QUALITY AND VALUE MONITERING OF ACUTE-CARE HOSPITALS

Abstract: Rising medical costs is a real and imminent problem; as a major health care services provider, Medicare covers nearly 16% of the U.S. population. This paper aims to investigate factors that affect the cost and quality of acute care hospitals reimbursed by Medicare. Multiple datasets from the Center for Medicare and Medicaid Services and IRS were merged to evaluate the effect of hospital ownership and local socioeconomic levels on hospital performance, based on three main quality metrics: average cost per beneficiary, 30-day readmission rate, and hospital acquired conditions (HAC) score. Both variables were found to have statistically significant effects. In addition, the results showed that CMS policy may have unfairly penalized hospitals serving more vulnerable populations, by using a metric that did not consider hospital location in lower income neighborhoods.

BY GRACE DENG

LAYOUT BY KORE LUM, GABBY SHVARTSMAN, ALAA ABDELMAGEED

INTRODUCTION

The economist Paul Krugman once said that "the U.S. government is [...] best thought of as a giant insurance company with a standing army." In terms of federal spending, this claim does have some merit, since the bulk of government expenditure is on Medicare, Medicaid, Social Security, and defense. In 2011, the total US population was approximately 311.7 million, 48.7 million of which were covered by Medicare. Furthermore, the Center for Medicare and Medicaid Services reported a 5.3% increase in national health expenditure in 2014, which amounts to $9,523 per person and a total of $3.0 trillion dollars, making up 17.5% of Gross Domestic Product (CMS, 2016). The problem of rising healthcare costs is exacerbated by parallel growth in out-of-pocket spending, hospital expenditures, physician and clinical services expenditures, and prescription drug spending. The extra costs not covered by Medicare or Medicaid will eventually fall onto and burden the patients.

Therefore, it has become very important to use quantitative metrics to evaluate the quality of care provided by hospitals and maximize the return on dollar spent. For example, encouraging lower readmission or complication rates could reduce the number of claims per patient paid for by Medicare and perhaps keep Medicare solvent for a longer period of time. Meanwhile, peer benchmarking in terms of medical procedure costs could encourage competition between local hospitals to keep prices low.

Traditional rankings or reviews of hospitals and physicians are often based on subjective reviews; for example, reviews on Yelp are written by previous or current patients. However, these reviews are composed more of comments on how friendly the staff was or how patient the doctor was, but does not include objective measures such as how effective the treatment prescribed by the physician was, how accurate the diagnosis was, how reasonable the cost was, etc. In addition, when patients are searching for a doctor or hospital through Google or a website like WebMD, they can filter through criteria such as location or specialty (pediatrician, neurologist, or cardiac surgeon), but are not presented with information on quality metrics such as 30-day readmission rates or Hospital Acquired Condition (HAC) scores.

There has been a joint effort between Medicare and the Hospital Quality Alliance (HQA), the first national public reporting system that provides performance data on each hospital, to promote reporting on hospital quality of care (Jha et al, 2005). As a result, many datasets on quality metrics and hospital comparison are available from Medicare.gov, and we can use descriptive statistics and models to objectively analyze value-of-care: measurable health outcomes per dollar spent (Porter, 2010). These stats could be further weighted by clinic demographics to avoid bias, since a clinic that accepts riskier patients may have a lower overall recovery rate. Furthermore, we can use statistical tests to evaluate whether policies enacted through the Center for Medicare and Medicaid Services (CMS)

and Affordable Care Act (Obamacare) are justified.
The goal of this research project is to explore the following questions:

1. Comparing cost per beneficiary and quality of care across different types of hospitals

In 2003, the largest proportion of acute care nonfederal hospitals is voluntary non-profit, at about 62% (Wikipedia, 2016). The next largest groups are government hospitals (20%) and for-profit (18%). Identifying which subgroups of hospitals provided better care (measured through variables such as 30-day readmission rates and HAC scores) could directly help two groups of people: policy makers who are deciding which types of hospitals to subsidize or penalize, and patients who are choosing a local hospital for short-term treatments.

2. Effect of socioeconomic status on average hospital cost

Although it is important to identify the "best" hospitals in terms of low cost and high quality care, these measurements are often affected by patient demographic variables. In addition, simple comparison of these measurements between hospital groups can lead to biased conclusions if socioeconomic status of patients is not taken into account. A model for predicting average hospital cost could prove useful for encouraging peer benchmarking, where more competition between similar hospitals can lead to better services at a lower price. By including the Income Per Capita variable in this model, matched to corresponding hospitals through zip code, we can observe if there is a statistically significant relationship between the two variables. If true, then perhaps hospitals can be evaluated against its "peers" that serve the same patient demographics, which will be more holistic and accurate than just comparison against a national average.

