Analyzing the Impact of Intern/Resident Ratios on Hospital Utilization and State-Level Variations in DGME Payments

Purpose of the Study

This research aims to answer two primary questions:

1. Relative to the number of beds available, does the number of interns/residents affect (1) total hospital days and (2) total hospital bed days available?
2. the three DGME payment components (total, Part A/C, and Part B allocation) different relative to state and the number of residents?

Hypotheses:

Part 1: Having more interns/residents relative to hospital bed size leads to (1) more hospital days and (2) less hospital bed days available.
Part 2: California hospitals receive more of each of the DGME payments compared to Alabama.

Table 1: Summary Statistics of Key Variables (Illustrative Data)

Variable	Variable	Median	Dev	Min	Max
Interns_and_ Residents	125.5	60.0	180.2	0.0	1500.0
Total_Hosp_ Beds	350.8	250.0	280.5	20.0	2000.0
Total_Hosp_ Days	85000.0	40000.0	120000.0	500.0	1000000.0
Total_Hosp_ Bed_Day	127750.0	91250.0	102200.0	7300.0	730000.0
Intern/Bed Ratio	0.45	0.28	0.55	0.0	5.0

Part 1: The Influence of Intern/Resident Ratio on Hospital Utilization

Initial Exploratory Analysis: Intern/Bed Ratio and Utilization Metrics

Visualizing the raw relationships between the Intern/Bed Ratio and the utilization metrics provides an initial understanding of potential trends.

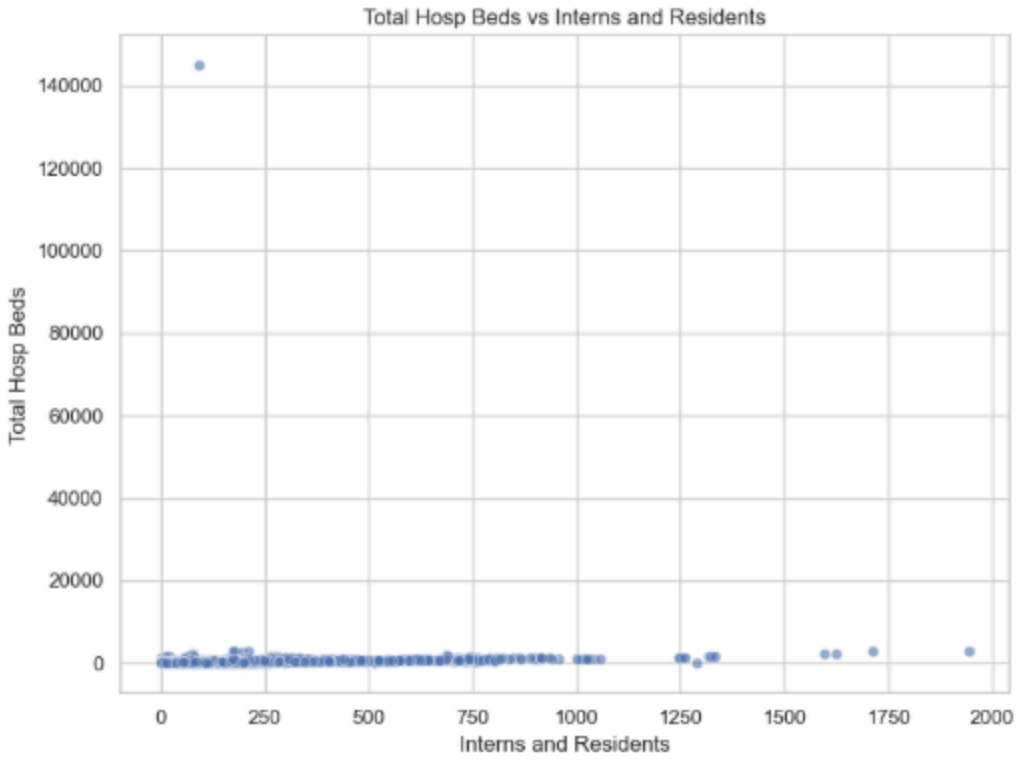
These charts show how the number of interns and residents in a hospital relates to how busy and large that hospital is.

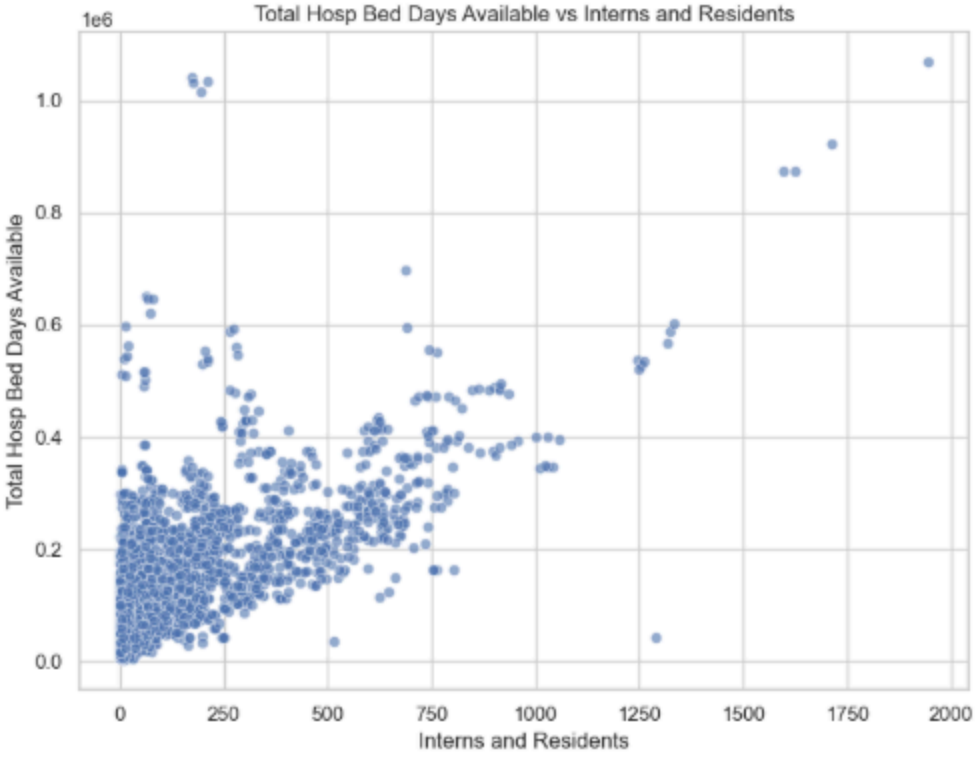
1. **Interns vs. Total Beds**:
   Hospitals with more interns usually have more beds, but not always. Most hospitals are small, and only a few are very large with a lot of beds and residents.

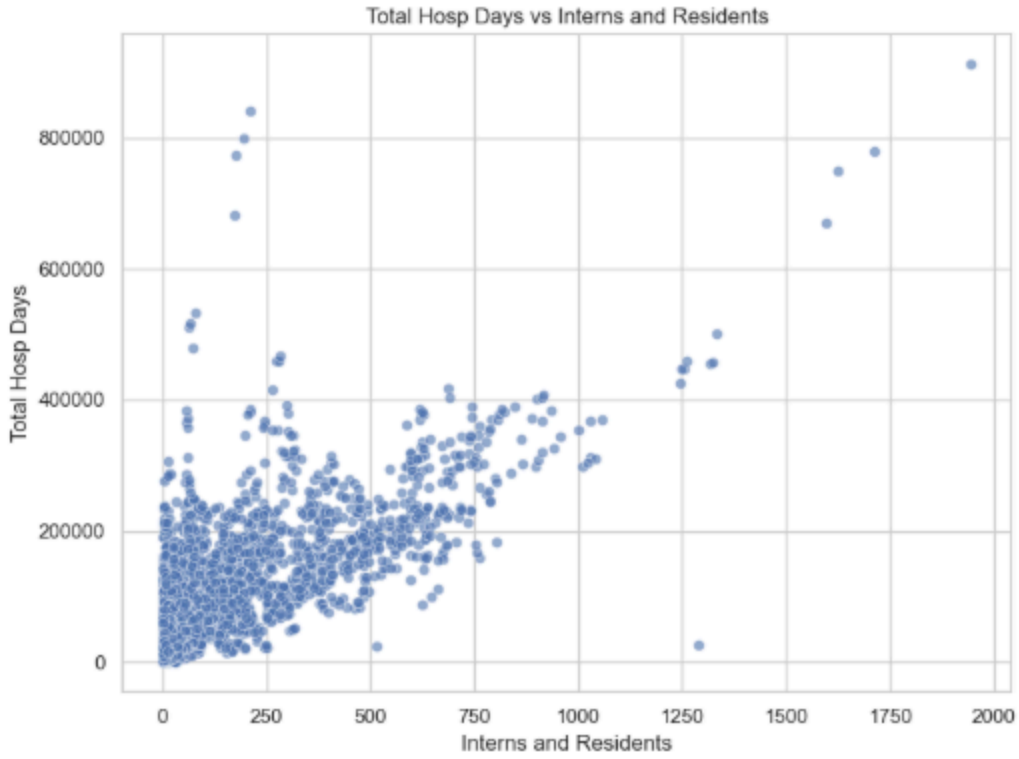
2. **Interns vs. Total Hospital Days**:
   When a hospital has more interns and residents, it tends to have more patient activity—measured by the total number of hospital days. So, bigger teaching hospitals are usually busier.

