Finally, we calculate the severity-adjusted average price for every hospital h using the hospital fixed effect γ_h estimate and the patient characteristic coefficient estimates evaluated at the mean of the population in year t. We perform this adjustment separately for each year of data in our sample, 2010-2015.

2 Robustness

Appendix Tables 1 and 2 presents the full set of results from our main extensive margin regression in Table 2 of the main text.

Table 1. Full Extensive Margin Results

	Log Mean Payment	Log Mean Net Charge	Log Medicaid Discharges	Log Medicare Discharges	Log Other Discharges
Net Penalty	0.019**	-0.004	-0.045	-0.031**	-0.004
	(0.008)	(0.016)	(0.032)	(0.016)	(0.021)
Hospital Characteristics					
Monopoly	-0.012	0.077	0.104*	0.052*	-0.031
	(0.026)	(0.055)	(0.058)	(0.027)	(0.034)
Duopoly	-0.010	0.048	0.111**	0.044**	-0.009
	(0.016)	(0.046)	(0.050)	(0.021)	(0.024)
Triopoly	0.009	0.090*	0.064	0.000	-0.031
	(0.014)	(0.053)	(0.040)	(0.012)	(0.020)
Large Market	-0.030*	-0.055**	-0.040	0.035**	0.119***
	(0.018)	(0.027)	(0.041)	(0.018)	(0.034)
Any Teaching	-0.024*	-0.016	-0.059	-0.029	-0.020
	(0.013)	(0.036)	(0.049)	(0.019)	(0.021)
Major Teaching	0.011*	0.018	0.119**	0.021	0.000
	(0.006)	(0.017)	(0.058)	(0.021)	(0.024)
System	0.032***	-0.019	-0.142**	-0.093***	-0.054***
	(0.010)	(0.024)	(0.055)	(0.021)	(0.019)
Nonprofit	0.021	0.015	0.164	0.027	-0.043
	(0.030)	(0.034)	(0.143)	(0.022)	(0.041)
For Profit	0.033	0.020	0.087	-0.000	-0.054
	(0.034)	(0.038)	(0.154)	(0.029)	(0.046)
County Age Share					
[18,34]	-2.255	2.240	8.954*	-2.481	-2.919
	(1.535)	(2.151)	(4.660)	(1.756)	(2.387)
[35,64]	-1.894	-0.789	6.282	-3.583*	-3.110
	(1.735)	(2.337)	(5.029)	(1.882)	(2.316)
>64	-1.519	1.582	2.461	0.902	1.414
	(1.369)	(2.571)	(5.210)	(1.562)	(2.763)

Notes: Notes: $n = 8,316$. The table presents the full set of parameter estimates from the top panel of Table 2 in the main text. All regressions adjust never penalized hospitals with entropy weights and include hospital and year fixed effects. Other hospital level controls include bed count, number of nurses, and number of other non-medical staff. Market power variables are constructed using the overall hospital service area. Large market is a binary variable for a hospital in the top half of the market size distribution. In cases in which independent variables are missing, we recode them and control for missing variable indicators to ensure a balanced panel. Standard errors are clustered at the hospital level. The range of penalties is the 1st and 99th percentile within a quartile or, in the extensive margin case, overall. *** p-value<0.01, ** p-value<0.05, * p-value<0.1. $n = 8,316$. *** p-value<0.01, ** p-value<0.05, * p-value<0.1.

Next, we present two alternative estimators to those discussed in Section 3.3 of the main text. First, we re-estimate Equation 1 when setting $\alpha_h = \alpha$ in order to gauge the sensitivity of our results to the presence of unobserved and time-invariant hospital factors. Second, we gauge the sensitivity of our results to the use of entropy weights.

