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SIMULATION METHODS IN HEALTH SERVICES RESEARCH: APPLICATIONS FOR POLICY, MANAGEMENT, AND PRACTICE

The Impact of Profitability of Hospital Admissions on Mortality

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Background. Fiscal constraints faced by Medicare are leading to policies designed to reduce expenditures. Evidence of the effect of reduced reimbursement on the mortality of Medicare patients discharged from all major hospital service lines is limited.

Methods. We modeled risk-adjusted 30-day mortality of patients discharged from 21 hospital service lines as a function of service line profitability, service line time trends, and hospital service line and year-fixed effects. We simulated the effect of alternative revenue-neutral reimbursement policies on mortality. Our sample included all Medicare discharges from PPS-eligible hospitals (1997, 2001, and 2005).

Results. The results reveal a statistically significant inverse relationship between changes in profitability and mortality. A \$0.19 average reduction in profit per \$1.00 of costs led to a 0.010–0.020 percentage-point increase in mortality rates ($p < .001$). Mortality in newly unprofitable service lines is significantly more sensitive to reduced payment generosity than in service lines that remain profitable. Policy simulations that target service line inequities in payment generosity result in lower mortality rates, roughly 700–13,000 fewer deaths nationally.

Conclusions. The policy simulations raise questions about the trade-offs implicit in universal reductions in reimbursement. The effect of reduced payment generosity on mortality could be mitigated by targeting highly profitable services only for lower reimbursement.

Key Words. Hospital quality, medicare reimbursement, hospital finances

Given the fiscal constraints of the Medicare program, policy makers will continue to be faced with the challenge of implementing policies to control expenditures. In this study, we simulate the effect of policies that reduce Medicare reimbursement relative to costs on 30-day mortality rates. If overall Medicare reimbursement levels are reduced, then hospitals may be forced to reduce resources directed to patient care and quality improvement. If such reductions are large enough, patient outcomes could be adversely affected. As policy makers consider such changes, a central question is to what extent quality of patient care will be affected by lower reimbursement.

It has long been recognized that hospitals faced with reductions in reimbursement may reduce quality of care, particularly in clinical contexts in which clinical quality is difficult to assess by most consumers (Arrow 1963; Weisbrod 1989; Dranove and Satterthwaite 1992). Much of the recent evidence about the relationship between hospital finances, costs, and quality has focused primarily on treatment for specific conditions, such as acute myocardial infarction (AMI), a common, high-mortality condition for which treatment is generally considered profitable (Kessler and McClellan 2000; Gowrisankaran and Town 2003; Shen 2003; Volpp et al. 2005b; Schreyögg and Stargardt 2010). However, several theoretical and empirical studies have shown that a provider's response to reduced payment depends upon whether an admission is expected to be profitable (Hodgkin and McGuire 1994; Ellis 1998; Meltzer, Chung, and Basu 2002; Lindrooth, Bazzoli, and Clement 2007). This suggests that evaluating the response of hospitals to reductions in provider reimbursement using only outcomes in profitable conditions may provide a misleading sense of the effect of changes in reimbursement on quality and reimbursement/quality trade-offs for unprofitable conditions.

This study aims to fill a gap in the recent literature by examining changes in average payment generosity across conditions with a range of profitability and to simulate the effect of alternative reimbursement policies on mortality. We borrow the term "payment generosity" from a study that examined trends in Medicare reimbursement and costs between 1987 and 1990 (McClellan 1997). Payment generosity refers to the average profitability of an admission to a service line relative to its average cost. This measure takes into account the cost of delivering a service, whereas reimbursement reflects only the level of payment for an admission regardless of its cost. The simulations of the impact of alternative reimbursement policies on mortality are conducted using estimates of the relationships between payment generosity and 30-day mortality.

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MODELS OF PROVIDER RESPONSE TO CHANGES IN REIMBURSEMENT

If the profitability of service lines varies, providers will have a financial incentive to invest in profitable service lines to the detriment of unprofitable service lines (Newhouse 1996; McClellan 1997). Investment may take the form of entry into a profitable service line (Chernew, Gowrisankaran, and Fendrick 2002) or it may include investments in quality-related processes or service-oriented amenities (Frank, Glazer, and McGuire 2000). If a service line is profitable, these economic models predict that the provision of quality will be a function of the level of reimbursement to the extent that quality is observable by others. Competition for patients creates a reward for higher quality that may be accrued through a favorable reputation and thus an increased likelihood that patients will select a high-quality hospital for treatment (Glazer and McGuire 2002). Providers are predicted to divert resources away from quality when faced with reductions in reimbursement because all competitors are faced with increased financial constraints and compete on quality less vigorously, leading to a lower equilibrium level of quality.

Higher quality of unprofitable services may be maintained if providers cross-subsidize quality using the financial surplus from other services; however, a provider's ability to cross-subsidize depends critically upon whether it has the financial surplus to subsidize unprofitable services (David et al. 2011). This is analogous to the case of hospital cost-shifting, wherein hospitals cross-subsidize quality covered by less generous payers by charging higher prices to more generous payers (Dranove 1988); here, however, the cross-subsidization is from one service line to another. If a profitable service becomes less profitable, the ability of a hospital to redistribute funds to subsidize the quality of other services is diminished. Thus, the quality of the unprofitable services is hypothesized to suffer if the flow of subsidies from other services is reduced.