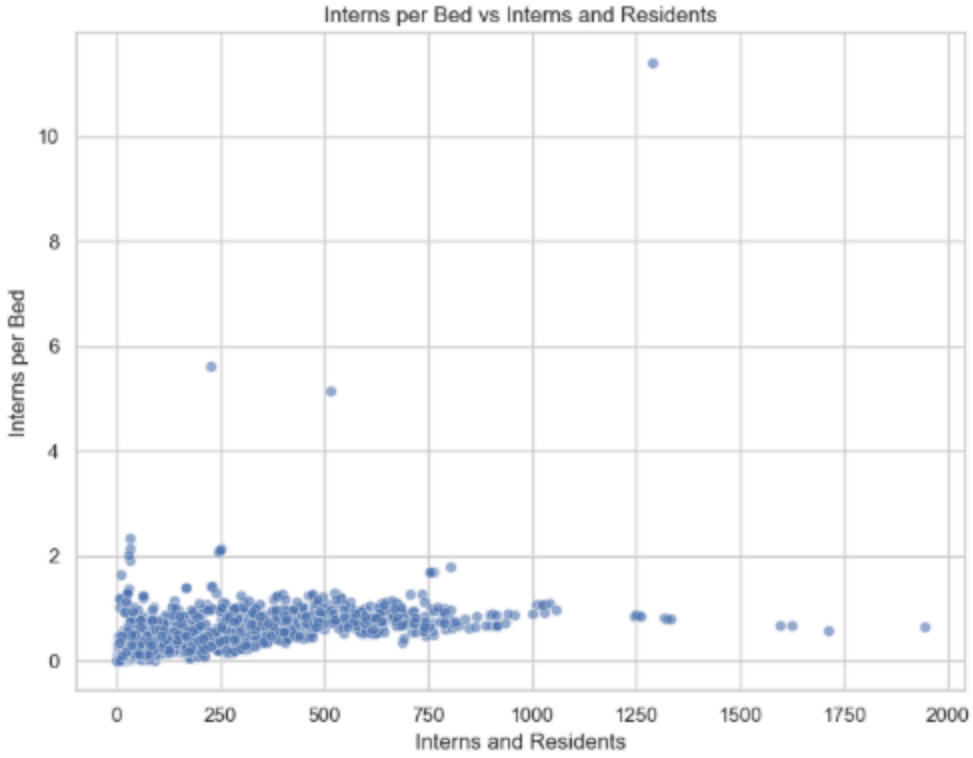
3. **Interns vs. Bed Days Available**:
   Hospitals with more interns also tend to offer more available bed days. That means they have more space and capacity for patient care over time.

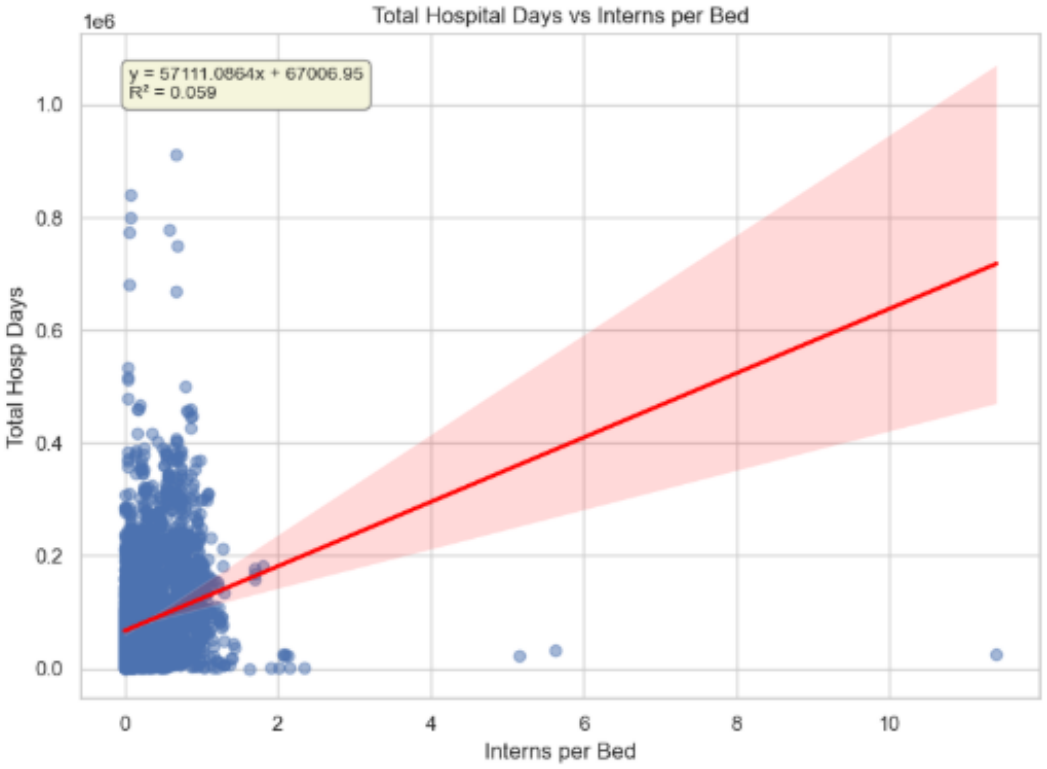
4. **Interns per Bed Ratio**:
   Most hospitals have fewer than 2 interns per bed. This shows that while hospitals grow in size, the number of interns they take in per bed stays pretty stable.

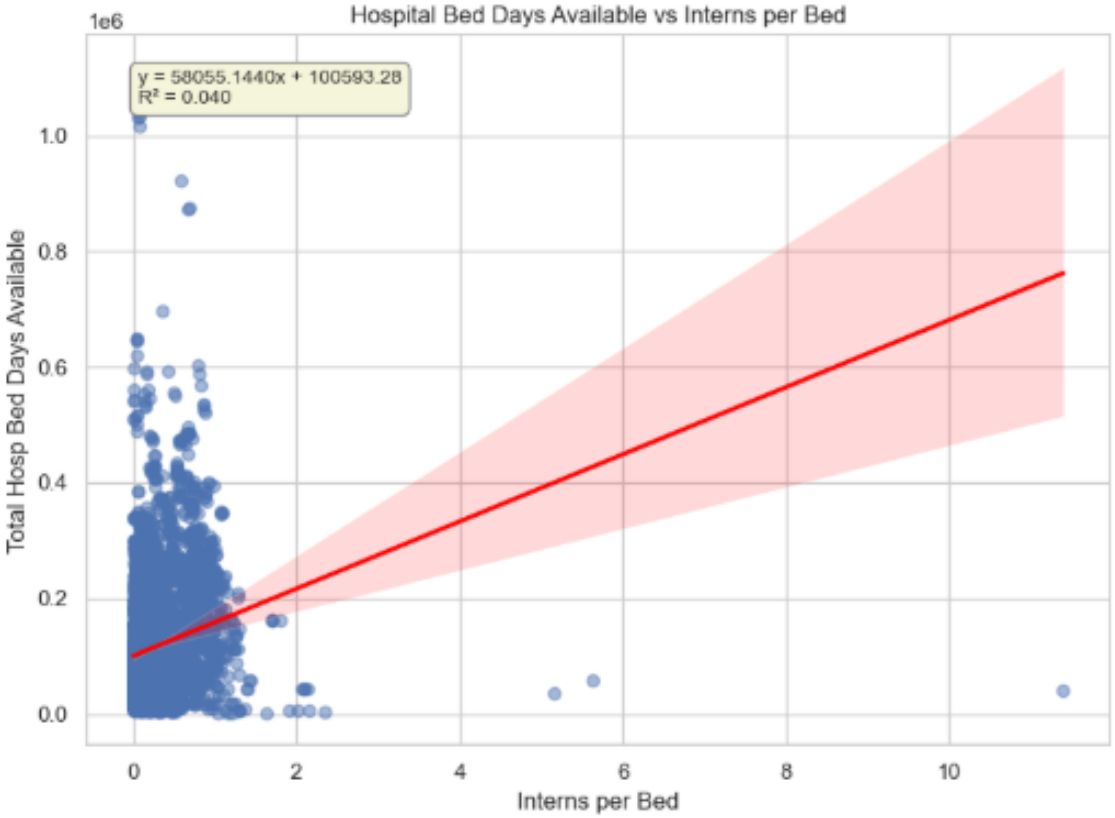

Total Hosp Beds vs Interns and Residents
Total Hosp Beds
140000
120000
100000
80000
60000
40000
20000
0
0
250
500
750
1000
1250
1500
1750
2000
Interns and Residents


