An Analysis of Variation in Hospital Billing Using Medicare Data

Ankit Agrawal and Alok Choudhary
Dept. of Electrical Engineering and Computer Science
Northwestern University
2145 Sheridan Rd
Evanston, IL 60201
USA
{ankitag,choudhar}@eecs.northwestern.edu

ABSTRACT

We analyze the recently released data from the Centers of Medicare and Medicaid Services (CMS), which includes hospital-specific charges for over 3,000 hospitals across the US for 100 most common inpatient discharges. The goal of this work is to study the variation in the amount that hospitals charge for a given diagnosis-related group (DRG), which is a group of similar diagnoses and clinical procedures. The inter-state variation in hospital billing, medicare payments, and normalized hospital billing (taking into account the variation in medicare payments) for a given DRG are presented visually as heatmaps, for the ease of identifying states where these values are significantly higher or lower than the average values over the entire US. The above analysis was done for the following 5 classes of DRGs: most common, most expensive, highest variation in average hospital billing, highest variation in average medicare payments, highest variation in normalized average hospital billing. The results reveal interesting insights. The variation in hospital billing was not only found to be much more than the variation in medicare payments, but the two variations are also not well correlated at all, raising important questions as to how hospitals determine the value of their services.

Categories and Subject Descriptors

H.2.8 [**Database Applications**]: Data mining; J.3 [**Life and Medical Sciences**]: Health

Keywords

Biomedical informatics, Healthcare costs, Hospital billing, Medicare

1. INTRODUCTION

KDD-DMH'13, August 11, 2013, Chicago, Illinois, USA.

Health care costs in the United States are known to be the highest per person as compared to any other country in the world [9]. According to the World Health Organization (WHO), the total health care spending in the US was 17.9% of its GDP in 2011, the highest in the world [10]. Several reasons are given for such extravagent costs, like the unit costs for medical goods, unnecessary use of high-cost services (sometimes as defensive medicine), administrative waste, inefficiently delivered services, excessive variation in service prices, fraud, and so on [9].

The Centers for Medicare and Medicaid Services (CMS) is a federal agency within the United States Department of Health and Human Services that administers the Medicare program and works in partnership with state governments to administer Medicaid and health insurance portability standards [2]. As part of the Obama administration's work to make US health care system more affordable, transparent, and accountable, CMS has recently released cost data [6] including hospital-specific charges for the more than 3,000 US hospitals that receive Medicare Inpatient Prospective Payment System (IPPS) payments for 100 most frequently billed discharges, paid under Medicare based on a rate per discharge using the Medicare Severity Diagnosis Related Group (MS-DRG) for Fiscal Year 2011. These DRGs represent almost 7 million discharges or 60% of total Medicare IPPS discharges.

Hospitals determine what they will charge for items and services provided to patients and these charges are the amount the hospital bills for an item or service, which is part of this data release at the hospital-level. Also included in this data is the total payment amount, which includes the MS-DRG amount, bill total per diem, beneficiary primary payer claim payment amount, beneficiary Part A coinsurance amount, beneficiary deductible amount, beneficiary blood deducible amount and DRG outlier amount [6]. The release of this dataset has already attracted widespread media attention [3, 7, 4, 5].

In this paper, we present our preliminary findings on health care cost variation across the US based on our analysis of the CMS data, and the results are visually depicted in the form of US state heat maps. Key findings include: a) Hospital billing variations are much higher than Medicare payment variations; b) Normalization helps reduce the variation in hospital billing; c) Although normalized hostpital billing does not vary as much as hospital billing, the variations are

still substantial; d) Normalization can change the relative position of a state in hospital billing with respect to the US average; e) Hospital billing variations are not well-correlated with medicare payment variation.

The rest of the paper is organized as follows: Section 2 briefly describes the dataset used in this study, followed by the description of the analytics approach used in this work in Section 3. Section 4 presents the results of the analytics we performed on this data, along with interesting insights. Conclusion and future work is presented in Section 5.