Table 2. Full Extensive Margin Results: Continued

	Log Mean Payment	Log Mean Net Charge	Log Medicaid Discharges	Log Medicare Discharges	Log Other Discharges
County Age Share					
[18,34]	-2.255	2.240	8.954*	-2.481	-2.919
	(1.535)	(2.151)	(4.660)	(1.756)	(2.387)
[35,64]	-1.894	-0.789	6.282	-3.583*	-3.110
	(1.735)	(2.337)	(5.029)	(1.882)	(2.316)
>64	-1.519	1.582	2.461	0.902	1.414
	(1.369)	(2.571)	(5.210)	(1.562)	(2.763)
County Shares					
Income 50k−75k	-0.244	-0.401	4.175	0.193	0.647
	(0.610)	(0.975)	(2.686)	(0.787)	(1.381)
Income 75k−100k	0.480	1.762	2.993	1.051	-0.901
	(0.643)	(1.350)	(3.530)	(0.981)	(1.516)
Income 100k−150k	-0.776	1.397	0.810	-0.035	0.284
	(0.611)	(1.526)	(2.845)	(1.026)	(1.643)
Income >150k	0.919	2.157	3.760	2.685**	-0.007
	(0.582)	(1.365)	(3.358)	(1.125)	(1.539)
White	-0.168	0.325	1.445	-0.016	-0.305
	(0.339)	(0.516)	(1.574)	(0.341)	(0.560)
Black	0.352	0.823	-1.476	-0.635	-1.921**
	(0.459)	(0.772)	(2.071)	(0.661)	(0.883)
High School Grad.	0.198	-0.692	0.156	-1.975*	-1.113
	(0.572)	(1.405)	(2.798)	(1.151)	(1.739)
College Grad.	1.499**	-1.424	-0.106	-3.642*	-0.809
	(0.707)	(1.236)	(3.491)	(2.029)	(2.644)
Total Population	0.000	0.000*	0.001*	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Year>2011	0.010	-0.010	-0.015	0.010	-0.016
	(0.012)	(0.019)	(0.039)	(0.019)	(0.021)
Labor Nurse	-0.000	-0.000	0.000*	0.000***	0.000*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Labor Other	0.000**	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Beds	0.000	0.000	0.001	0.000***	0.000
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)
Year=2011	0.079***	-0.011	-0.059	-0.022*	-0.030*
	(0.007)	(0.019)	(0.037)	(0.012)	(0.018)
Year=2012	0.102***	-0.030	-0.125**	-0.061***	-0.008
	(0.011)	(0.024)	(0.057)	(0.015)	(0.025)
Year=2013	0.136***	-0.047	-0.155**	-0.089***	-0.017
	(0.018)	(0.036)	(0.078)	(0.021)	(0.034)

Table 3. Alternative Specifications

	Log Mean Payment	Log Mean Net Charge	Log Medicaid Discharges	Log Medicare Discharges	Log Other Discharges
Unweighted Results					
OLS	-0.061***	-0.049***	0.220***	0.094***	0.069***
	(0.015)	(0.018)	(0.045)	(0.026)	(0.022)
OLS + Hospital FE	0.014***	0.008	-0.045**	-0.027***	-0.004
	(0.005)	(0.008)	(0.021)	(0.007)	(0.011)
Entropy-Weighted Results					
OLS	0.019	0.011	0.054	-0.017	0.050
	(0.030)	(0.036)	(0.056)	(0.042)	(0.034)
OLS + Hospital FE	0.019**	-0.004	-0.045	-0.031**	-0.004
	(0.008)	(0.016)	(0.032)	(0.016)	(0.021)

Notes: *** p-value<0.01, ** p-value<0.05, * p-value<0.1.

Appendix Table 3 presents results with and without entropy weights. The first panel includes unweighted results, where the first regression exploits both between and within-hospital variation and the second regression focuses on within-hospital variation. Without weights and hospital fixed effects, the signs in both the payment and discharge results flip: HRRP/HVBP penalties are associated with a decrease in mean payments (6.1%) and an increase in publicly insured patients (22% for Medicaid and 9.4% for Medicare). Adding either entropy weights or hospital fixed effects causes the results to revert to the results to those presented in Table 2 of the main text. Relative to our initial results, these findings suggest that persistent and unobserved hospital-level heterogeneity is an important driver of outcomes in our setting. Furthermore, when comparing the fixed effects estimates with and without weights, we conclude that our entropy weighting scheme does not drive the qualitative conclusions.

Appendix Table 3 also suggests that hospital fixed effects may in fact go a long way toward controlling for mean differences between charges and payments. Many studies of hospital pricing proxy for payments with hospital charges and argue that hospital fixed effects control for mean differences between charges and payments (Cutler *et al.*, 2000). Our results offer some assurance that findings of a significant effect using charge-based estimates of prices may indeed be reflective of a true price increase; however, we also emphasize the importance of payment data with respect to the precision and measurement of private insurance payments, noting the lack of statistical significance in our model of log mean net charges presented in Table 2 of the main paper. Findings of an insignificant effect using charge-based proxies for private payments may therefore be driven by incorrect inference (e.g., due to measurement error) or due to a true underlying null effect.

Finally, Appendix Table 4 presents results in which we use individual-level data to estimate Equation 1. That is, rather than aggregate private payments to the hospital level, we model individual-claim payments as a function of hospital characteristics, including our net penalty binary variable. The top panel of Appendix Table 4 repeats our main extensive margin results from Table 2 of the main text. The bottom panel presents the extensive margin result for payments when we estimate the model on over 4.7 million individual claims. As in the hospital-level results, we use hospital-level entropy weights to achieve hospital-level balance in pre-HRRP/HVBP characteristics across penalized and non-penalized hospitals. The results are very similar to the hospital-level results. We find that a net penalty is associated with a 1.5% increase in the log mean payment, a result that is statistically significant at the 95% level of confidence.