3. CMS payment reduction against low-performing hospitals

Effective on October 1, 2012, the CMS established the Hospital Readmission Reduction Program to record and monitor 30-day readmission rates for hospitals, as well as imposing a fine on payments to hospitals with excessive readmissions. The metric used to evaluate which hospitals should be fined is called Excess Readmission Ratio, which measures the ratio of predicted readmissions to expected readmissions. When the ratio exceeds 0.97, the CMS imposes a 3% reduction in payments to the hospital (CMS, 2016). However, there has also been arguments against the policy, which some claim will target "stand-alone hospitals that treat vulnerable patient populations" and force them to "join systems to help absorb the impact of financial cuts" (McKinney, 2012). Furthermore, the evaluation criterion does not take into account the socioeconomic status of the patients served by each hospital. Small, rural hospitals that are penalized and required to reduce readmissions often serve low-income and elderly patients that lack "community support mechanisms" and readmissions data collected from these hospitals may be biased from adverse selection. Hence, it could be worthwhile to split the dataset into two groups, Reduced Payment hospitals affected by the penalty and Full Payment hospitals not affected, and then compare if differences in average cost, income per capita, and HAC scores are statistically different.

4. CMS restrictions on physician operated hospitals

As part of the Affordable Care Act, the CMS "imposed additional requirements for physician-owned hospitals to qualify for the whole hospital and rural provider exceptions", which effectively banned the expansion of Physician Operated hospitals with very few exceptions (CMS, 2016). The motivation behind these restrictions stem mainly from research investigating the effectiveness of physician owned hospitals. For example, Congress's independent Medicare Payment Advisory Commission (MedPAC) found evidence that 48 physician-operated hospitals would take easier cases with healthier patients and higher paying medical procedures (Rau, 2015). However, it has been over a decade since that report, so it may be worth comparing if the differences in cost and quality measures between physician-operated hospitals and all other hospitals are still statistically significant.

DATA

Four datasets were downloaded from Data.Medicare.gov titled "Medicare Hospital Spending by Claim", "Hospital General Information", "Hospital-Acquired Condition Reduction Program", and "Hospital Readmissions Reduction Program". The datasets were then merged into a final dataset by Hospital ID, with a total of 2541 acute-care hospitals and 17 variables, including both quality-of-care measurements, hospital costs, and demographic variables for each hospital

It's important to note, however, that there may be a reporting bias in the dataset, since they are all hospitals that accept Medicare. This means the data is not necessarily representative of all hospitals in the United States. Nevertheless, since most of the hospitals listed are acute care hospitals, the results of this dataset could still be extrapolated to acute care and emergency centers.

In addition, we can assume that patients who filed claims from these hospitals are from a certain demographic group, since they are eligible and covered by Medicare. This means that the collected metrics for each hospital is comparable across hospitals and geographic locations. Due to the federal law Emergency Medical Treatment and Active Labor Act (EMTALA), which mandates that all emergency room patients must be offered care regardless of ability to pay, there may also be adverse selection in the hospital data. Patients who are more ill than the average person could be included in the data, since people who ordinarily cannot afford health care or physician visits may be brought into the emergency room. Inclusion of these data could possibly inflate the readmission rate, HAC score, or cost of medical procedures.

Because none of the datasets provided by Medicare.gov scale individual hospital data by the demographics of the