Providers may cross-subsidize quality in unprofitable services if they have the financial ability to do so. Paradoxically, a chronically unprofitable hospital is less likely to reduce quality in the face of reductions in reimbursement because its provision of quality and the ability to cross-subsidize has already been constrained by fiscal realities and it may instead be forced to the more extreme case of reducing access to unprofitable services. As a result, quality at unprofitable hospitals may be less affected by reductions in reimbursement because it had already been reduced to minimally acceptable levels.

The potential for a smaller effect at unprofitable hospitals may seem counterintuitive, but it is based on the premise that unprofitable hospitals have less “slack” in their finances, and this slack is what finances quality above a minimally acceptable level. Quality in both profitable and unprofitable services will be constrained at minimally acceptable levels as hospitals cut costs to remain solvent. Individual hospitals may define the minimally acceptable level of quality in different ways—nonprofits and teaching hospitals, for example, may set a minimum level of quality that is higher than the regulatory minimum—but chronically unprofitable hospitals are more likely to have reached that level prior to the reductions in reimbursement and thus are constrained from reducing quality further. The lack of an effect of changes in reimbursement would be observationally equivalent to a binding minimum quality level if this were the case.

Finally, the effect of reductions in Medicare reimbursement is predicted to decline as the Medicare share is reduced. This is the case if some element of quality is a public good and cannot be fine-tuned based on a patient’s insurance. We interacted providers’ Medicare share with hospital profitability in all empirical specifications to test for and measure the size of a differential effect of Medicare reimbursement by Medicare share.

Although we are unable to test for the specific mechanisms leading from changes in reimbursement to changes in mortality in this study, we assume that the causal chain includes changes in both short-term variable inputs, such as nurse staffing levels and skill-mix and the use of ancillary services and tests, and longer term fixed inputs such as the acquisition of new technology. Profitability may also affect training, the skill of newly hired clinicians and staff, and investment in quality improvement initiatives.

The above models are dependent to some extent on the notion that hospitals will compete for the admissions of patients with profitable conditions more vigorously than they would for unprofitable patients. An important assumption required for hospitals to compete over clinical quality is that patients will be more likely to choose a hospital with high clinical quality. Empirical studies have documented a small but consistent relationship between hospital quality and patients’ choice of a hospital (Luft et al. 1990; Kolstad and Chernew 2009). However, other determinants of provider choice have been shown to play a substantial role in patient decision making (Scanlon, Lindrooth, and Christianson 2008; Jung, Feldman, and Scanlon 2011; Sinaiko 2011; Werner et al. 2012) and the reaction of patients may depend on whether they observe evidence of poor quality versus excellent quality (Cutler, Ilckman, and Landrum 2004; Dranove and Sfekas 2008; Wang et al. 2011).

The goal of this study is to assess the effect of service line payment generosity on hospital quality by performing policy simulations that are grounded in established theory. A critical step in doing so is to estimate the coefficients of a model that is grounded in existing theory. The estimated coefficients from the empirical models are used to simulate how reductions in payment generosity result in worsened outcomes under alternative revenue-neutral policy scenarios.

DATA

Patient-level data were drawn from Medicare Provider and Analysis Review File (MEDPAR) Research Identifiable File 100 percent sample. Each record in the MEDPAR includes the following: codes for up to six procedures and 10 diagnoses, demographic information, unique beneficiary numbers linked to death certificates, submitted and allowed charges, admission source, and discharge status. Hospital net patient revenue, costs, investment income, and cost-to-charge ratios were drawn from the Center for Medicare & Medicaid Services Healthcare Cost Report Information System (HCRIS). Other hospital characteristics, including ownership, teaching status, and location, were drawn from the American Hospital Association's Annual Survey of Hospitals (AHA). Teaching status is defined as a Council of Teaching Hospital Member and urban hospitals are defined as those located within a Metropolitan Statistical Area. Service line definitions were based on the Massachusetts Health Data Consortium CMS-DRG Map (v24.0) (Consortium 2011). We further separated medical from surgical orthopedics and invasive from medical cardiology because both the levels and trends in reimbursement for these service lines were dramatically different and the volume of patients warranted further disaggregation.

We started with a sample of discharges of patients aged 66–90 from PPS-eligible hospitals in sample years 1997, 2001, and 2005. Only discharges from hospitals that reported costs and charges in the year before and after a given sample year were included in the sample for that year. This initial dataset consisted of 19,817,463 discharges. Index admissions were identified as those with no previous admissions within 30 days. We used the following exclusion restrictions: patients enrolled in HMOs within 5 years or admissions referred by HMOs ($n = 1,621,211$ discharges and 1 hospital) because HMOs do not report to MEDPAR; admissions from long-term care facilities ($n = 275,615$ discharges and two hospitals); admissions with cost-based reimbursement