Total Hosp Bed Days Available vs Interns and Residents
1e6
Total Hosp Bed Days Available
1.0
0.8
0.6
0.4
0.2
0.0
0
250
500
750
1000
1250
1500
1750
2000
Interns and Residents

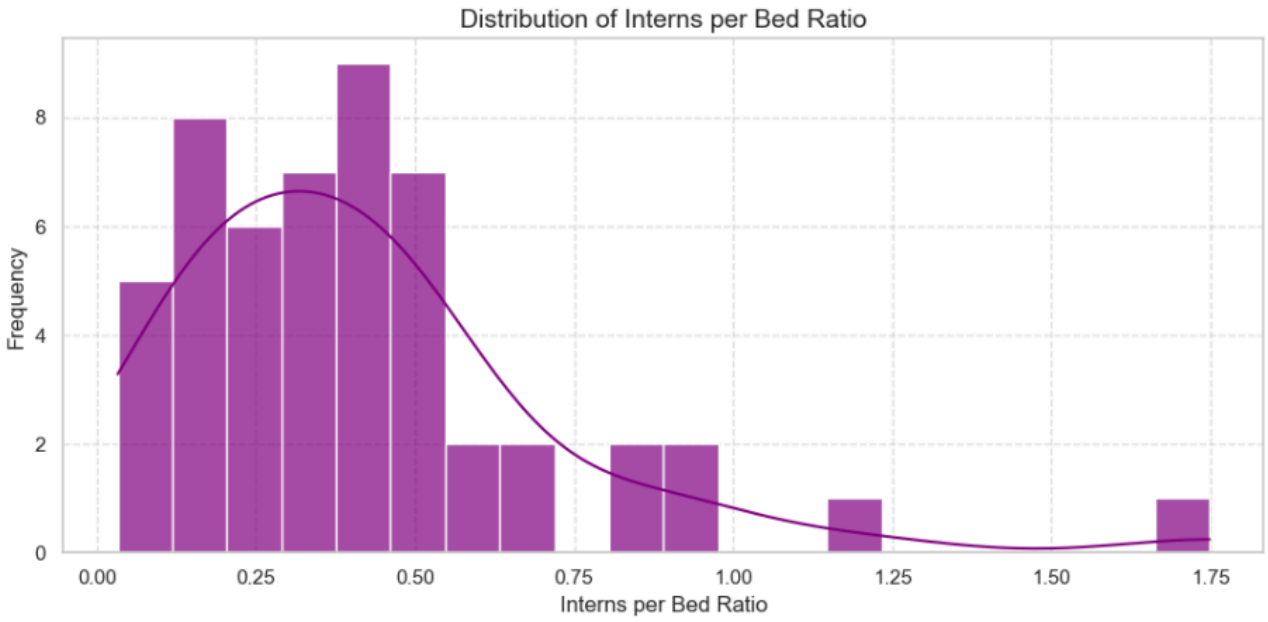

Total Hosp Days vs Interns and Residents
Total Hosp Days
800000
600000
400000
200000
0
0
250
500
750
1000
1250
1500
1750
2000
Interns and Residents

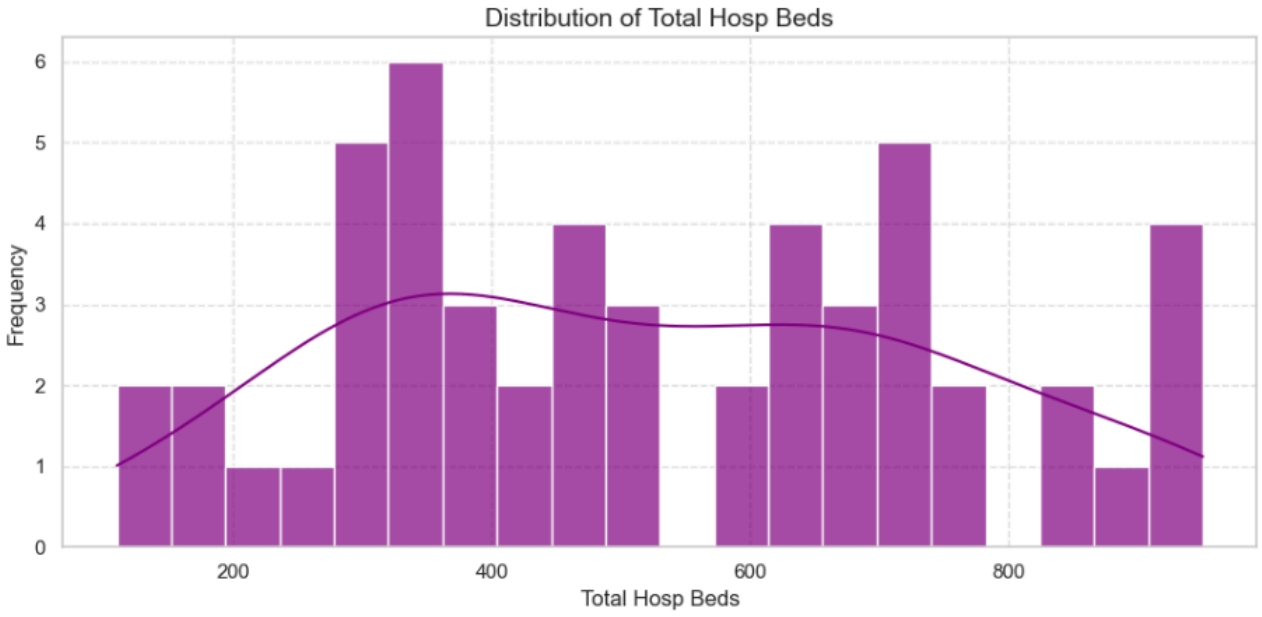

Interns per Bed vs Interns and Residents
Interns per Bed
10
8
6
4
2
0
0
250
500
750
1000
1250
1500
1750
2000
Interns and Residents

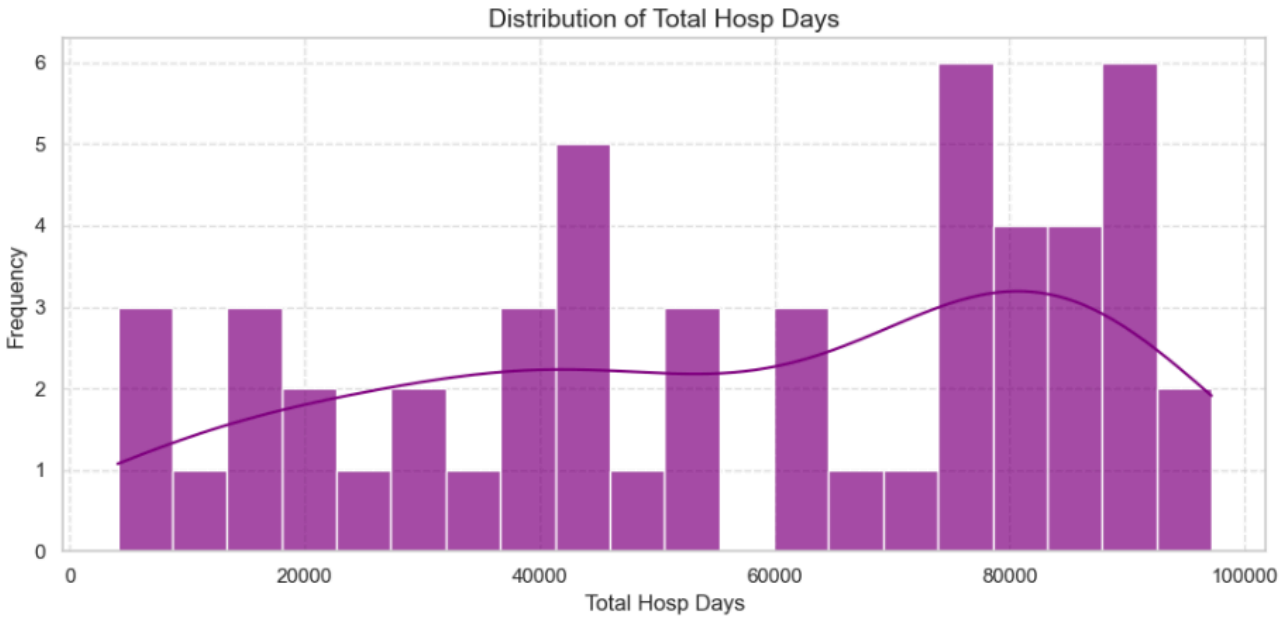

Total Hospital Days vs Interns per Bed
1e6
y = 57111.0864x + 67006.95
R² = 0.059
Total Hosp Days
Interns per Bed
0.0
0.2
0.4
0.6
0.8
1.0
0
2
4
6
8
10