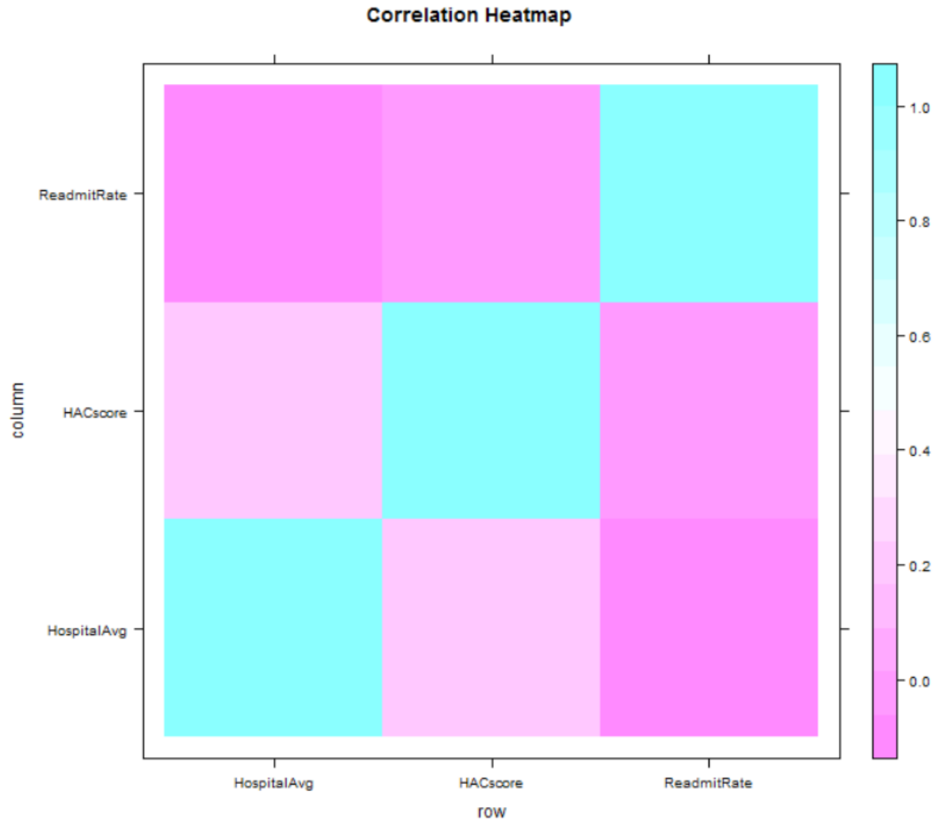


Figure 1: Correlation Heat Map

neighborhoods they serve, another variable was included in the analysis called Income by Zip Code. The data was downloaded from the IRS (Internal Revenue Service) website, and consists of 114 tax related variables for 27790 zip code areas for the year 2013. The variable chosen to represent income per capita by zip code was the Adjusted Gross Income (AGI). We can now match the zip code of each hospital's location with the corresponding AGI, and test if the socioeconomic status of the hospital's surrounding neighborhood affects the price and quality of care.

QUESTION 1 -- COST AND QUALITY ACROSS HOSPITAL TYPES

1. Correlation Heatmap:

The figure above shows the heatmap of the correlation matrix between Readmission Rate, HAC Score, and Hospital Avg (average cost per beneficiary per hospital). If we assume that higher costs by hospitals result in better quality care, we would expect a negative correlation between average cost per beneficiary and HAC score or readmission rates. However, the heatmap above shows that there is a very low positive correlation ($p = 0.167$) between Hospital Acquired Conditions (HAC) score and average cost per beneficiary, suggesting that hospitals that charge more does not necessarily have a low number of hospital complications (low HAC score). This could potentially indicate that when the CMS wishes to penalize hospitals with low-quality care, the HAC score is not necessarily a good reference measure.

2. Bubble Plots:

The bubble plot on the next page (see Figure 2) compares hospitals in each state across three factors: readmission rates, HAC scores, and average total cost per beneficiary claim (proportional to the area of each state's bubble). The intersecting red lines represent the average readmission rates and HAC scores across all the states, which also conveniently categorizes each state into a quadrant: the upper-right quadrant represents high readmission rate, high HAC score; the upper-left quadrant represents high readmission rate, low HAC score; the lower-right quadrant represents low readmission rate, high HAC score; and the lower-left quadrant represents low readmission rate, low HAC score. Lower readmission rates and HAC scores are more preferable, and a smaller sized circle represents a lower average cost compared to the national average. Based on these quadrants, indicators can be created for hospitals in states that are more preferable.

We can observe that there are some interesting outliers, such as Washington D.C. in the upper right quadrant, which suggests that hospitals in D.C. on average have higher readmission rates and higher number of hospital acquired conditions, as well as higher than average costs. Therefore, assuming that transportation is not a problem, patients in D.C. may find it more desirable to go to a hospital in Maryland or Virginia. (On the plot, we can see that Virginia scores nearly 2 points lower on