2. MEDICARE DATA

The data is provided by CMS Medicare Provider Analysis and Review (MEDPAR) which contains discharge information for 100% of Medicare fee-for-service beneficiaries using hospital inpatient services. The study population consists of Medicare Inpatient Prospective Payment System (IPPS) providers within the 50 United States and District of Columbia with a known Hospital Referral Region (HRR) who billed Medicare fee-for-service beneficiaries for the top 100 DRGs, with at least 11 cases in the year 2011. The top 100 DRGs are determined by the number of discharges, which is also present in the data at the hospital level. The data also contains geographic variables - the provider's address including street, city, state abbreviation and zip code and the Hospital Referral Region (HRR) based on the providers zip code. Cost information in the data includes the provider's average total covered charges (billing) and average total payments within DRG. Total payments consist of Medicare payments, beneficiary cost-share payments, and coordination of benefit payments.

For completeness, it is important to note that because Maryland is exempt from Medicare's payment system for inpatient care, payments to hospitals there may appear higher in comparison to hospitals in other states. More details on the data are available from the CMS [6].

The dataset contains 163,065 rows and 11 columns (DRG, provider ID, provider name, provider street address, provider city, provider state, provider zip code, provider HRR, total discharges, average covered charges, average total payments).

3. ANALYTICS APPROACH

This work aims at studying the variation in hospital billing for a given DRG. For each DRG, the coefficient of variation (CV_b) of hospital billing across all hospitals in US was calculated to rank them in decreasing order of CV_b. The coefficient of variation is defined as the ratio of the standard deviation (σ) and average (μ), i.e.

$$CV_b = \sigma_b / \mu_b$$

which is a normalized measure of dispersion of a frequency distribution, and basically measures how spread-out the data is. A similar ranking on DRGs was generated based on the variation coefficient in medicare payments to the providers, denoted by CV_p.

It is important to note that health care costs can legitimately vary across hospitals because of many factors like geographical location, whether the hospital is a teaching hospital, whether it serves a older and/or sicker patient base. Thus, we believe that to fairly assess the cost variation across hospitals, we also need to generate a normalized hospital billing value, which can eliminate the component of cost variance that could possibly have arisen due to the abovementioned factors, thereby allowing hospitals to have their due opportunity of justifying their higher costs due to legitimate factors. Of course, what normalization factor to use is an important question here. In this work, we use the average medicare payments to a hospital as a fraction of average medicare payments across the entire US, to be the normalization factor NF. Thus, normalization factor NF_h for a given hospital h would be given by

$$NF_h = \mu_{p,h} / \mu_{p,us}$$

where $\mu_{p,h}$ and $\mu_{p,us}$ are the average medicare payments to hospital h and across the entire US respectively, for the given DRG.

The reason for this choice is two-fold: a) the required data for that is available right in the same dataset; and b) NF as defined above actually does possess some of the charateristics we are looking for in a good normalization factor, since medicare payments (as in this data) include the DRG amount, teaching, disproportionate share, capital, and outlier payments for all cases. It also includes the co-payment and deductible amounts that the patient is responsible for and payments by third parties for coordination of benefits. So in one sense, the fact that medicare payments vary across hospitals and geographical locations can be thought of as arising due to Medicare's taking into account the above mentioned legitimate reasons for cost variation. It should be emphasized however that coming up with more sophisticated normalization factors could be an interesting direction to pursue in the future, and is beyond the scope of this paper.

Thus, we created normalized hospital billing values as well in the data, and another ranking of DRGs was generated based on variation coefficient of this normalized hospital billing CV_{nb}. Further, we also ranked the DRGs in the order of number of discharges (N_d), and average hospital billing amount across the US ($\mu_{b,us}$). In this way, we ended up with 5 ranked lists of DRGs.