(organ acquisition charges) ($n = 2,331$ discharges); admissions for AMI or stroke but discharged alive within 2 days ($n = 75,683$ discharge); admissions with a date of death earlier than date of admission ($n = 1,066$ discharges); transfers in from another hospital ($n = 236,078$ discharges and two hospitals); rare DRGs/conditions, defined as DRGs with fewer than 500 discharges or three-digit primary diagnosis codes with less than 100 discharges ($n = 37,415$ discharges) annually; and we limited our analysis to major service lines and dropped those with under 50,000 discharges per year ($n = 162,198$ discharges). Finally, we excluded hospitals whose Medicare revenue share could not be calculated due to missing or incomplete data ($n = 167,225$ discharges, 165 hospitals). The resulting study sample consisted of 17,238,641 admissions from 4,651 unique hospitals, of which there were 5,899,224 discharges from 4,588 hospitals in 1997; 5,809,304 discharges from 3,833 hospitals in 2001; and 5,530,113 discharges from 3,058 hospitals in 2005. Most of the decline in the number of hospitals was due to rural hospitals converting to Critical Access Hospital status.

Predicted 30-day mortality was used for risk adjustment in the multivariate analysis. It was measured using the fitted values from a logistic regression of observed 30-day mortality on patient age and dummy variables reflecting gender, race, admission type (i.e., emergency, urgent, or elective), admission source (i.e., ER; Clinic referral, HMO referral, or other), three-digit ICD9 diagnosis code, and the rank order of index admission if there were multiple admissions in previous 180 days to control for previous utilization. The coefficients from the logistic regression were estimated using out-of-sample data (1999 and 2003). These coefficients were used to predict 30-day mortality with sample data.

Submitted charges from each revenue center were converted to costs with cost-center-specific cost-to-charge ratios from HCRIS. Hospital-level cost-to-charge ratios were used either if a revenue center did not have an equivalent cost center or a hospital did not report cost-center-specific cost-to-charge ratios. Cost-to-charge ratios at about 90 hospitals experienced more than a 50 percent change in cost-to-ratio from 1 year to the next. These changes were larger than what could reasonably be expected in practice. We smoothed the cost-to-charge ratios of all hospitals by taking the 3-year average using data from 1 year before and 1 year after each sample year to lessen the effect of large transitory changes in cost-to-charge ratios. The cost of a hospital stay was computed as the sum of all costs incurred during the stay. Markups are measured by subtracting the cost of the stay from the allowed charge and dividing this term by the cost. The national average markup for each service

line in each year is used in the analysis. Allowed charges include DRG-based reimbursement plus adjustments for disproportionate share, graduate medical education, outlier reimbursements, and regional wages. Average service line markups were also calculated annually for urban and rural hospitals for each service line. Lagged total hospital margins were calculated for each hospital by dividing net patient revenue plus investment income minus patient care expenses by patient care expenses for the year prior to the year of patient discharge data being examined. We defined total margin quartiles using cutoffs based on 1996–2004 data.

EMPIRICAL METHODS

Our analytic approach relies on variability across 21 major hospital service lines in changes in reimbursement generosity over time. Service lines without large reduction in reimbursement generosity service as a control for service lines that experienced large changes. This approach is analogous to a difference in difference type specification where the treatment is a change in service line reimbursement generosity. Reimbursement generosity is defined as the markup of average reimbursement over average costs:

$$\text{Markup}_{st} = \frac{\text{Reimbursement}_{st}}{\text{Cost}_{st}} \quad (1)$$

where the subscripts s and t denote service line and time, respectively. Note that this measure does not vary by hospital; rather, it reflects the national average of reimbursement and costs for each service line in each time period due to concerns that a hospital-specific measure would be endogenous. Under this definition, a policy that increases reimbursement at the same rate as costs will not affect reimbursement generosity. Reimbursement generosity is reduced if reimbursement is lowered relative to costs or costs increase at a greater rate than reimbursement. As discussed earlier, providers as a whole are predicted to reduce costs in the face of lowered reimbursement. Thus, reimbursement generosity measures the net effect of lowered reimbursement on the average profitability of a service line. There may also be secular changes in input costs over time, driven by technological change and unrelated to provider behavior, that are thus accounted for. We make the assumption that the national average of the service line-specific markup is exogenous, conditional upon hospital service line-fixed effects and service line-specific time trends.

There were substantial changes in Medicare reimbursement policy due to the Balanced Budget Act (BBA), its subsequent refinements, and the Medicare Modernization Act. Reductions in the general level of reimbursement related to these acts caused the average admission in several service lines to switch from profitable to unprofitable. An additional source of across service line variation in changes in profitability came from changes in diagnosis-related group (DRG) weights, the introduction of new DRGs, changes reimbursement for transfers, and changes in outlier reimbursements.