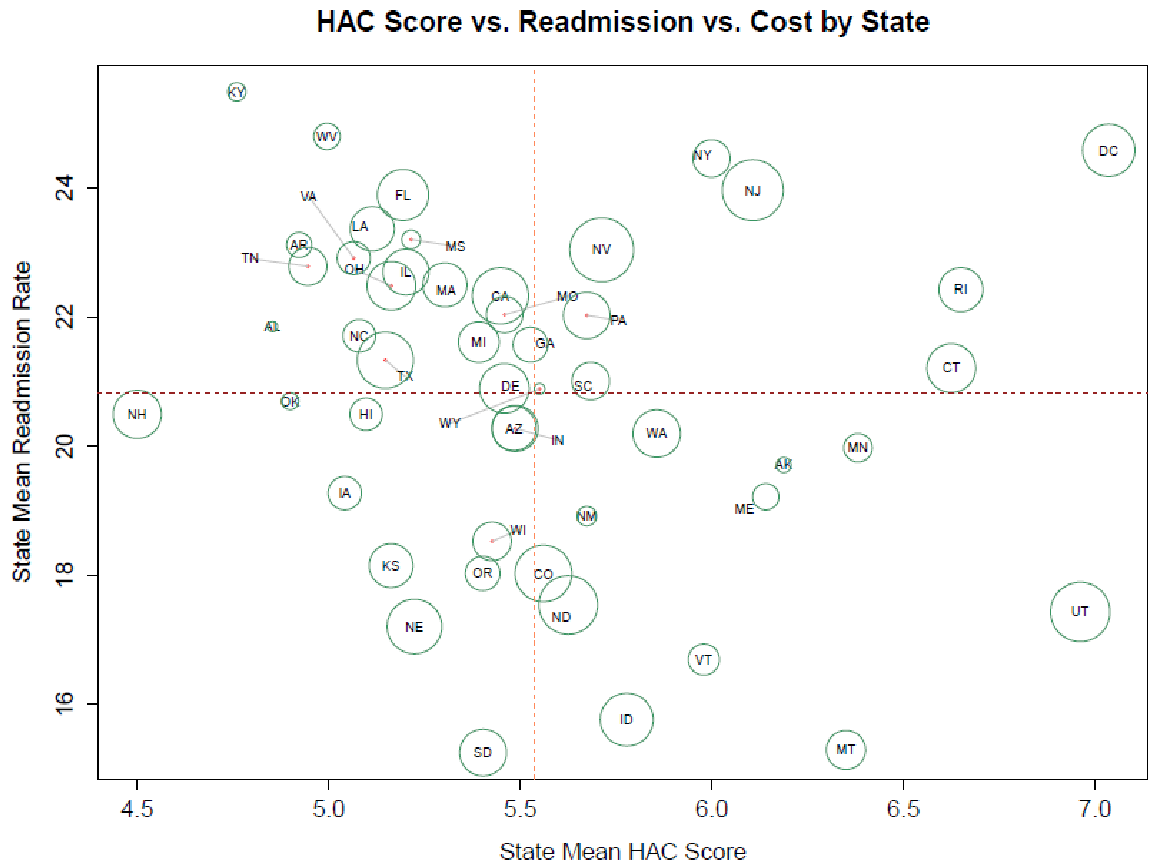


Figure 2: Bubble Plot by State

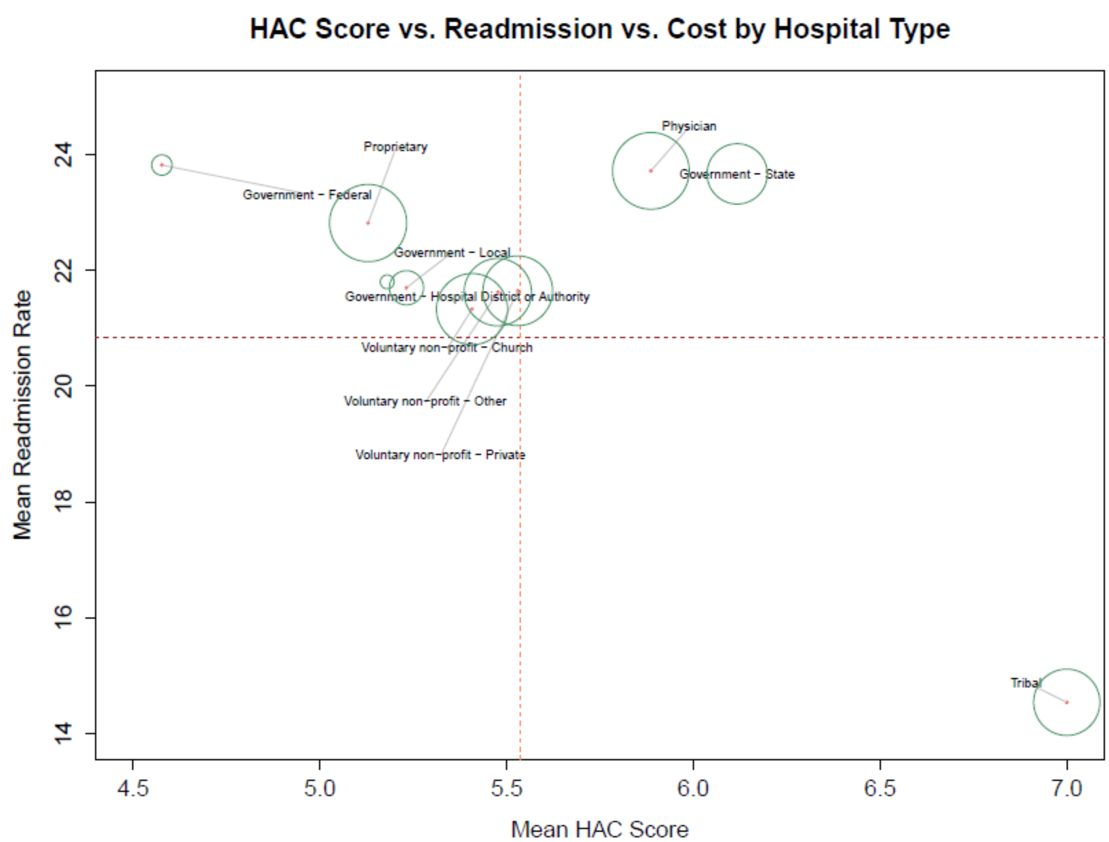
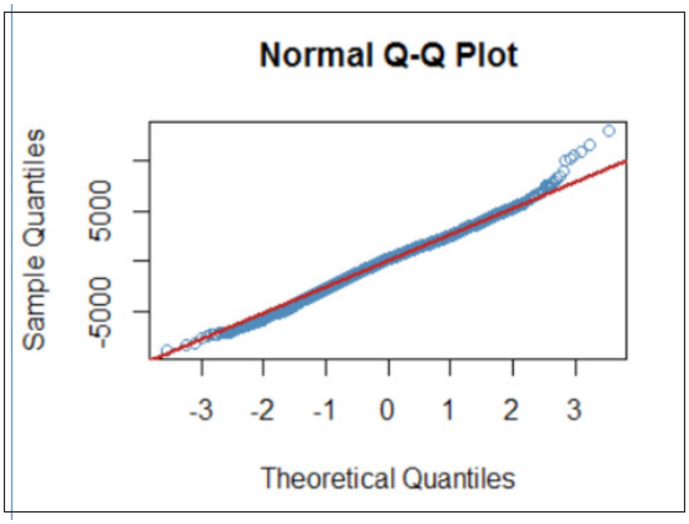