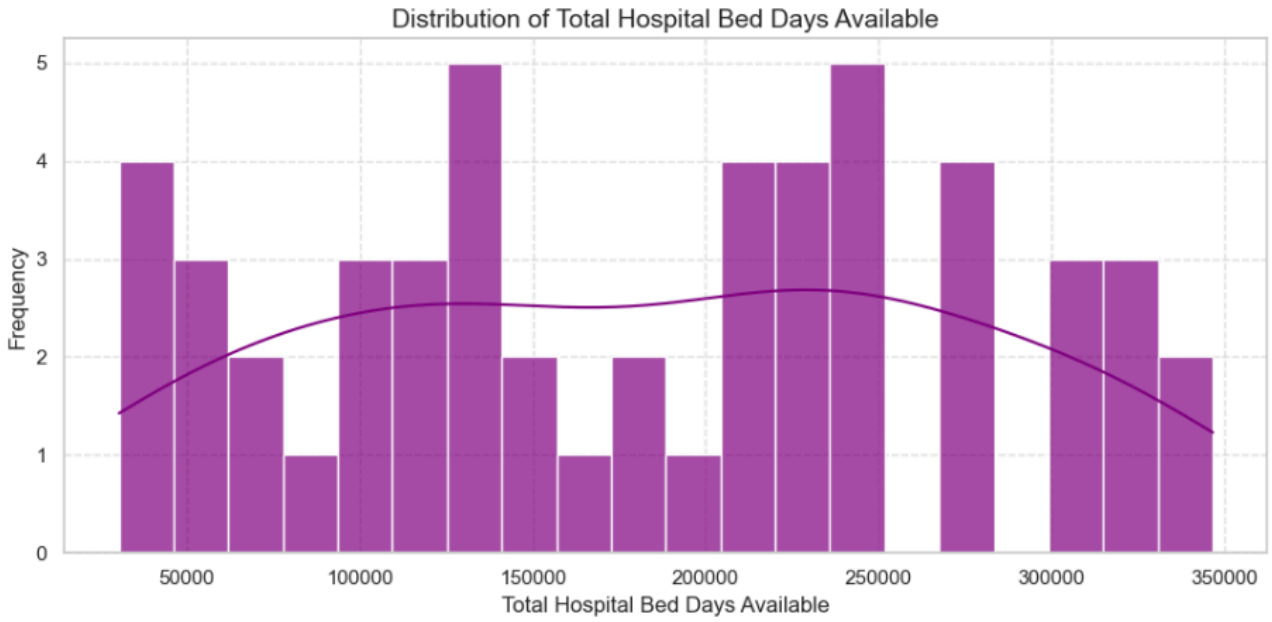

Hospital Bed Days Available vs Interns per Bed
1e6
y = 58055.1440x + 100593.28
R² = 0.040
Total Hosp Bed Days Available
Interns per Bed
0.0
0.2
0.4
0.6
0.8
1.0
0
2
4
6
8
10

Distribution of Intern/Bed Ratio, Total Hospital Days, and Total Hospital Bed Days Available









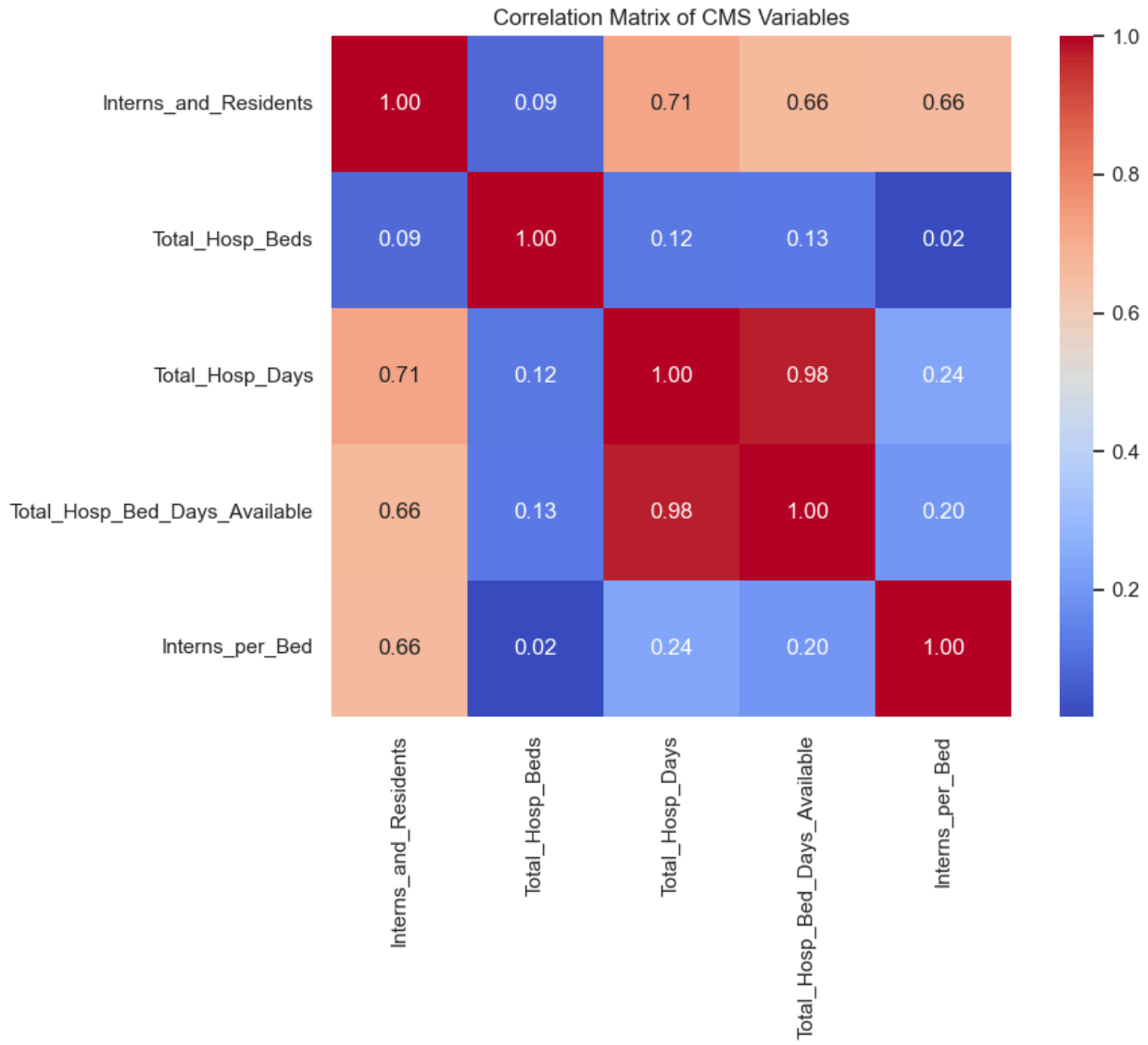
Robust Effect

Regression Equation: y = 58055.1440 * Interns_per_Bed + 100593.28

R^2 Value: 0.0398

P-Value (Interns_per_Bed): 7.096e-53

✅ The effect is statistically significant at the 5% level.