In this work, we visualize the results in the form of three US state heat maps for a given DRG, showing the interstate variation in a) hospital billing, b) medicare payments, and c) normalized hospital billing. For a given state s, the following three values are used to draw the three heat maps respectively:

$$B_{map,s} = \log_2(B_s) = \log_2\left(\frac{\mu_{b,s}}{\mu_{b,us}}\right)$$

$$P_{map,s} = \log_2(P_s) = \log_2\left(\frac{\mu_{p,s}}{\mu_{p,us}}\right)$$

$$NB_{map,s} = \log_2(NB_s) = \log_2\left(\frac{B_s}{P_s}\right) = \log_2\left(\frac{\mu_{b,s} \times \mu_{p,us}}{\mu_{b,us} \times \mu_{p,s}}\right)$$

Note that P_s effectively acts as a normalization factor to get NB_s from B_s. Another thing to note is that we have used log scale values for making the heat maps since these values are ratios based on US average values, and we would like to depict, for example, $0.5 \times \mu_{b,us}$ and $2 \times \mu_{b,us}$ as equally far from $\mu_{b,us}$ in the heat maps.

We also looked at the correlation between B_s and P_s, both at the DRG-level and at the state-level, to see if the variations in hospital billing and medicare payments were correlated, even if one was much more than the other. Correlation

betwen X and Y is defined as:

$$\rho_{XY} = corr(X,Y) = \frac{\sum_{i=1}^{n}(x_i - \overline{x})(y_i - \overline{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \overline{x})^2 \sum_{i=1}^{n}(y_i - \overline{y})^2}}$$

4. RESULTS

Tables 1, 2, 3, 4, and 5 present the top 5 DRGs in each of the five ranked lists described earlier. The bold-faced column denotes the criterion for ranking the DRGs. Major joint replacement is the most common DRG in the US, while severe sepsis infection condition is the most expensive to treat. Psychosis, or mental disorder condition has the highest variation in hospital billing, while bronchitis and asthma procedures have the highest variation in medicare payments. Finally, when hospital billing is normalized by variation in medicare payments), alcohol/drug abuse was found to be have the highest variation in normalized hospital billing.

Figure 1 depicts the heat maps for the top ranked DRG in each of the five categories. For the left and center figures, darker shades of red (blue) represent that the hospital billing and medicare payment values in the corresponding states are much higher (lower) than the US average. The right figures present the same thing as the left figures but the values are normalized by the corresponding normalization factor for that state. Recall from Section 3 that costs and payments are expressed as factors of US averages and hence the red and blue colors depict only relative variations and not absolute numbers. In this sense, a heatmap with higher contrasts implies high variations from the average.

Figure 2 presents the distribution (across all 100 DRGs) of correlation values between hospital billing and medicare payments, when both are expressed as fraction of their respective US averages. Thus, it is the correlation between B_s and P_s, or in other words, the correlation between the left and center figures in Figure 1, for each DRG. Figure 3 presents same across the US states, and Figure 4 depicts the corresponding heat map. We discover the following interesting insights from Tables 1 - 5 and Figures 1 - 4.

Insight 1 *Hospital billing variations are much higher than Medicare payment variations.* This is evident both from the tables and Figure 1. The maximum coefficient of variation in hospital billing (CV_b) in Table 3 is much higher than the maximum variation in medicare payments (CV_p) in Table 4. Also, from Figure 1, it is easy to observe that center figures are much lighter (both in terms of red and blue), or low-contrast than the left figures.

Insight 2 *Normalization helps reduce the variation in hospital billing.* This insight is also evident both from the tables and Figure 1. The maximum coefficient of variation in normalized hospital billing (CV_{nb}) in Table 5 is less than the maximum variation in hospital billing (CV_b) in Table 3. Also, from Figure 1, the right figures are slightly lighter/low-contrast than the left figures, suggesting that our chosen methodology of normalization does reduce variation in hospital billing.