Figure 3: Bubble Plot by Hospital Type



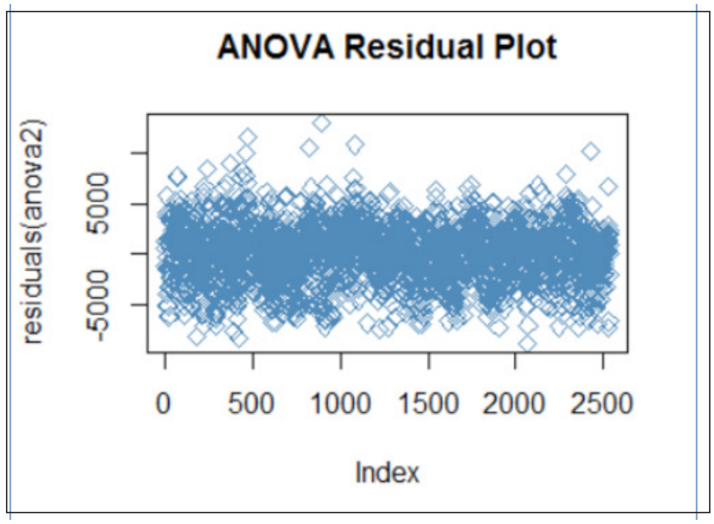


Figure 4: QQ and Scatter Plot of ANOVA Residuals

The bubble plot in Figure 3 compares hospitals in each hospital type across three factors: readmission rates, HAC scores, and average total cost per beneficiary claim which is proportional to the area of each state's bubble. We can see that at roughly the same average readmission rate, government operated hospitals charge less on average than proprietary or even most voluntary non-profit hospitals based on the size of corresponding bubbles. Although it seems reasonable that proprietary hospitals will charge more on average due to profit-seeking behavior, it is surprising that nonprofit hospitals' costs are similar in amount. To formally test if the cost differences between hospital types are statistically significant, a two-sample t-test will need to be performed.

An interesting outlier is the Tribunal hospitals, which has very low readmission rates but high HAC score. However, there was only one data point for hospitals under this type, so it is not very informative.

3. One-way ANOVA:

The Hospital Ownership variable in the dataset lists 10 different types of acute-care hospitals, which can be simplified and merged into 4 main categories: Government Operated, Non-profit, Proprietary, and Physician Operated. Tribunal hospitals were eliminated because there was only one data point. In this case, a one-way ANOVA can be performed to check if the different types of hospitals charge the same amount of money per beneficiary on average. The one-way ANOVA is more appropriate because it generalizes the two-sample t-test to multiple groups, and is also more conservative and reduces Type 1 error (Wikipedia, 2016).

To check whether the Normality and Constant Variance assumptions of one-way ANOVA have been met, a QQ plot and a scatter plot of the residuals were created. The residuals appear normally distributed, with a few outliers at the right tail. The residual plot shows mostly uniform random scatter centered about 0, with no discernible nonlinear shapes or a funnel shape that suggests heteroskedasticity, so we can also assume the errors are constant.