Specification

The probability of mortality within 30 days was modeled as a function of service line markups, service line markups interacted with the hospital's 1997 Medicare share of inpatient days, predicted 30-day mortality as a patient risk adjuster, service line-specific time trends, and hospital service line and year-fixed effects. Markup and markup*Medicare share interaction coefficients measure the effect of reimbursement generosity on mortality. Service line-specific time trends were included to control for secular, unmeasured trends in treatment patterns that could differentially affect mortality in each service line. Year-fixed effects control for secular, unmeasured trends that affect mortality in all service lines. Hospital*service line-fixed effects control for all time-invariant characteristics that may differ among hospitals and among service lines, such as baseline mortality rates. In effect, our specification treats service lines that experienced little variation in reimbursement generosity as a control for service lines that experienced large amount of variation during the sample period. We hold Medicare share constant at 1997 levels because a hospital's behavioral response to changes in reimbursement may include a change in the Medicare share. For example, if a hospital were to lower quality between 1997 and 2001, then the Medicare share in 2001 may be significantly lower. However, the higher 1997 share is what would have spurred the behavioral response.

The main equation was estimated at the patient level using the full sample of discharges and separately for subsamples of discharges from urban hospitals stratified by lagged total margin quartiles to examine whether effects depended on a hospital's overall financial strength.¹ Margins were calculated using the following equation: $\text{Margin} = (\text{Net Patient Income} + \text{Investment Inc}) / \text{Net Patient Revenue}$.

Finally, we created a dummy variable that equaled one if the service line had a positive markup and zero otherwise. This dummy variable was interacted with markup to estimate whether service lines with positive markups

were more or less sensitive to changes in markups than service lines that were losing money. This enabled us to incorporate the potential for a differential effect depending upon the baseline profitability of a service into the policy simulations. We also estimate models that allow a hospital's response to vary by its profitability. However, we do not take into account the profitability of a hospital in our policy simulations because it would unlikely to be feasible (or wise) for Medicare to target individual hospitals for subsidies (Capps, Dranove, and Lindrooth 2010). We report Huber-White robust standard errors adjusted for clustering at the hospital/service line level associated with parameter estimates.

Policy Simulations

Using the coefficients from the econometric model, we first simulated the effect of the observed reduction in markups over the sample period. To do this, we calculated predicted 2005 mortality rates assuming reimbursement generosity was at 1997 levels and subtracted predicted 2005 mortality rates assuming reimbursement generosity was at the actual 2005 levels. We also simulated the differential effect for services that were profitable at baseline versus services that were unprofitable based on a specification with a dummy variable that equals one if a service was profitable (i.e., markup >0) and zero if it was unprofitable (i.e., markup <0). The dummy variable is interacted with the time-varying service line markup. The coefficient on this interaction term measures the differential effect of changes in reimbursement generosity of profitable versus unprofitable services. As we show in Table 1 below, all services were profitable in 1997 and by 2005 only about half remained profitable. The coefficients measure the differential effect of a service line moving from being profitable to being unprofitable and potentially being cross-subsidized by other services.

We also simulated the effect of three additional revenue-neutral policy scenarios and compared them with the simulation based on actual 1997–2005 changes. The scenarios place increasing burden of reduced reimbursement on profitable service lines while relaxing the burden on unprofitable service lines in a way that holds the discharge-weighted average reduction in markup constant. To do this, first we assume a maximum allowable markup. Then, given the maximum markup, we increase the minimum markup until the discharge-weighted average reduction in markup is equal to the observed. The first scenario assumes a maximum markup of 0.10, which implies a minimum markup of -0.037 under revenue neutrality. The second scenario caps markups at 0.05, and a minimum markup of -0.0042 is implied under revenue neutrality.

Table 1: Medicare Markups and Unadjusted 30-day Mortality Rates, by Service Line

	Medicare Markup [†]				Unadjusted 30-day Mortality				# Discharges
	1997	2001	2005	Change [‡]	1997	2001	2005	Change [‡]	
Surgical orthopedics	0.243	0.086	-0.046	-0.290*	0.023	0.021	0.017	-0.006*	1,657,663
Cardiovascular surgery	0.373	0.269	0.107	-0.266*	0.051	0.045	0.039	-0.013*	285,258
General surgery	0.335	0.227	0.086	-0.249*	0.066	0.061	0.059	-0.007*	1,344,890
Neurosurgery	0.327	0.243	0.080	-0.247*	0.045	0.044	0.045	0.000	283,607
Thoracic surgery	0.375	0.283	0.137	-0.238*	0.106	0.104	0.097	-0.009*	167,898
Vascular surgery	0.289	0.185	0.056	-0.232*	0.086	0.077	0.068	-0.019*	379,462
Hematology	0.259	0.153	0.030	-0.230*	0.077	0.071	0.065	-0.013*	174,511
Pulmonology	0.209	0.088	-0.017	-0.226*	0.122	0.120	0.104	-0.017*	2,364,083
General medicine	0.213	0.088	-0.002	-0.215*	0.118	0.111	0.131	0.012*	745,356
Urology	0.243	0.176	0.036	-0.207*	0.017	0.018	0.019	0.002*	449,785
Psychiatry	0.054	-0.068	-0.149	-0.203*	0.036	0.039	0.035	-0.001	128,627
All Discharges	0.206	0.112	0.010	-0.196*	0.079	0.074	0.069	-0.011*	17,238,641
Gynecology	0.193	0.138	0.004	-0.189*	0.009	0.009	0.009	0.000	235,090
Medical orthopedics	0.113	-0.018	-0.074	-0.187*	0.058	0.060	0.059	0.000	449,764
Endocrine	0.165	0.045	-0.015	-0.181*	0.090	0.090	0.076	-0.014*	562,080
Oncology	0.226	0.153	0.046	-0.179*	0.293	0.306	0.306	0.013*	402,669
Nephrology	0.167	0.054	-0.008	-0.176*	0.097	0.100	0.091	-0.006*	588,644
Invasive cardiology	0.309	0.315	0.139	-0.170*	0.019	0.017	0.014	-0.005*	1,030,647
Gastroenterology	0.159	0.074	-0.006	-0.165*	0.052	0.051	0.047	-0.003*	1,521,025
Otolaryngology	0.143	0.080	-0.015	-0.158*	0.014	0.014	0.015	0.001	139,987
Cardiology	0.141	0.071	-0.005	-0.146*	0.078	0.069	0.066	-0.012*	3,155,906
Neurology	0.115	0.028	-0.018	-0.133*	0.107	0.104	0.102	-0.005*	1,171,689