Insight 3 *Although normalized hostpital billing does not vary as much as hospital billing, the variations are still substantial.* Since the right figures in Figure 1 correspond to hospital billing normalized by a normalization factor based on medicare payments, they essentially represent a ratio of left and center figures. Recall that we assume that the variance in medicare payments is, in a sense, accounting for the legitimate factors that can contribute to variation in costs. Thus, the purpose of normalizing hospital billing is to remove such legitimate variance. While we observe that doing so certainly reduces the variance (Insight 2), but ideally, the variance should have been very low if the hospitals were billing fairly for their services. If we assume the normalization procedure is reasonable, the resulting dark red (blue) regions would correspond to states that are over-(under-)charging.

Insight 4 *Normalization can change the relative position of a state in hospital billing with respect to the US average.* We found that for nearly 12% of <DRG,State> pairs, the state moved from red to blue or vice-verca after normalization. Of course, all such heat maps cannot be shown in the paper, but we can see some instances of this in Figure 1. For example, AK changes from red to blue, while AL changes from blue to red in Figures 1a and 1b; SC changes from blue to red in Figure 1b; TN and KS change from blue to red in Figure 1c and Figure 1d respectively; NY changes from red to blue in Figure 1e. This indicates that in some cases, states might be wrongly perceived to be over- or under-charging for their services.

Insight 5 *Hospital billing variations are not well-correlated with medicare payment variation.* This is directly evident from Figures 2 - 4, and well-supported by Figure 1. The first insight of hospital billing variations being higher than medicare payments variation is surprising, but at least the variations would have been expected to be well-correlated. But the maximum correlation at the DRG-level itself being less than 0.4 with the median correlation 0.175, and having a few negative correlations as well is even more surprising and concerning, as it suggests that either or both of hospitals and medicare are assigning arbitrary value to different services. At the state level (Figures 3 and 4), the correlations are slightly better, but still many states have very low correlation, and even negative correltion. This insight even more strongly emphasizes that clearer guidelines to estimate the true value of the services need to be established and followed.

Three DRGs with minimum correlation in Figure 2 are: 244 - Permanent cardiac pacemaker implant w/o cc/mcc (-0.13); 419 - Laparoscopic cholecystectomy w/o CDE w/o cc/mcc (-0.08); 247 - Perc cardiovasc proc w drug-eluting stent w/o mcc. Due to space limitations, we do not present the heat maps for these DRGs in the paper, but they are available at our project website below. Five states with minimum correlation in Figures 3 and 4 are: AZ (-0.12), NM (-0.10), AK (-0.04), ND (-0.01), and SD (-0.01).

Google chart tools [1] were used to create the maps in Figure 1, and web-based interactive versions of these charts are available at our project website [8].

5. CONCLUSION AND FUTURE WORK

In this workshop paper, we present our preliminary findings of analyzing the CMS data on provider costs, and discuss the resulting insights. Ongoing/future work includes conducting more fine grained analysis for automated identification of hospitals that may be unfairly charging more than what they are supposed to. We can also try to develop more sophisticted techniques to normalize hospital charges by incorporating, for example, the local cost of living. Another direction can be to try to link this data with actual patient outcomes like health condition, survival, etc., and find correlation between health care costs and patient out-

Table 1: Five most common DRGs with number of discharges, average hospital billing, and average medicare payments

DRG Definition	N_d	$\mu_{b,us}$	$\mu_{p,us}$
470 - Major joint replacement or reattachment of lower extremity w/o mcc	**427,207**	50,105.26	14,324.48
871 - Septicemia or severe sepsis w/o mv 96+ hours w mcc	**319,072**	49,418.6	13,650.96
392 - Esophagitis, gastroent & misc digest disorders w/o mcc	**244,854**	20,321.55	5,097.08
292 - Heart failure & shock w cc	**22,2038**	25,113.91	7,098.42
690 - Kidney & urinary tract infections w/o mcc	**206,695**	19,865.56	5,409.83