H0: The mean cost per beneficiary for different ownership types of acute-care hospitals is equal.
HA: The mean cost per beneficiary for different ownership types of acute-care hospitals is not all equal.
$\alpha = 0.05$

Analysis of Variance Table					
Response: Average Cost Per Beneficiary for Each Hospital					
	df	SS	MS	F-stat	p-value
Hospital Ownership	3	4.9593e+08	165311185	21.634	7.818e-14
Residuals	2536	1.9378e+10	7641154	-------	-------
	Government Operated	Nonprofit	Proprietary/ Profit	Physician Operated	Total
Group Means	$17720.73	$19008.77	$18907.09	$20152.09	$18757.17

Table 1: One-way ANOVA Hospital Ownership vs. Cost

Given a p-value of 7.818e-14, we reject the null hypothesis and conclude that different types of acute-care hospitals do not charge equally per beneficiary. Observing the group means for each type of hospital, it appears the Government Operated hospitals charge the lowest on average per beneficiary. In addition, Nonprofit hospitals cost higher on average than both Government Operated and For-Profit hospitals, which is surprising since a major argument for non-profit seeking hospitals is that they would have responsibilities as charities and serving the community instead of only focusing on financial stability. Intuitively, we would expect privately-owned profit-seeking hospitals to cost more per beneficiary, since previous research has shown that these hospitals attempt to specialize in more profitable services, such as open heart surgery, which are reimbursed at higher rates by insurance companies (Horwitz, 2005).
Whether these cost differences are statistically significant will require more specific comparisons (such as a two-sample t-test). Further investigation in how non-profit hospitals are operated financially may be needed to determine if this major subgroup of acute-care hospitals (64.3% of the dataset) is the best method of delivering high value-of-care.

QUESTION 2 -- EFFECT OF INCOME PER CAPITA ON AVERAGE HOSPITAL COST

To observe how average hospital cost is affected by Income Per Capita by Zip Code, a log-log OLS regression was performed. Quality metrics such as readmission rates and HAC scores were also included, as well as indicators to control for factors such as hospital ownership and whether the hospital offered emergency services.

From the regression output, it's easy to see that the coefficient for Income Per Capita is positive and statistically significant (p-value < 2e-16), meaning that as the average income in a neighborhood increased, so will the average cost charged by a hospital in that neighborhood. From an economic perspective, hospitals can afford to raise prices on high-earning population with more disposable income without losing too much demand. Although the model only explains 17.8% of the variation in average cost per beneficiary (adjusted R2 = 0.178), it is still useful in showing the significance of including socioeconomic status when analyzing hospital performance.

Due to the Emergency Medical Treatment and Active Labor Act, hospitals that provide emergency services are often accused of charging other patients high costs to balance out the patients who cannot afford to pay but must be

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Call:
lm(formula = log(HospitalAvg) ~ log(IncomePerCapita) + ReadmitRate +
    HACscore + StateIndicator + EM_Indicator + NonprofitIndicator +
    GovtIndicator + ProfitIndicator + PhysicianIndicator, data = newfinalDF)

Residuals:
     Min       1Q   Median       3Q      Max
-0.52775 -0.08829  0.00510  0.08614  0.50475