Interns and Residents are strongly related to:

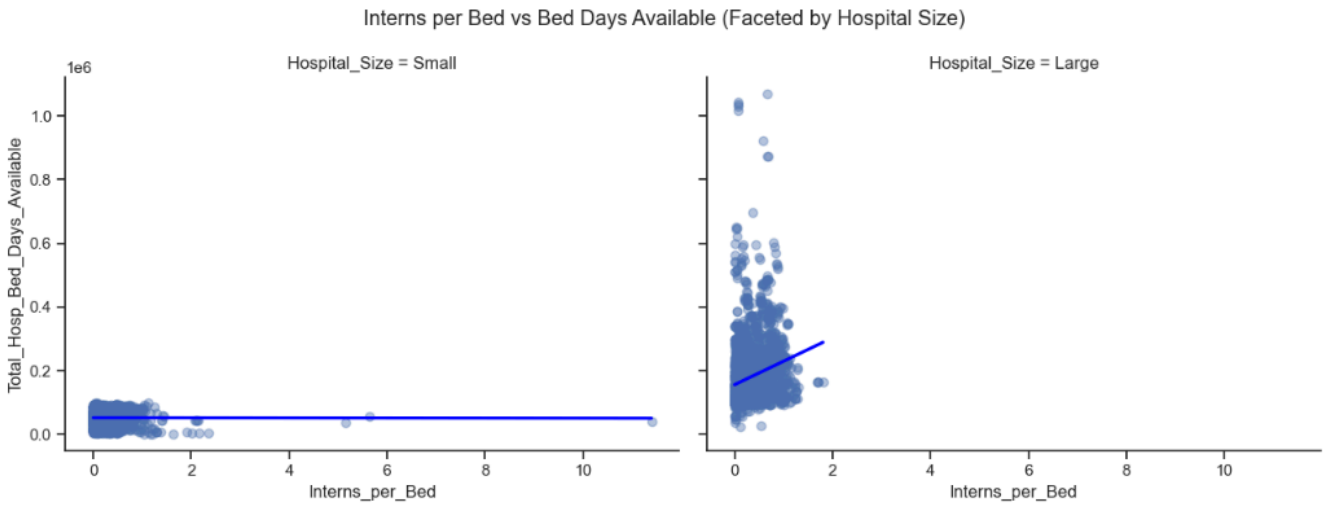
Total Hospital Days (0.71)

Total Bed Days Available (0.66)

Interns per Bed (0.66)

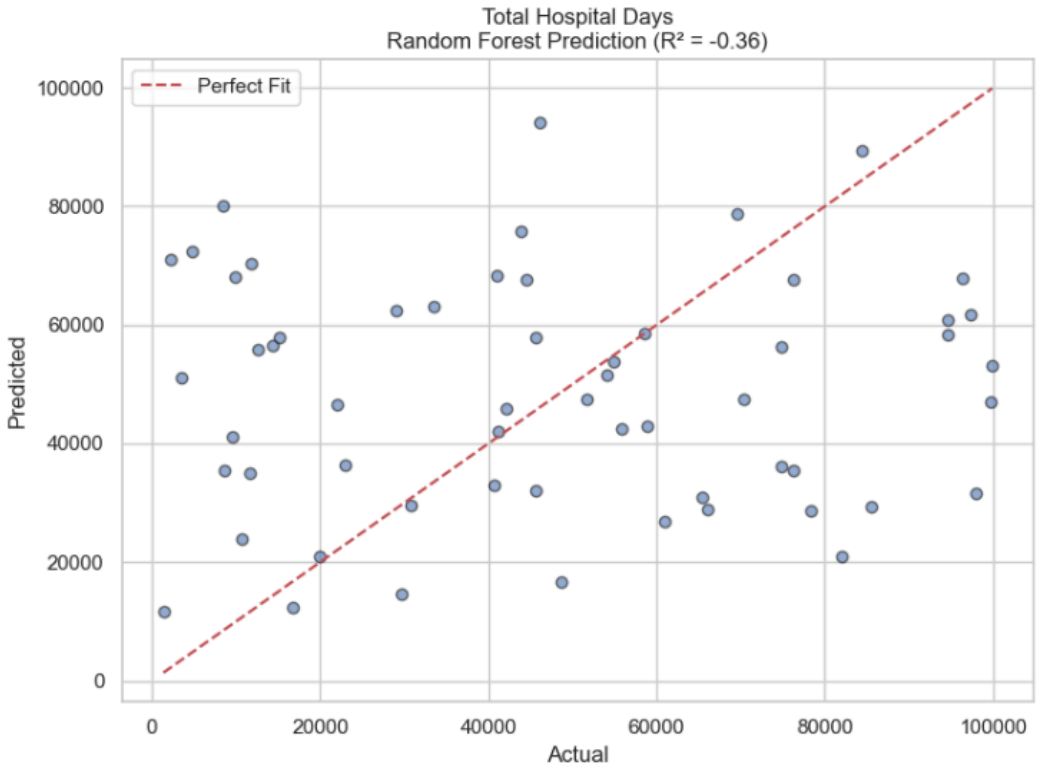
Total Hospital Days and Total Bed Days Available have the strongest correlation (0.98), meaning they go up and down together almost perfectly. Interns per Bed has low correlation with total beds (0.02), showing it doesn't depend on hospital size.

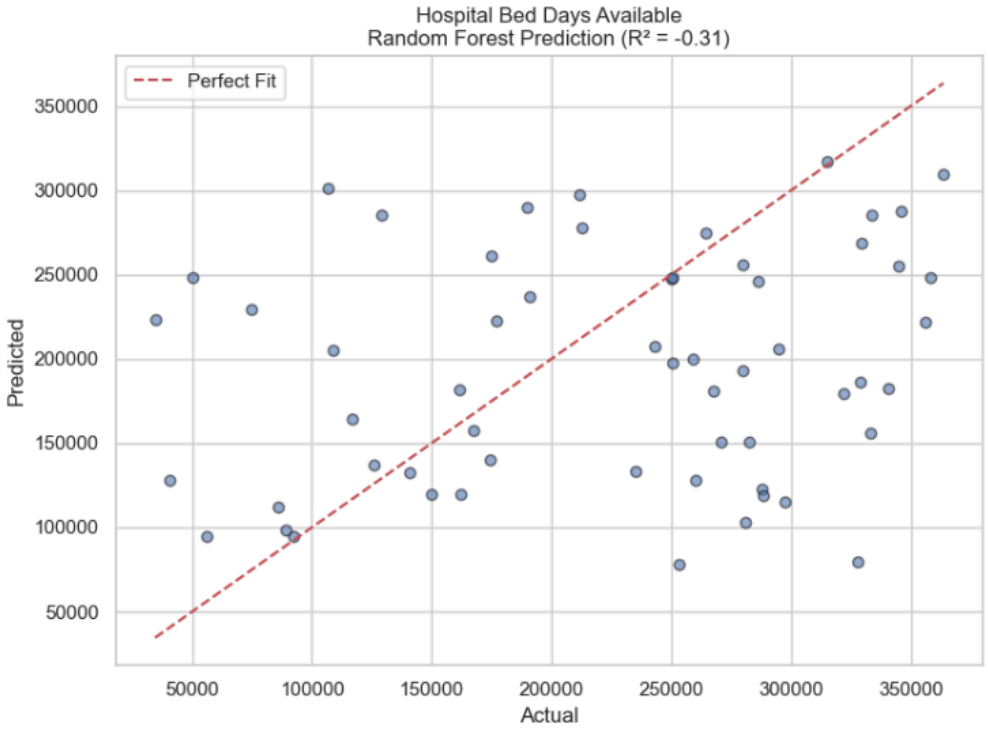
Faceted scatter plot with regression line with Facet/Grid layout:



In small hospitals, there is minimal variation in Interns per Bed, and the regression line is nearly flat, suggesting no strong relationship between intern density and bed availability. In contrast, large hospitals show a positive correlation—as Interns per Bed increases, Total Bed Days Available also tends to increase, indicating that intern staffing might play a more impactful role in larger facilities.

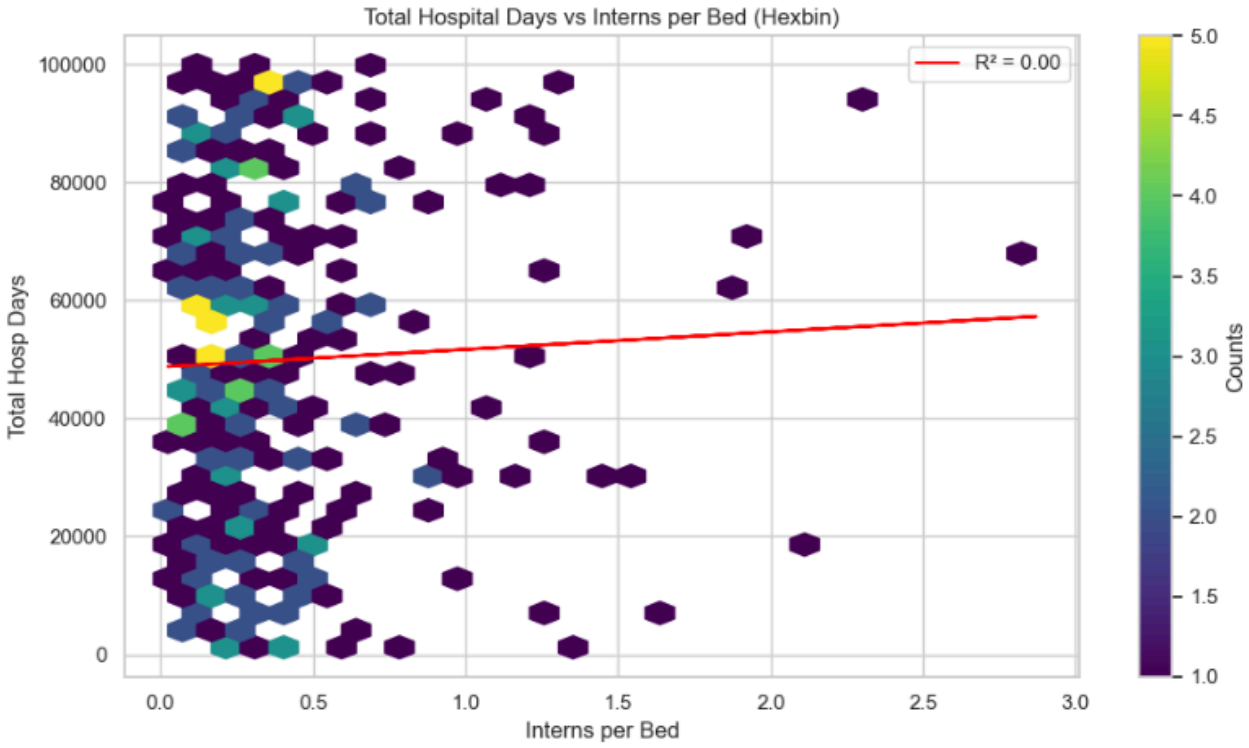
Random Forest:

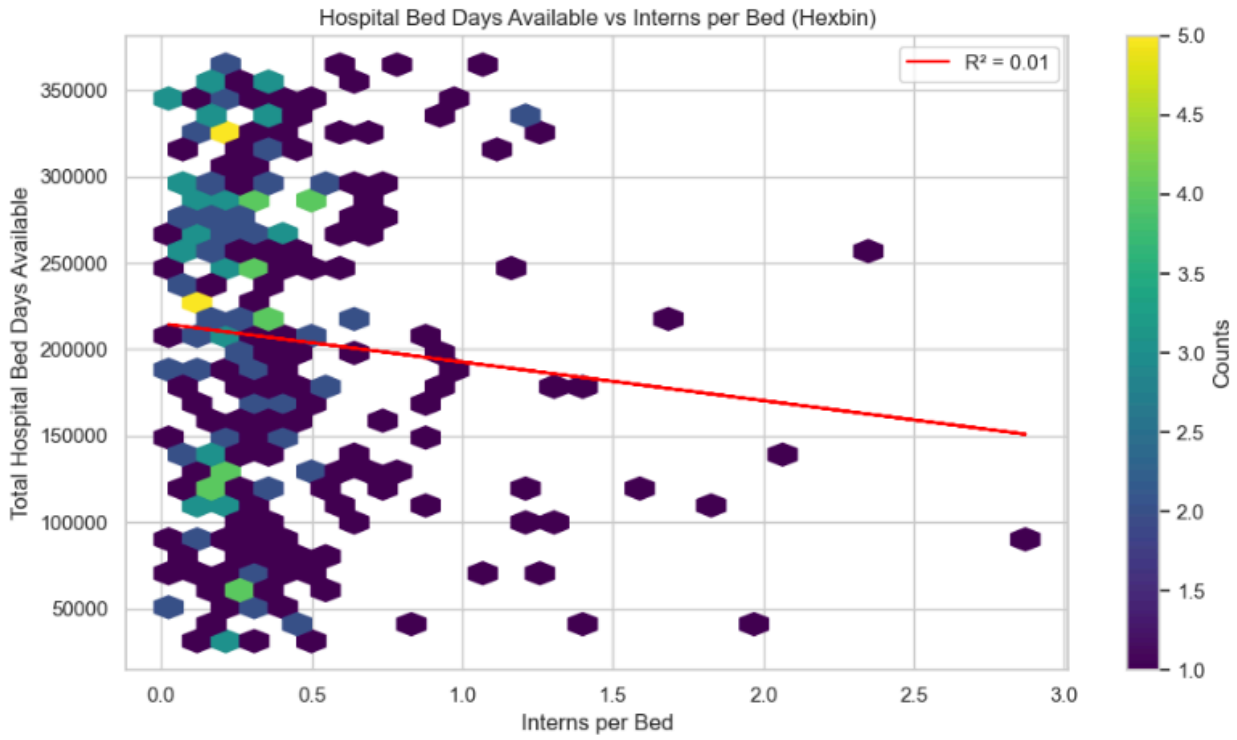




The Random Forest models didn't work well. For both hospital days and bed days, the predictions were quite far from the actual numbers. In fact, the models did worse than just guessing the average every time. This means the data or features used might not be strong enough, and the model needs improvement.