Table 2: Five most Expensive DRGs in terms of average hospital billing

DRG Definition	N_d	$\mu_{b,us}$	$\mu_{p,us}$
870 - Septicemia or severe sepsis w mv 96+ hours	22,624	**163,325.92**	45800.3
207 - Respiratory system diagnosis w ventilator support 96+ hours	26,412	**143,768.97**	39,075.22
853 - Infectious & parasitic diseases w o.r. procedure w mcc	39,482	**141,995.09**	41,267.56
329 - Major small & large bowel procedures w mcc	37,250	**135,584.77**	38,262.29
246 - Perc cardiovasc proc w drug-eluting stent w mcc or 4+ vessels/stents	27,104	**93,363.32**	23336.48

Table 3: Top five DRGs with highest coefficient of variation in hospital billing

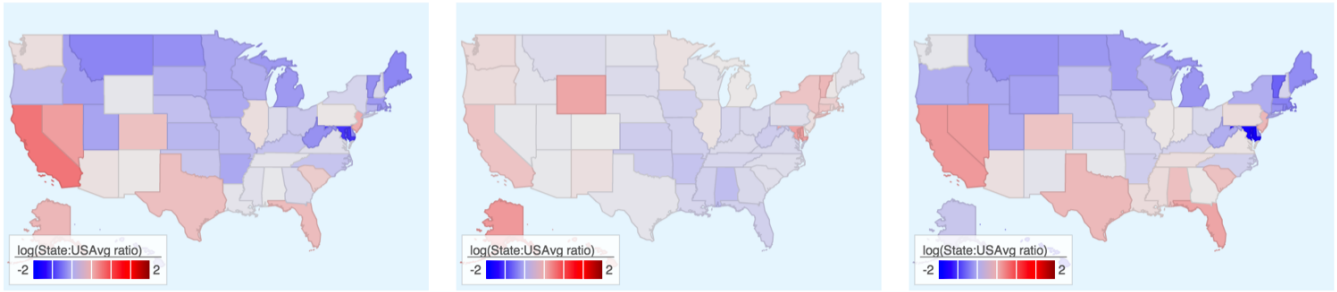
DRG Definition	N_d	$\mu_{b,us}$	$\mu_{p,us}$	CV_b
885 - Psychoses	89,733	18,761.07	7,180.20	**0.72**
897 - Alcohol/drug abuse or dependence w/o rehabilitation therapy w/o mcc	31,935	14,383.20	5,067.19	**0.63**
917 - Poisoning & toxic effects of drugs w mcc	16952	39,321.72	10,835.57	**0.61**
190 - Chronic obstructive pulmonary disease w mcc	149,677	30,161.78	8,121.58	**0.61**
189 - Pulmonary edema & respiratory failure	95,099	31,953.15	8,965.91	**0.61**

Table 4: Top five DRGs with highest coefficient of variation in medicare payments