Coefficients:
                      Estimate Std. Error t value Pr(>|t|)
(Intercept)           8.685374   0.149412  58.130  < 2e-16 ***
log(IncomePerCapita)  0.065835   0.003367  19.550  < 2e-16 ***
ReadmitRate          -0.154141   0.066730  -2.310   0.0210 *
HACscore              0.011084   0.001477   7.507 8.34e-14 ***
StateIndicator1       0.006908   0.006844   1.009   0.3130
EM_Indicator1        -0.030629   0.022405  -1.367   0.1717
NonprofitIndicator1   0.276683   0.140741   1.966   0.0494 *
GovtIndicator1        0.228536   0.140850   1.623   0.1048
ProfitIndicator1      0.288156   0.140850   2.046   0.0409 *
PhysicianIndicator1   0.324351   0.146911   2.208   0.0273 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.1405 on 2531 degrees of freedom
Multiple R-squared:  0.1809, Adjusted R-squared:  0.178
F-statistic: 62.13 on 9 and 2531 DF,  p-value: < 2.2e-16
```

Figure 5: Regression Output

provided care under law. However, it is interesting to note that the Emergency Services Indicator coefficient is not statistically significant in the figure above, suggesting that hospitals with ER do not overcharge after controlling for other variables.

QUESTION 3 - CMS HOSPITAL READMISSION REDUCTION PROGRAM PENALTY

As part of the Hospital Readmission Reduction Program, the CMS imposes a 3% reduction in payments to hospitals that have excessive readmissions after surgeries such as heart failure and acute myocardial infarction. Because the metric used, Excess Readmission Ratio, does not weigh in factors such as socioeconomic status, we want to know if the penalty disproportionately affects hospitals that suffer from adverse selection and serving poorer neighborhoods.
Given that a hospital is penalized if its Excess Readmission Ratio exceeds 0.97, there are 1713 hospitals that receive reduced payments and 818 hospitals that receive full payments from Medicare in the dataset. We can start by comparing the average Income by Zip Code for the neighborhoods in the two hospital subgroups, Reduced Payment and Full Payment. In this case, a two-sample t-test is not appropriate because the histogram of Income by Zip Code is not normally distributed, as seen in the graph on the right.

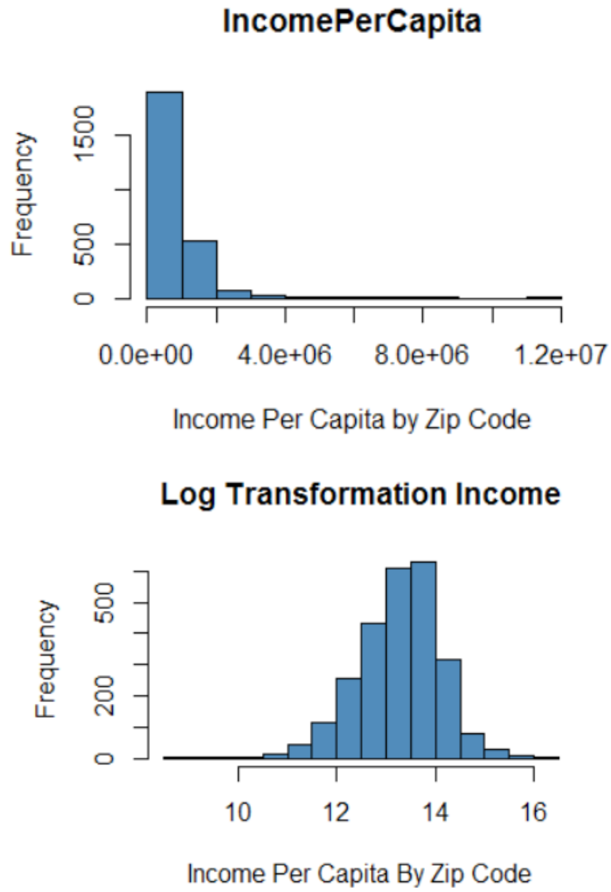

Figure 6: Histograms of Income Per

As an alternative, we can perform the Mann-Whitney U test, which does not require the normally distributed assumption and is almost as efficient as a two-sample t-test in the case of normal distributions. One of the assumptions for the Mann-Whitney test is that the observations in the two hospital groups are independent. It seems reasonable to claim that this assumption holds in our scenario, since the Income by Zip Code for each hospital and Excess Readmission Ratio, the measurement used to split up the dataset, should be independent. Therefore, the Reduced Payment and Full Payment hospital groups should not have been presorted into higher and lower income groups. To formally test for independence, the Pearson product-moment correlation coefficient was calculated to be 0.00449 , with a t-value of 0.2258 and p-value = 0.821. At a significance level of 5%, we fail to reject the null hypothesis, and there is evidence of no statistical dependence between the two variables.

With a p-value less than 0.05, we reject the null hypothesis and find evidence that hospitals penalized by the CMS serve neighborhoods with on average lower income per capita than those not penalized. This means that the payment reduction disproportionately affect hospitals which are located in poorer neighborhoods. Since people with more income tend to be able to afford health care before reaching age 65 (when people start qualifying for Medicare), the patients from richer neighborhoods tend to be healthier. A healthier patient demographic could artificially lower the number of readmissions and complications in hospitals serving high-income areas, granting these hospitals an advantage when the CMS penalty is evaluated by Excess Readmission Ratios.

Mann-Whitney U test: Reduced Payment vs. Full Payment Hospitals

H0: The neighborhood income distribution for Reduced Payment Hospitals and Full Payment Hospitals are equal.
HA: The neighborhood income distribution for Reduced Payment Hospitals has lower mean ranks (location shift is negative) than that of Full Payment Hospitals.
$\alpha = 0.05$

	t-statistic	df	p-value	95% CI	Equal Variance?
Hospital Avg Cost	1.1338	10	0.2832	(-1352.674, 4158.563)	False
Readmit Rate	1.3898	2539	0.1647	(-0.007442821, 0.043670607)	True
HAC score	0.927	2539	0.354	(-0.5942919, 1.6599045)	True

Table 2: Mann-Whitney

With a p-value less than 0.05, we reject the null hypothesis and find evidence that hospitals penalized by the CMS serve neighborhoods with on average lower income per capita than those not penalized. This means that the payment reduction disproportionately affect hospitals which are located in poorer neighborhoods. Since people with more income tend to be able to afford health care before reaching age 65 (when people start qualifying for Medicare), the patients from richer neighborhoods tend to be healthier. A healthier patient demographic could artificially lower the number of readmissions and complications in hospitals serving high-income areas, granting these hospitals an advantage when the CMS penalty is evaluated by Excess Readmission Ratios.

Two Sample t-tests: Reduced Payment vs. Full Payment Hospitals