* $p \leq .01$.

[†]National average markup of each service line and year, where Medicare Markup = (Reimbursement-Cost)/Cost.

[‡]Difference between the 2005 and 1997 levels.

Source: Authors calculations using MEDPAR and Medicare Cost Reports (1997–2005).

The third scenario sets markups at all service lines at 0.010. These three scenarios highlight the relationship between the profitability of a service line and the sensitivity of mortality to reimbursement cuts. The standard errors of the simulations are based on a statistical bootstrap with service line clustering. We highlight the statistical significance of the estimated coefficients based on a two-sided test statistics in all analyses only if the p -value is less than .001 because of our extremely large sample.

RESULTS

Table 1 displays the average Medicare markups and unadjusted 30-day mortality by service line in 1997, 2001, and 2005. The service lines are sorted in ascending order by the 1997–2005 change in markup. There were consistent declines in markups across all service lines during this time period. Overall, the decline in markups was larger than average for service lines that provide procedural interventions, with some reductions being as large as 27 percentage points.

The results of the regression analysis of 30-day mortality in Table 2 reveal that a decrease in the generosity of reimbursement, measured by markup, is related to increased mortality. The coefficient on the markup, markup*Medicare share interaction, and the combined effect for the average hospital are negative and significant in the sample of all hospitals and urban hospitals.

Table 3 presents the results of the specification that included a *positive markup* interaction using a dummy variable that equaled 1 if markups were positive for that service line and zero otherwise. The results show that quality in profitable service lines was less sensitive to changes in markup overall. Furthermore, the offsetting effect of positive markups is only significant at hospitals with margins in the top two margin quartiles, which measure the hospitals that have the potential to cross-subsidize quality in unprofitable services. The effect of markups at hospitals in the lower two quartiles of profitability is not statistically significant, regardless of service line profitability.

The policy simulations appear in Table 4. The first scenario based on actual changes in markup reveals about a 2 percentage-point reduction in the mortality rate, which translates to about 100,000 deaths nationally. The next scenarios take advantage of the lower sensitivity of mortality to changes in markups at service lines with positive markups reported in Table 3. Each successive simulation redistributes an increasing amount of reimbursement from

Table 2: Analysis of the Effect of Markups on 30-day Mortality Rates

	Coefficient on Medicare Markup	Coefficient on Medicare Markup * Medicare Share Interaction	Combined Effect on Mortality at Average Medicare Share [†]	Simulated Effect of 1997–2005 Declines in Markup on Mortality [‡]
All hospitals	−0.055*	−0.0301*	−0.071*	0.0139*
All urban hospitals	−0.031*	−0.030*	−0.046*	0.0100*
Lagged total margin Less than −0.093	−0.032 ($p = .116$)	−0.022 ($p = .460$)	−0.043 ($p = .015$)	0.0094 ($p = .015$)
Between −0.092 and −0.007	−0.025 ($p = .122$)	−0.032 ($p = .133$)	−0.041 ($p = .002$)	0.0089 ($p = .002$)
Between −0.006 and 0.053	−0.061*	0.015 ($p = .389$)	−0.053*	0.0115*
Greater than 0.053	−0.018 ($p = .150$)	−0.056 ($p = .002$)	−0.046*	0.0101*

Note. Robust standard errors with hospital service line clustering were used for hypothesis tests.

* $p \leq .001$.

[†] $(\beta_1 + \beta_2 * \text{Medicare Share})$.

[‡] $(\beta_1 + \beta_2 * \text{Medicare Share}) * \Delta \text{Markup}$.

Source. Authors estimates using an ordinary least-squares regression controlling for predicted mortality; service line time trends; year-fixed effects; and hospital service line-fixed effects.

profitable service lines to unprofitable service lines. A switch to more equitable reimbursement across service lines has the potential to reduce the effect of the overall cut in reimbursement on mortality by 0.004 points. The estimate of number of deaths that could be prevented can be calculated by subtracting the number of deaths from the baseline policy from the number of deaths in alternative policies. Thus, the potential reduction in mortality from more equitable reductions ranges from 12,902 annual deaths at the high end with redistribution resulting in equal markups to 707 deaths with a small redistribution of payment generosity. The high-end estimate is likely an overestimate because it simulates significantly larger reductions in payment of profitable service lines than what occurred in practice.