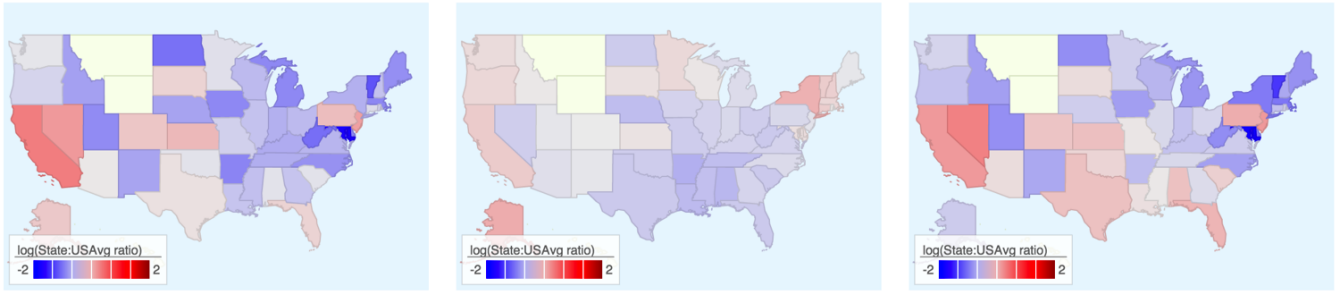
DRG Definition	N_d	$\mu_{b,us}$	$\mu_{p,us}$	CV_p
203 - Bronchitis & asthma w/o cc/mcc	16,577	17,131.74	4,455.95	**0.37**
885 - Psychoses	89,733	18,761.07	7,180.20	**0.35**
698 - Other kidney & urinary tract diagnoses w mcc	22,085	42,212.75	12,369.46	**0.32**
286 - Circulatory disorders except ami, w card cath w mcc	21,820	61,115.13	15,560.63	**0.31**
189 - Pulmonary edema & respiratory failure	95,099	31,953.15	8,965.91	**0.31**

Table 5: Top five DRGs with highest coefficient of variation in normalized hospital billing

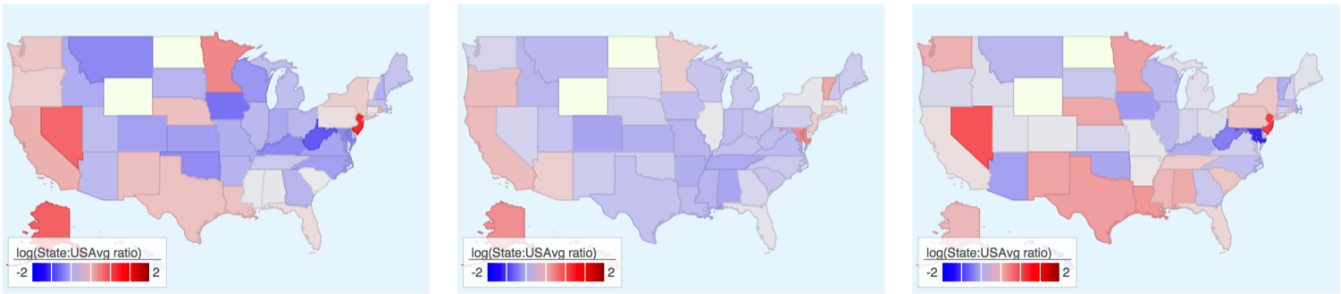
DRG Definition	N_d	$\mu_{b,us}$	$\mu_{p,us}$	CV_{nb}
897 - Alcohol/drug abuse or dependence w/o rehabilitation therapy w/o mcc	31,935	14,383.20	5,067.19	**0.58**
885 - Psychoses	89,733	18,761.07	7,180.20	**0.57**
203 - Bronchitis & asthma w/o cc/mcc	16,577	17,131.74	4,455.95	**0.54**
190 - Chronic obstructive pulmonary disease w mcc	149,677	30,161.78	8,121.58	**0.54**
178 - Respiratory infections & inflammations w cc	56,100	36,088.80	9,961.06	**0.54**



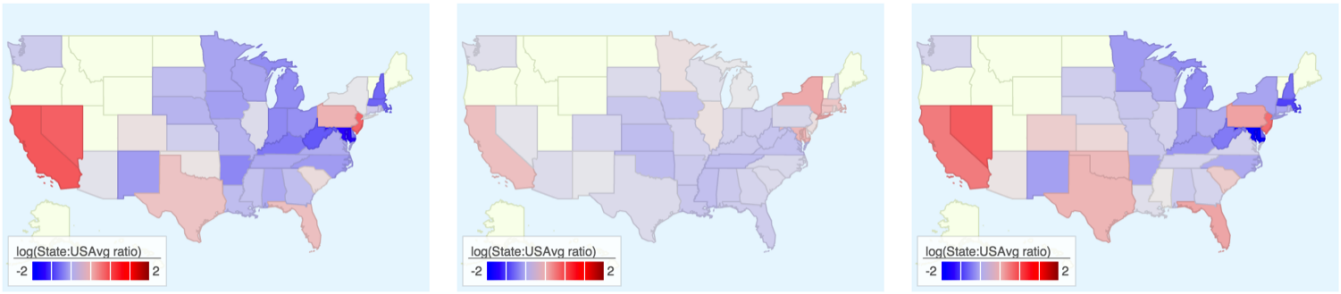
(a) Most common DRG (N_d = 427,207): 470 - Major joint replacement or reattachment of lower extremity w/o mcc