Table 4. Patient Level Results

	Log Mean Payment	Log Mean Net Charge	Log Medicaid Discharges	Log Medicare Discharges	Log Other Discharges
Hospital-Level: Extensive Margin Results					
Net Penalty	0.019**	-0.004	-0.045	-0.031**	-0.004
	(0.008)	(0.016)	(0.032)	(0.016)	(0.021)
Patient-Level: Extensive Margin Results; n=4,721,161					
Net Penalty	0.015**				
	(0.007)				

Notes: The top panel repeats our main results found in Table 2 of the main text. These results are at the hospital-level. The bottom panel presents individual-level regression results from a modified version of Equation 1 in the main text. Sample size includes over 3 million individual claims. *** p-value<0.01, ** p-value<0.05, * p-value<0.1.

3 Hospital Cost-Shifting

An alternative mechanism behind our results may be hospital cost-shifting, in which hospitals attempt to extract higher payment levels from private insurers as a result of public payment reductions, *without* *changing the underlying product.* Given the stated intention of the HRRP/HVBP and existing evidence on hospital responses to these programs, we suspect that cost-shifting is *not* a major mechanism driving our results. Nonetheless, in the absence of evidence on hospital investments or quality improvements for commercial insurance patients, we are obligated to at least consider cost-shifting as a potential mechanism.

As initially examined in Dranove (1988), a hospital may pursue a cost-shifting strategy if the hospital's objective function includes something other than pure profit (e.g., if the hospital receives direct utility from the quantity of services provided). For this reason, cost-shifting is thought to more likely occur among non-profit hospitals.[1] However, the model posited in Dranove (1988) assumes that hospitals set payments unilaterally, and it is not immediately clear whether this prediction extends to a modern managed care market in which hospitals and private insurers negotiate over private prices.

To more formally examine the presence of cost-shifting in a bargaining context, we embed the hospital cost-shifting model from Dranove (1988) in a hospital-insurer bargaining model similar to that in Ho & Lee (2017) (HL), Gowrisankaran *et al.* (2015), Lewis & Pflum (2015), and Dor *et al.* (2004). Specifically, we consider a hospital whose objective is to maximize a function of profits and quantity of care provided, denoted by

$$U\left(\pi_j = \sum_{i=1}^{N_j} \pi^h_{i,j} + \pi^h_{g,j}, \sum_{i=1}^{N_j} D^h_{i,j}, D^h_{g,j}\right), \tag{2}$$

where π_j denotes total profits for hospital j and $D^h_{i,j}$ denotes hospital demand from insurer i. Following HL, we assume

$$\pi^h_{i,j} = D^h_{i,j}(p_{i,j} - c_i),$$

where $p_{i,j}$ denotes the negotiated payment between insurer i and hospital j. We also follow HL in assuming that patients are "unaware or unable to determine their [financial] liability prior to choosing their provider." In other words, the negotiated payment $p_{i,j}$ does not affect demand for a specific hospital.[2] The subscript

[1]Of course, this does not mean that non-profit hospitals are fully altruistic. In fact, evidence on non-profit hospital behavior relative to for-profit hospital behavior is mixed. For example, Silverman & Skinner (2004) and Dafny (2005) find evidence that non-profits "upcode" less frequently, while Gaynor & Vogt (2003) find that non-profit hospitals have lower marginal costs but higher markups than for-profit hospitals.

[2]This assumption has implications for the traditional model of a profit maximizing firm operating in a two-price market. In that model, which is often cited as theoretical support for a prediction of lower private prices following a reduction in public payments, firms lower private prices in order to attract more private market patients on the margin. But in a bargaining

g denotes public (or government) insurers, for which the payment is administratively set at p_g. Finally, again following HL, we assume that profits for insurer i are

$$\pi_i^M = D_i\left(\theta_i - \eta_i\right) - \sum_{j=1}^{N_i} D_{i,j}^h p_{i,j}, \tag{3}$$

where D_i denotes the number of enrollees for insurer i, θ_i denotes the insurer's premiums, η_i denotes insurer costs per-enrollee other than inpatient hospital care, and $D_{i,j}^h p_{i,j}$ reflects payments to hospitals for care provided to the insurer's enrollees.

The negotiated price between hospital j and insurer i is such that

$$p_{ij} = \arg\max_{p_{ij}} \left(\triangle U_j\right)^{b_j} \times \left(\triangle \pi_i^M\right)^{1-b_j}, \tag{4}$$

where $\triangle U_j$ denotes the change in hospital j's utility from reaching an agreement with insurer i, and similarly $\triangle \pi_i^M$ denotes the change in insurer profits from an agreement with hospital i. b_j denotes the bargaining weight of hospital j, expressed as the weight to which the hospital's payoffs are given in the overall net value.