DISCUSSION

We find that decreases in Medicare service line reimbursement markups between 1997 and 2005 were associated with statistically significant increases in risk-adjusted 30-day mortality. The previous literature evaluating the

Table 3: Ordinary Least-Squares Coefficients from Analysis of the Effect of Markups and Service Line Profitability on 30-day Mortality Rates

	<i>Medicare Markup</i>	<i>Medicare Markup * Medicare Share Interaction</i>	<i>Medicare Markup * Positive Markup[†] Interaction</i>	<i>Positive Markup[†] Dummy Variable</i>
Change in 30-day mortality at urban hospitals	-0.215*	-0.030*	0.159*	0.002 (<i>p</i> = .013)
By lagged total margin				
Less than -0.093	-0.194 (<i>p</i> = .146)	-0.022 (<i>p</i> = .464)	0.137 (<i>p</i> = .226)	0.001 (<i>p</i> = .777)
Between -0.092 and -0.007	-0.084 (<i>p</i> = .364)	-0.032 (<i>p</i> = .133)	0.055 (<i>p</i> = .478)	0.002 (<i>p</i> = .315)
Between -0.006 and 0.053	-0.279*	0.015 (<i>p</i> = .388)	0.183 (<i>p</i> = .007)	0.000 (<i>p</i> = .801)
Greater than 0.053	-0.327*	-0.056 (<i>p</i> = .002)	0.262*	0.001 (<i>p</i> = .388)

Note. **p* ≤ .001.
[†]Positive markup = 1 if markup >0, which was the case for cardiovascular surgery, general surgery, gynecology, hematology, invasive cardiology, neurosurgery, oncology, thoracic surgery, urology, and vascular surgery.
Positive markup = 0 for cardiology, endocrine, gastroenterology, general medicine, medical orthopedics, nephrology, neurology, otolaryngology, psychiatry, pulmonology, and surgical orthopedics.
Source: Authors estimates using an ordinary least-squares regression controlling for predicted mortality, service line time trends, year-fixed effects, and hospital service line-fixed effects. Robust standard errors with hospital service line clustering were used for hypothesis tests.

impact of changes in hospital reimbursement on quality has primarily focused on treatment of acute myocardial infarction, which, as a cardiac condition that often involves procedures, has historically been relatively profitable. We find that the relationship between markups and mortality was stronger within unprofitable services lines than within profitable service lines, implying that results based solely on cardiac patients may not be generalizable to less profitable service lines. This differential likely reflects continued quality competition for patients in profitable service lines despite reductions in service line markups. At the same time, the increased sensitivity of mortality to reimbursement changes within unprofitable services lines at profitable hospitals is consistent with cross-subsidization of quality by profitable hospitals. In other words, as hospitals' margins have shrunk, their ability to subsidize the quality of unprofitable service lines also declined.

The policy simulations revealed that the effect of reimbursement cuts on mortality can be reduced if the burden of a cut in reimbursement is

Table 4: Policy Simulations of the Effect of Revenue-Neutral Changes in Markups on 30-day Mortality Rates and Deaths

	<i>All Service Lines</i>	<i>Profitable Service Lines</i>	<i>Unprofitable Service Lines</i>
Actual 1997–2005 change $-0.149 \geq \text{markup} \leq 0.139$	0.0194* (101,094)	0.0179*	0.0204*
Policy simulations			
Redistribution of payment from service lines with markups >0.10 to unprofitable service lines [†]	0.0193* (100,387)	0.0188*	0.0196*
Redistribution of payment from service lines with markups >0.05 to unprofitable service lines [‡]	0.0170* (88,462)	0.0208*	0.0144*
Markup = 0.010 at all service lines	0.0169* (88,192)	N/A	N/A

Note. Simulations using parameter estimates of all urban hospital sample in Table 4.

Implied number of deaths in parentheses.

* $p \leq .001$ based on bootstrapped standard errors with hospital service line clustering.

[†]Results in: $-0.037 \geq \text{markup} \leq 0.100$.

[‡]Results in: $-0.0042 \geq \text{markup} \leq 0.05$.

redistributed from unprofitable to profitable service lines. The simulations did not allow the underlying behavioral response to vary based on the alternative policies, which implies that the results become less realistic as the assumptions of the policy scenarios depart from the actual policy. This is a problem inherent in static policy simulations.

Our analysis is also limited by the fact that we cannot measure the underlying mechanism that relates service line markups and 30-day mortality. Note that the service lines that became unprofitable in 2005 were much more likely to be medical service lines. It may be that quality in medical service lines is more sensitive to a number of hospital administrative decisions about variable inputs that are related to profitability and quality, such as nurse staffing levels and skill-mix, the use of ancillary services and tests, and caseloads for health care providers. In contrast, quality in surgical service lines may rely more on skill and other fixed cost inputs that yield benefits in subsequent periods and are unlikely to deteriorate in the short run. For example, inputs that have a longer lasting effect on quality, such as quality improvement initiatives, training, and the acquisition of new technology predominately related to fixed costs that have already been incurred. Rather, hospital administrative

decisions regarding future investments may be affected by reimbursement, which would be detrimental to quality in the long run.