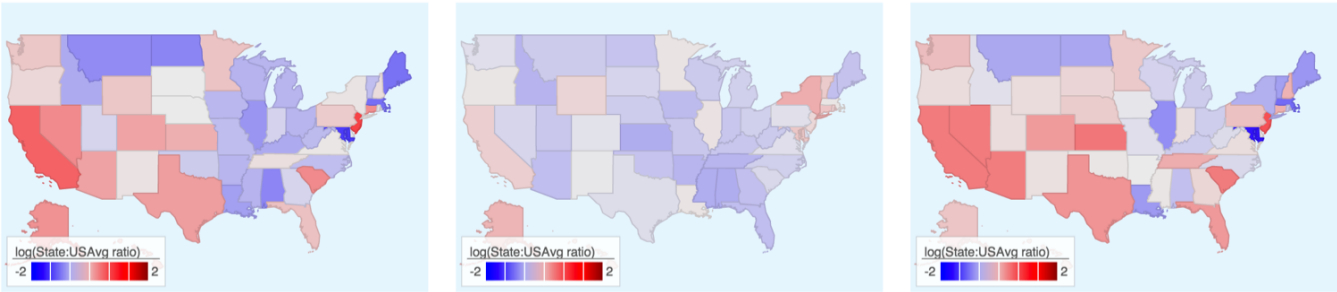
(b) Most expensive DRG ($\mu_{b,us}$=\$163,325.92; $\mu_{p,us}$=\$45,800.30): 870 - Septicemia or severe sepsis w mv 96+ hours



(c) DRG with highest CV_b (0.72): 885 - Psychoses



(d) DRG with highest CV_p (0.37): 203 - Bronchitis & asthma w/o cc/mcc



(e) DRG with highest CV_{nb} (0.58): 897 - Alcohol/drug abuse or dependence w/o rehabilitation therapy w/o mcc

Figure 1: U.S. state heat maps depicting inter-state variation in health care costs for a given DRG. For each of the figures (a) through (e), the left map corresponds to hospital billing (B_{map}), the center map corresponds to medicare payments (P_{map}), and the right map corresponds to normalized hospital billing (NB_{map}). Red and blue color intensity represent correpondingly high and low values compared to the average value across the US. Pure white colors in some states represent the fact that there were no corrsponding DRGs from that state included in the data.

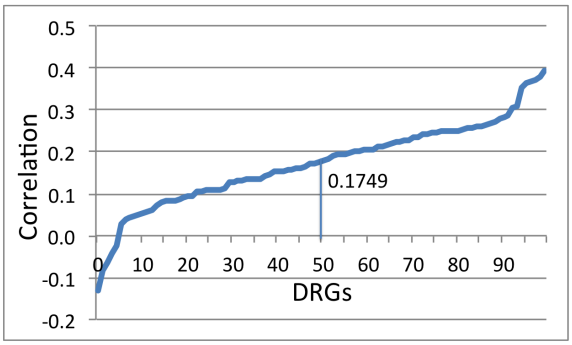


Figure 2: Line chart of sorted correlation values between B_s and P_s for all the 100 DRGs. The median value is also indicated. It shows that hospital billing and medicare payments are not well correlated at the DRG level.