The first order condition for Equation 4 can be simplified to

$$b_j \triangle \pi_i^M \frac{\partial U_j}{\partial \pi_{ij}^h} - (1-b_j)\triangle U_j = 0, \tag{5}$$

and appyling the implicit function theorem yields the relevant comparative static:

$$\frac{\mathrm{d}p_{ij}}{\mathrm{d}p_g} = \frac{-b_j \triangle \pi_i^M \frac{\partial^2 U_j}{\partial \pi_j^2} D_g^h}{D_{ij}^h \left(b_j D_{ij}^h \frac{\partial^2 U_j}{\partial \pi_j^2} - (1-b_j)\frac{\partial U_j}{\partial \pi_j}\right)}. \tag{6}$$

We can see immediately from Equation 6 that $\frac{\mathrm{d}p_{ij}}{\mathrm{d}p_g} < 0$ whenever $\frac{\partial^2 U_j}{\partial \pi_j^2} < 0$. This means that hospitals must have some diminishing marginal utility of profits for cost-shifting to occur. Importantly, we obtain a prediction of cost-shifting without hospitals deriving utility from something other than profits, which

context in which the hospital remains in the insurer's network, there should be no such marginal response from patients.

is necessary for cost-shifting to occur in Dranove (1988). If we interpret diminishing marginal utility simply as a reflection of risk-aversion (e.g., in the context of uncertain demand or uncertain "exposure" to the HVBP/HRRP penalties), then this model predicts any risk-averse hospital to potentially cost shift, regardless of whether the hospital is for-profit or non-profit.[3] A related explanation could be something akin to a target income hypothesis, in which hospitals maintain some target profit margin and work to negotiate increases from private insurers when forced below the target margin due to a public payment reduction. Our model also predicts that cost-shifting should be largest for hospitals with more bargaining power, b_j, or a better bargaining position.

There is a perception in the literature that hospitals are indeed risk-averse (Cooper *et al.*, 2017);[4] however, in the case of a risk-neutral profit maximizing firm, the presence of cost-shifting requires that the firm must have some unused bargaining power in order to increase commercial insurance prices following a reduction in public payments. Even then, the nature of the hospital-insurer negotiation process suggests that this is at least a possibility. For example, public descriptions of hospital-insurer negotiations depict a relatively informal process.[5] This depiction is consistent with several discussions we have had with insurance and hospital executives, as well as consultants hired specifically to assist with hospital-insurer contract negotiations. Indeed, experts cited several examples where seemingly sophisticated negotiating parties (i.e., large hospitals systems and insurers) had not previously examined publicly available information on hospital costs and revenues as part of their research leading up to contract renegotiations. While this evidence is anecdotal, it suggests an informal process in which hospitals incorporate general changes in their environment over prior periods to argue in favor of a larger rate increase in any given negotiation.

[3] While it is commonly assumed that for-profit firms are risk-neutral, there is an influential literature examining the role of risk aversion in the context of demand uncertainty. See, for example, Sandmo (1971), Holthausen (1979), McDonald & Siegel (1985), Guiso & Parigi (1999), Chavas & Holt (1996), Asplund (2002), and many others. Intuitively, risk aversion could be introduced through the presence of risk-averse shareholders or managers/administrators. In the case of physician-owned hospitals, diminishing marginal utility of profits is analogous to diminishing marginal utility of income to the physicians, since they are the residual claimants for hospital profits. Note that the costs of additional tests, longer inpatient stays, or other complications incurred outside of the initial surgery are generally borne by the hospital rather than the physician. In this way, the presence of risk aversion is less of an issue in the market for physician services since physicians are not generally exposed to the risk of higher costs for the same patient.

[4] As discussed in Cooper *et al.* (2017), risk aversion is a natural reason that a hospital may prefer charge-based contracts as opposed to a prospective payment, since the hospital is exposed to uncertainty underlying a given inpatient stay in a prospective payment model.

[5] See, for example, a recent guide from Becker's Hospital Review on The Ins and Outs of Successful Hospital Insurance Negotiations and Service Pricing.

Sacarny (2018) also provides direct empirical evidence that, even when the hospital has full control over potential revenue increases, they may not fully maximize profits and thus effectively "leave money on the table" in any given period.

Given that 80% of the hospitals in setting are non-profit, and given our finding of larger effects for those hospitals with more bargaining power, we cannot rule out cost-shifting as a potential mechanism underlying our results. However, we emphasize that cost-shifting is only plausible in our setting if we assume that the HRRP/HVBP did not induce any costly investments among penalized hospitals – by definition, cost-shifting is an increase in payments for a fixed product. Since the HRRP/HVBP were specifically designed as quality improvement programs, it is likely that penalized hospitals would rationally incur some additional costs (not necessarily direct monetary costs) as they attempt to improve their performance, which casts doubt on cost-shifting as the main mechanism.

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