The estimates are generally consistent with the few studies that examined the effect of reimbursement changes using variation across a variety of conditions over time from earlier time periods, with a few exceptions. Within the context of Medicare's shift to prospective reimbursement during the 1980s, there is evidence that reductions in average reimbursement led to an increase in 30-day mortality but not longer term mortality (Cutler 1995). More recent research in the context of the BBA found that neither AMI processes of care nor outcomes for AMI and three other medical conditions worsened among patients at financially stressed hospitals (Volpp et al. 2005a,b). Another study showed that reductions in average Medicare reimbursement related to the BBA led to lower inpatient treatment intensity only for the most severely ill patients with conditions that were relatively generously reimbursed, implying a minimum quality threshold, but that changes in treatment intensity related to changes in aggregate reimbursement were larger for more profitable conditions (Lindrooth and Weisbrod 2007). A recent study found that reduced hospital cash flow, rather than total hospital margins, predicted poor performance on in-hospital mortality in low-mortality DRGs and patient safety measures (Bazzoli et al. 2008). Finally, a related study using the same identification strategy found that changes in service line level markups over time did not affect 30-day readmission rates (Navathe et al. 2012).

If Medicare's Hospital Compare and Value-based Purchasing initiatives are implemented in a zero-sum fashion where high performers receive higher reimbursements at the expense of low performers, then our results suggest that the overall effect of value-based purchasing on 30-day mortality will be uncertain. The incremental improvement among high performers may not be great enough to offset the reduction in quality at low performers. At the same time, we found that the effect of reduced reimbursement is relatively small at hospitals with negative margins, suggestive of a minimally acceptable quality level. This asymmetry suggests a potential for net reductions in 30-day mortality, even if it is funded as a zero-sum game. The introduction of MS-DRGs increased the link between costs and reimbursement and diminished the incentive to shirk on quality, although at the expense of lowered incentives to reduce cost. The role of service line profitability in determining the potential consequences of reductions in reimbursement must be taken into account as Medicare struggles to find the appropriate balance of cost containment and quality as health reform is implemented.

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NOTE

1. As part of a sensitivity analysis we found that our main results were robust to alternative specifications of contemporaneous trends (i.e., no service line-specific trend or quadratic service line-specific trend) or use of hospital and service line rather than hospital*service line-fixed effects. We also tested whether the effect varied by ownership, reflecting different nonfinancial goals tied to mission, and by urban versus rural location due to reimbursement policies that specifically targeted rural hospitals as well as different specifications. From a policy simulation perspective the results were robust to alternative specifications.

REFERENCES

- Arrow, K. J. 1963. "Uncertainty and the Welfare Economics of Medical Care." *American Economic Review* 53: 941–73.
- Bazzoli, G. J., H. Chen, M. Zhou, and R. C. Lindrooth. 2008. "Hospital Financial Condition and the Quality of Patient Care." *Health Economics* 17 (8): 977–95.
- Capps, C., D. Dranove, and R. C. Lindrooth. 2010. "Hospital Closure and Economic Efficiency." *Journal of Health Economics* 29 (1): 87–109.
- Chernew, M., G. Gowrisankaran, and A. M. Fendrick. 2002. "Payer Type and the Returns to Bypass Surgery: Evidence from Hospital Entry Behavior." *Journal of Health Economics* 21: 451–74.
- Consortium, M. H. D. 2011. [accessed on May 2, 2011]. Available at <http://mahealth-data.org/Resources/Documents/data/FY2007CmsDrugsBySubspecialty.pdf>
- Cutler, D. 1995. "The Incidence of Adverse Medical Outcomes under Prospective Payment." *Econometrica* 63 (1): 29–50.
- Cutler, D. M., R. S. Ilickman, and M. B. Landrum. 2004. "The Role of Information in Medical Markets: An Analysis of Publicly Reported Outcomes in Cardiac Surgery." *American Economic Review* 94 (2): 342–6.
- David, G., R. C. Lindrooth, L. A. Helchem, and L. R. Burns. 2011. "Do Hospitals Cross Subsidize?" NBER Working Papers 17300.