H0: The true difference in means between Reduced Payment and Full Payment hospitals is 0.
HA: The true difference in means between Reduced Payment and Full Payment hospitals is less than 0.
$\alpha = 0.05$

In the first t-test, we reject the null hypothesis with a p-value of 0.004552 and conclude that the average cost per beneficiary is lower in Reduced Payment hospitals compared to that of Full Payment hospitals. In the second t-test, we fail to reject the null hypothesis with a p-value of 0.7991 and find evidence that there is no significant difference between HAC scores of Reduced Payment hospitals compared to that of Full Payment hospitals.

These two results combined with that from the Mann-Whitney test on neighborhood income, shed some interesting light on the CMS Hospital Readmission Reduction Program. First, hospitals affected by payment reductions are at a disadvantage in the evaluation process because they serve lower income neighborhoods with patient demographic that potentially have less access to health care over their lifetime and are less healthy overall than their counterparts in higher-earning neighborhoods. At the same time, these Reduced Payment hospitals charge less per beneficiary on average compared to Full Payment hospitals, and combined with payment reductions from Medicare, results in even less overall revenue. Reduced income to these hospitals could prevent hiring of more physicians and medical staff, upgrading of medical equipment, and expanding of facilities to better serve more patients.

Finally, because the Excess Readmission Ratio is only one of many hospital quality metrics, it is worth considering whether the penalty can be justified by comparing another metric between the two hospitals groups, such as HAC scores. However, the difference in hospital acquired conditions between the penalized and non-penalized hospitals is not statistically significant. Overall, the CMS should consider reweighing the Excess Readmission Ratio by demographic and socioeconomic factors, or using a more holistic evaluation process to identify low-performance hospitals and to encourage readmission rate reductions.

QUESTION 4 -- CMS RESTRICTIONS ON EXPANSION OF PHYSICIAN-OPERATED HOSPITALS

Two Sample t-tests: Physician Hospitals vs. All Other Acute-Care Hospitals

H0: The true difference in means between Physician operated hospitals compared to all other hospitals is 0.
HA: The true difference in means between Physician operated hospitals compared to all other hospitals is not equal to 0.
$\alpha = 0.05$

From the table above, we can compare whether there is a significant difference between the average cost and quality of physician operated hospitals versus other types of hospitals. It is important to note that the data was not sampled randomly since

	t-statistic	df	p-value	95% CI	Equal Variance?
Hospital Avg Cost	-2.8409	1705	0.004552	(-555.2740, -101.6981)	False
HAC score	-0.2546	2529	0.7991	(-0.1790679, 0.1379121)	True

Table 3: Two Sample t-tests for Reduced vs. Full Payment Hospitals

	t-statistic	df	p-value	95% CI	Equal Variance?
Hospital Avg Cost	1.1338	10	0.2832	(-1352.674, 4158.563)	False
Readmit Rate	1.3898	2539	0.1647	(-0.007442821, 0.043670607)	True
HAC score	0.927	2539	0.354	(-0.5942919, 1.6599045)	True

Table 4: Two-Sample t-tests for Physician Hospitals vs. Other

the data was collected as a survey. However, the results could still be useful in analyzing whether the CMS was justified, or not, on banning physician hospitals from expanding facilities and serving more patients.

Observing the column of p-values, we fail to reject the null hypothesis for all three t-tests, comparing the average cost per beneficiary per claim, readmission rate, and HAC score between the two types of hospitals respectively. This suggests that physician-operated hospitals are not overcharging their patients on average, and the quality of care provided is not significantly different from those provided by other hospitals, such as non-profit or government-operated. Of course, it is also important to note that there were only 10 physician operated hospitals in the dataset, possibly a consequence of the restrictions enacted by the Affordable Care Act in 2012. More research should be conducted by the CMS to fully evaluate the effectiveness of physician hospitals and enact appropriate policies to encourage higher value-of-care.

CONCLUSION

This paper explores how cost per beneficiary and quality of care varies between different types of acute-care hospitals, as well as the effect of exogenous variables such as socioeconomic status of neighborhoods and income per capita of the patients served by the hospitals. The results of these evaluations were then used to identify drawbacks and potential areas of improvements in two CMS policies involving payment reductions and hospital expansion restrictions. Due to lack of data availability, analysis of performance was not extended to the medical specialty or individual physician level. Further research in this area could prove useful in to all parties in the healthcare industry: individual patients would be able to pinpoint the physician or specialty group that most suits their medical needs, CMS could implement reward systems for high quality care independent of overall hospital performance, and insurance companies could prioritize reimbursements for procedures with a record of positive measurable health outcomes per dollar spent.

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