Hexbin Chart

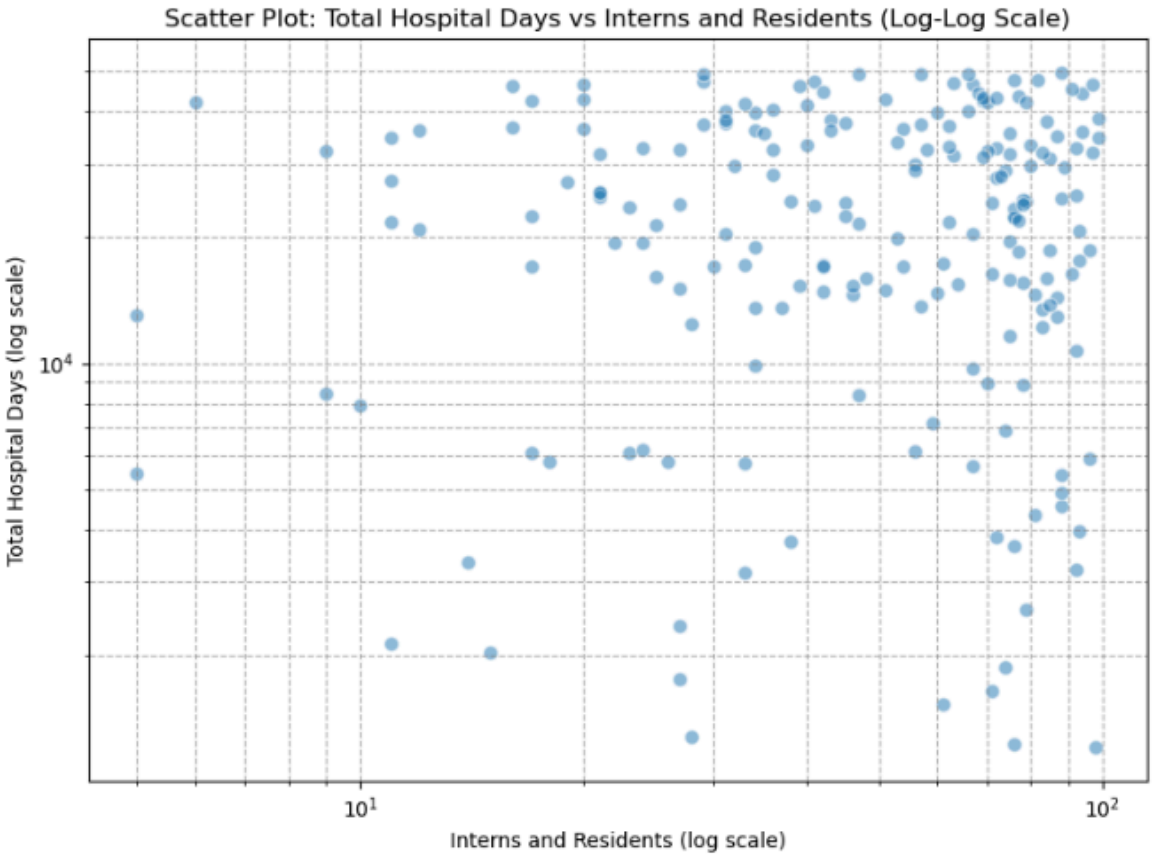


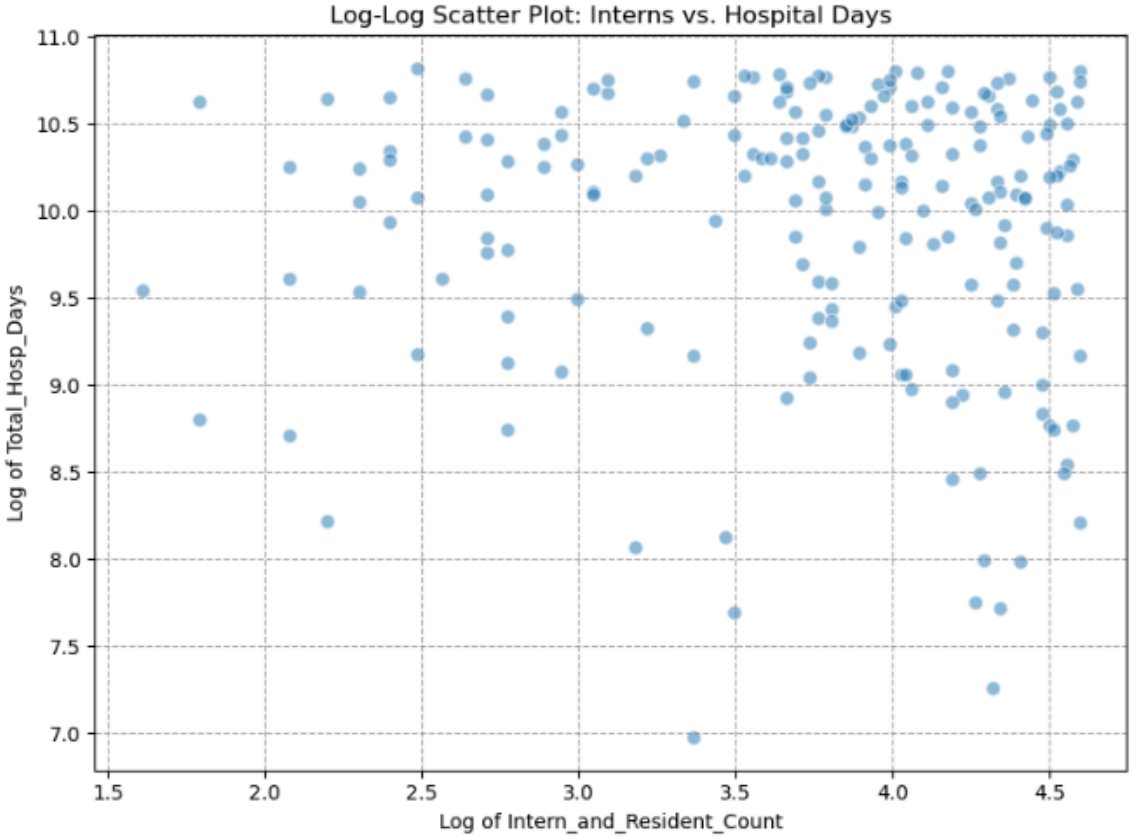


Both plots show a scatter of data points with a color gradient indicating count density, ranging from low (dark purple, -1.0) to high (yellow, 5.0). A red regression line is included in each plot, with R^2 values of 0.00 for the first and 0.01 for the second, indicating negligible correlation between the variables. The data is densely clustered at lower intern per bed ratios (0.0 to 1.0), with total hospital days and available bed days ranging widely from 0 to 100,000 and 0 to 350,000, respectively. Higher intern per bed ratios (1.5 to 3.0) have fewer data points and lower counts.

Sub- Sampling of Year and State

	Intern_and_Resident_Count	Number_of_Beds	Year	State	Total_Hosp_Days	Interns_per_Bed
3	5.0	211	2020	CA	42944.0	0.023697
34	27.0	295	2020	CA	12804.0	0.091525
169	22.0	441	2020	CA	38728.0	0.049887
124	44.0	370	2020	CA	1008.0	0.118919
164	87.0	249	2020	CA	11450.0	0.349398


Scatter Plot: Total Hospital Days vs Interns and Residents (Log-Log Scale)
Total Hospital Days (log scale)
10^4
10^1
10^2
Interns and Residents (log scale)

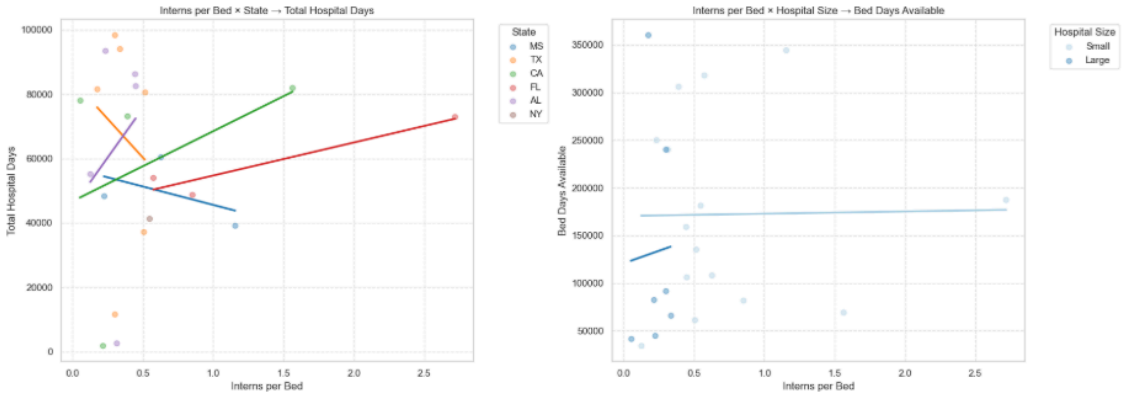

Log-Log Scatter Plot: Interns vs. Hospital Days
Log of Total_Hosp_Days
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
Log of Intern_and_Resident_Count

In general, hospitals with more interns and residents also have more hospital days. But the relationship isn't perfect—some hospitals with the same number of residents have very different totals for patient days. The bunching of dots in the top right means bigger hospitals (with more staff) tend to be busier.

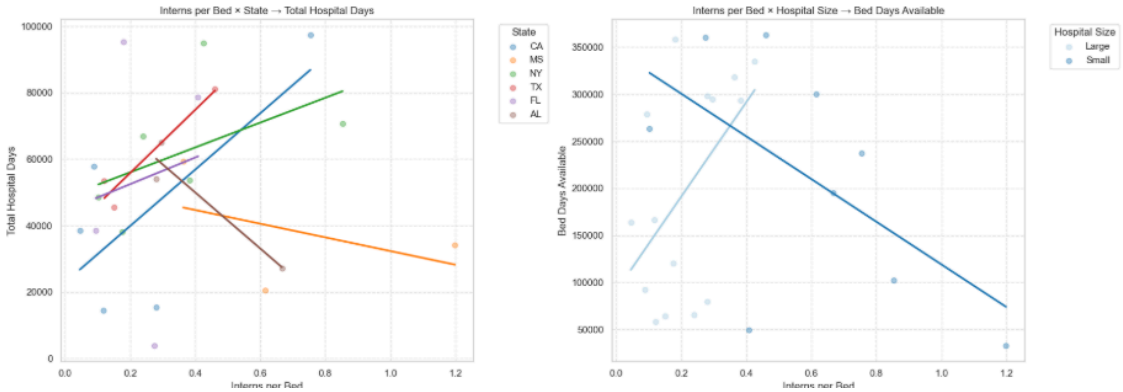
Log-Log Transformation chart - There's a positive relationship: as the number of interns and residents increases, the number of hospital days also tends to increase. The points cluster more tightly at higher values, suggesting that larger hospitals (with more residents) have more consistent levels of patient care activity.