- Dranove, D. 1988. "Pricing by Non-profit Institutions: The Case of Hospital Cost-shifting." *Journal of Health Economics* 7 (1): 47–57.
- Dranove, D., and M. A. Satterthwaite. 1992. "Monopolistic Competition When Price and Quality Are Imperfectly Observable." *The RAND Journal of Economics* 23 (4): 518–34.
- Dranove, D., and A. Sfeekas. 2008. "Start Spreading the News: A Structural Estimate of the Effects of New York Hospital Report Cards." *Journal of Health Economics* 27 (5): 1201–7.
- Ellis, R. P. 1998. "Creaming, Skimping and Dumping: Provider Competition on the Intensive and Extensive Margins." *Journal of Health Economics* 17 (5): 537–55.
- Frank, R. G., J. Glazer, and T. G. McGuire. 2000. "Measuring Adverse Selection in Managed Health Care." *Journal of Health Economics* 19 (6): 829–54.
- Glazer, J., and T. G. McGuire. 2002. "Multiple Payers, Commonality and Free-riding in Health Care: Medicare and Private Payers." *Journal of Health Economics* 21 (6): 1049–69.
- Gowrisankaran, G., and R. Town. 2003. "Competition, Payers, and Hospital Quality." *Health Services Research* 38 (6): 1403–22.
- Hodgkin, D., and T. G. McGuire. 1994. "Payment Levels and Hospital Response to Prospective Payment." *Journal of Health Economics* 13 (1): 1–29.
- Jung, K., R. Feldman, and D. Scanlon. 2011. "Where Would You Go for Your Next Hospitalization?" *Journal of Health Economics* 30 (4): 832–41.
- Kessler, D. P., and M. B. McClellan. 2000. "Is Hospital Competition Socially Wasteful?" *Quarterly Journal of Economics* 115 (2): 577–615.
- Kolstad, J. T., and M. E. Chernew. 2009. "Quality and Consumer Decision Making in the Market for Health Insurance and Health Care Services." *Medical Care Research and Review* 66 (1 suppl): 28S–52S.
- Lindrooth, R. C., G. Bazzoli, and J. Clement. 2007. "The Effect of Reimbursement on the Intensity of Hospital Services." *Southern Economic Journal* 73 (3): 575–87.
- Lindrooth, R. C., and B. A. Weisbrod. 2007. "Do Nonprofit and For-profit Hospices Really Differ? An Analysis of the Hospice Industry." *Journal of Health Economics* 26 (2): 342–57.
- Luft, H. S., D. W. Garnick, D. H. Mark, D. J. Peltzman, C. S. Phibbs, E. Lichtenberg, and S. J. McPhee. 1990. "Does Quality Influence Choice of Hospital?" *Journal of the American Medical Association* 263 (21): 2899–906.
- McClellan, M. 1997. "Hospital Reimbursement Incentives: An Empirical Analysis." *Journal of Economics and Management Strategy* 6: 91–128.
- Meltzer, D., J. Chung, and A. Basu. 2002. "Does Competition under Medicare Prospective Payment Selectively Reduce Expenditures on High-cost Patients?" *RAND Journal of Economics* 33: 447–68.
- Navathe, A. S., K. G. Volpp, R. T. Konetzka, M. J. Press, J. Zhu, W. Chen, and R. C. Lindrooth. 2012. "A Longitudinal Analysis of the Impact of Hospital Service Line Profitability on the Likelihood of Readmission." *Medical Care Research and Review* 69 (4): 414–31.
- Newhouse, J. P. 1996. "Reimbursing Health Plans and Health Providers: Efficiency in Production versus Selection." *Journal of Economic Literature* 34 (3): 1236–63.

- Scanlon, D. P., R. C. Lindrooth, and J. B. Christianson. 2008. "Steering Patients to Safer Hospitals? The Effect of a Tiered Hospital Network on Hospital Admissions." *Health Services Research* 43 (5p2): 1849–68.
- Schreyögg, J., and T. Stargardt. 2010. "The Trade-Off between Costs and Outcomes: The Case of Acute Myocardial Infarction." *Health Services Research* 45 (6): 1585–601.
- Shen, Y. C. 2003. "The Effect of Financial Pressure on the Quality of Care in Hospitals." *Journal of Health Economics* 22 (2): 243–69.
- Sinaiko, A. D. 2011. "How Do Quality Information and Cost Affect Patient Choice of Provider in a Tiered Network Setting? Results from a Survey." *Health Services Research* 46 (2): 437–56.
- Volpp, K. G., J. D. Ketcham, A. J. Epstein, and S. V. Williams. 2005a. "The Effects of Price Competition and Reduced Subsidies for Uncompensated Care on Hospital Mortality." *Health Services Research* 40 (4): 1056–77.
- Volpp, K. G., R. T. Konetzka, J. Zhu, L. Parsons, and E. Peterson. 2005b. "Effect of Cuts in Medicare Reimbursement on Process and Outcome of Care for Acute Myocardial Infarction Patients." *Circulation* 112 (15): 2268–75.
- Wang, J., J. Hockenberry, S.-Y. Chou, and M. Yang. 2011. "Do Bad Report Cards Have Consequences? Impacts of Publicly Reported Provider Quality Information on the CABG Market in Pennsylvania." *Journal of Health Economics* 30 (2): 392–407.
- Weisbrod, B. A. 1989. "Rewarding Performance That Is Hard to Measure – The Private Nonprofit Sector." *Science* 244 (4904): 541–6.
- Werner, R. M., E. C. Norton, R. T. Konetzka, and D. Polsky. 2012. "Do Consumers Respond to Publicly Reported Quality Information? Evidence from Nursing Homes." *Journal of Health Economics* 31 (1): 50–61.

SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article:

- Appendix SA1: Author Matrix.
- Appendix SA2. Results of Sensitivity Analysis, Stratified by Hospital Ownership and Location.
- Appendix SA3. Results of Alternative Econometric Specifications.
- Appendix SA4: Ordinary Least Squares Estimates of the Effect of Mark-ups and Lagged Total Margins on 30-day Mortality Rates.