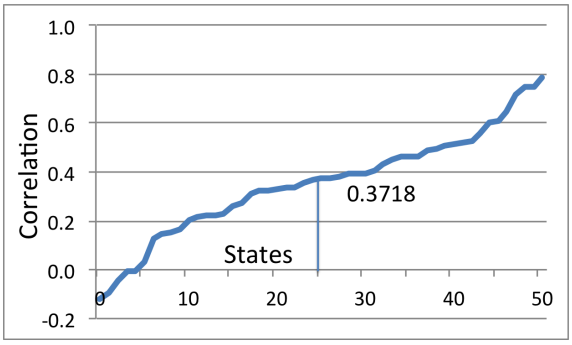


Figure 3: Line chart of sorted correlation values between B_s and P_s for US states. The median value is also indicated. It shows that for most states, hospital billing and medicare payments are not well correlated.

comes. Further, using geographical information available in this dataset, an interactive query-based system can be developed to answer questions like: What are the top cost-effective and safe hospitals in this area for a given health condition?

6. REFERENCES

[1] Google chart tools, google, https://developers.google.com/chart/, accessed may 13, 2013.

[2] Url: Centers for medicare and medicaid services, wikipedia, http://en.wikipedia.org/wiki/Centers_for_Medicare_and_Medicaid_Services, accessed may 14, 2013.

[3] Url: Cms data show wide variation in hospital billing, modernhealthcare, http://www.modernhealthcare.com/article/20130508/NEWS/305089960/cms-data-show-wide-variation-in-hospital-billing, accessed may 14, 2013.

[4] Url: Hospital billing varies wildly, government data shows, nytimes, http://www.nytimes.com/2013/05/08/business/hospital-billing-varies-wildly-us-data-shows.html?_r=0, accessed may 14, 2013.

[5] Url: Hospital charges billed to medicare cover wide range, njspotlight, http://www.njspotlight.com/stories/13/05/09/hip-knee/, accessed may 14, 2013.

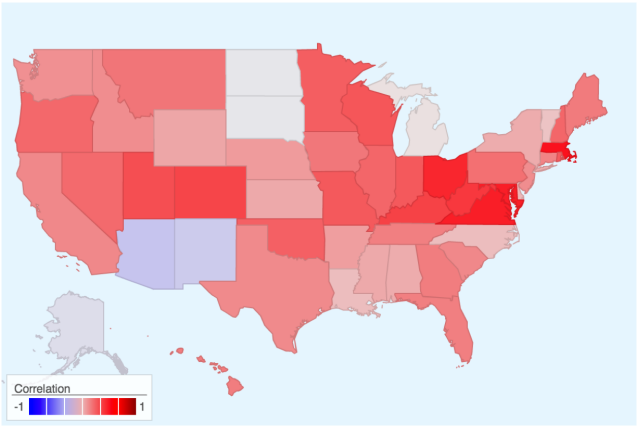


Figure 4: Heat map of correlation values between B_s and P_s for US states.

[6] Url: Medicare provider charge data, cms, http://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/Medicare-Provider-Charge-Data/index.html, accessed may 14, 2013.

[7] Url: New provider data demonstrates variation in medicare charges, ehrintelligence, http://ehrintelligence.com/2013/05/09/new-provider-data-demonstrates-variation-in-medicare-charg accessed may 14, 2013.

[8] Url: U.s. state heat maps depicting inter-state variation in health care costs for a given diagnosis-related group (drg), northwestern university, http://users.eecs.northwestern.edu/~ankitag/hospitalbilling/.

[9] Url: Why does u.s. health care cost so much?, regence, http://www.regence.com/transparency/regence-and-reform/what-drives-up-health-care-costs.jsp, accessed may 14, 2013.

[10] Url: World health statistics 2011, who, http://www.who.int/gho/publications/world_health_statistics/2011/en/index.html, accessed may 14, 2013.