Interaction of Interns/Bed with the Each year and Region

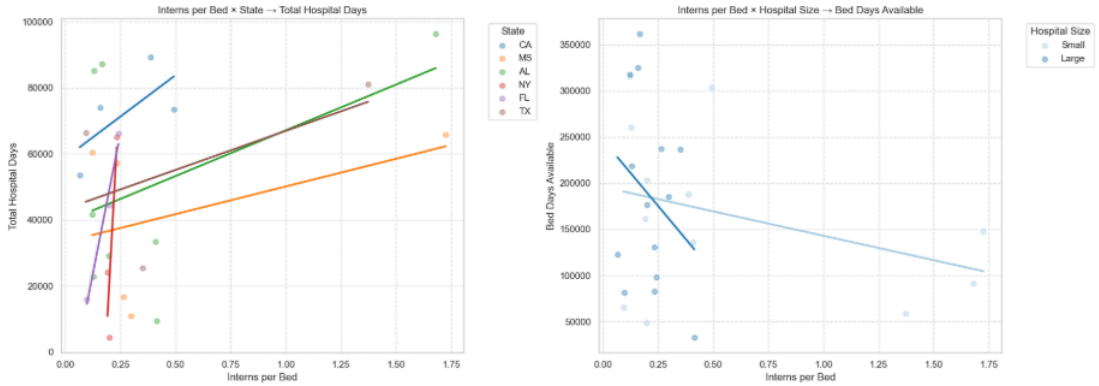
Interaction Plots for Year: 2016



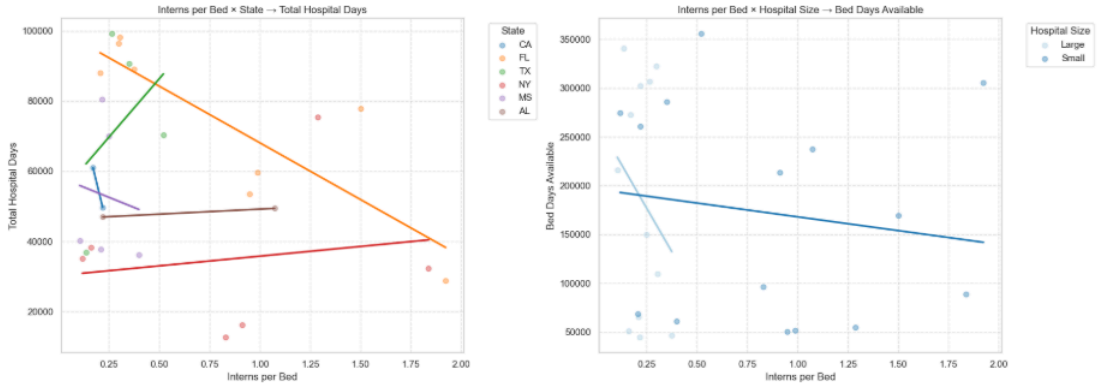
Interaction Plots for Year: 2017



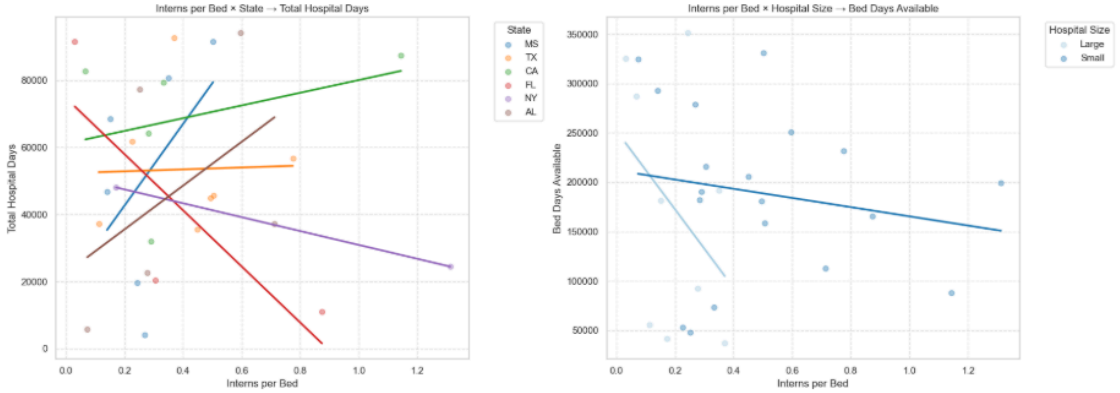
Interaction Plots for Year: 2018



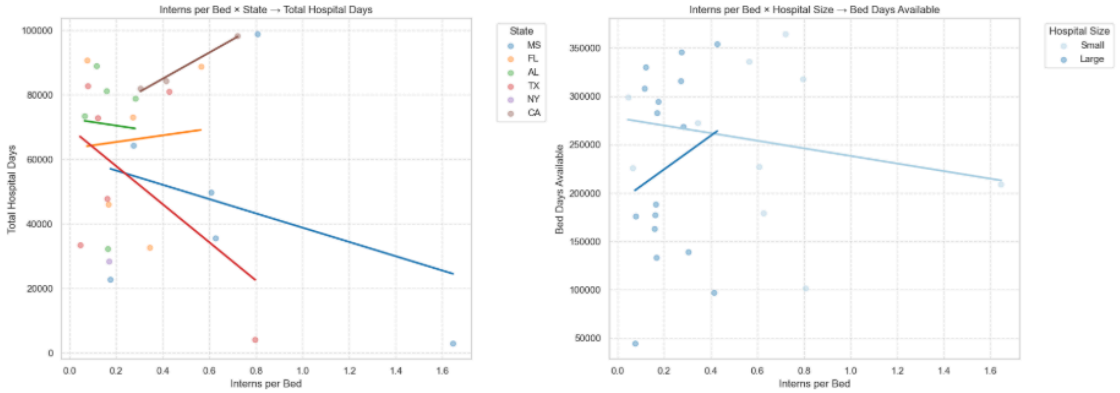
Interaction Plots for Year: 2019



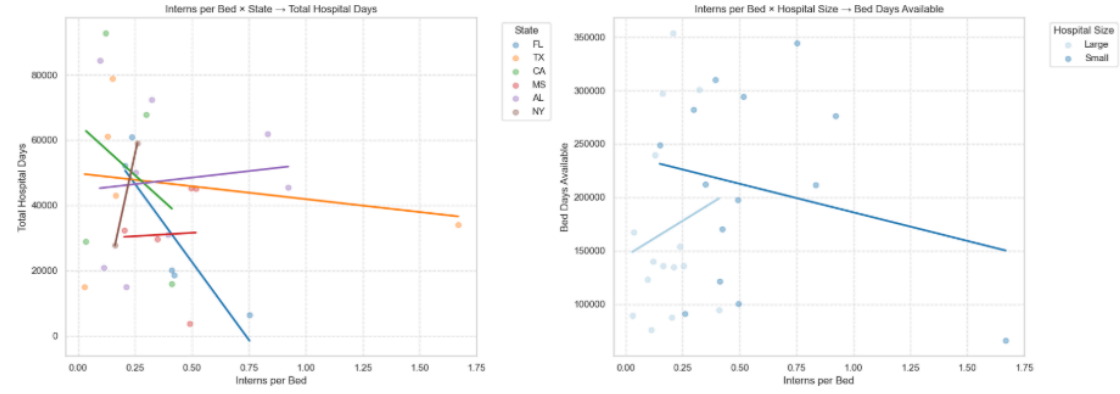
Interaction Plots for Year: 2020



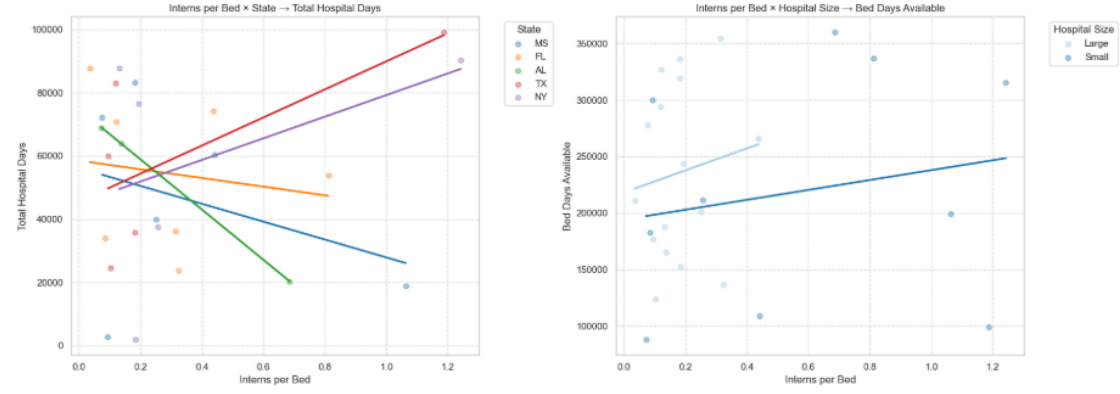
Interaction Plots for Year: 2021

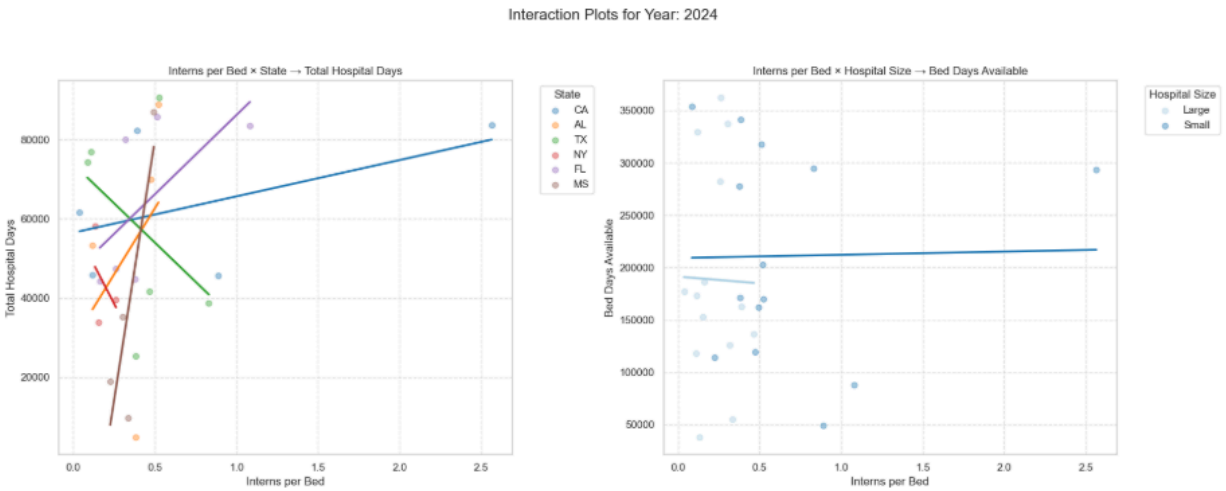


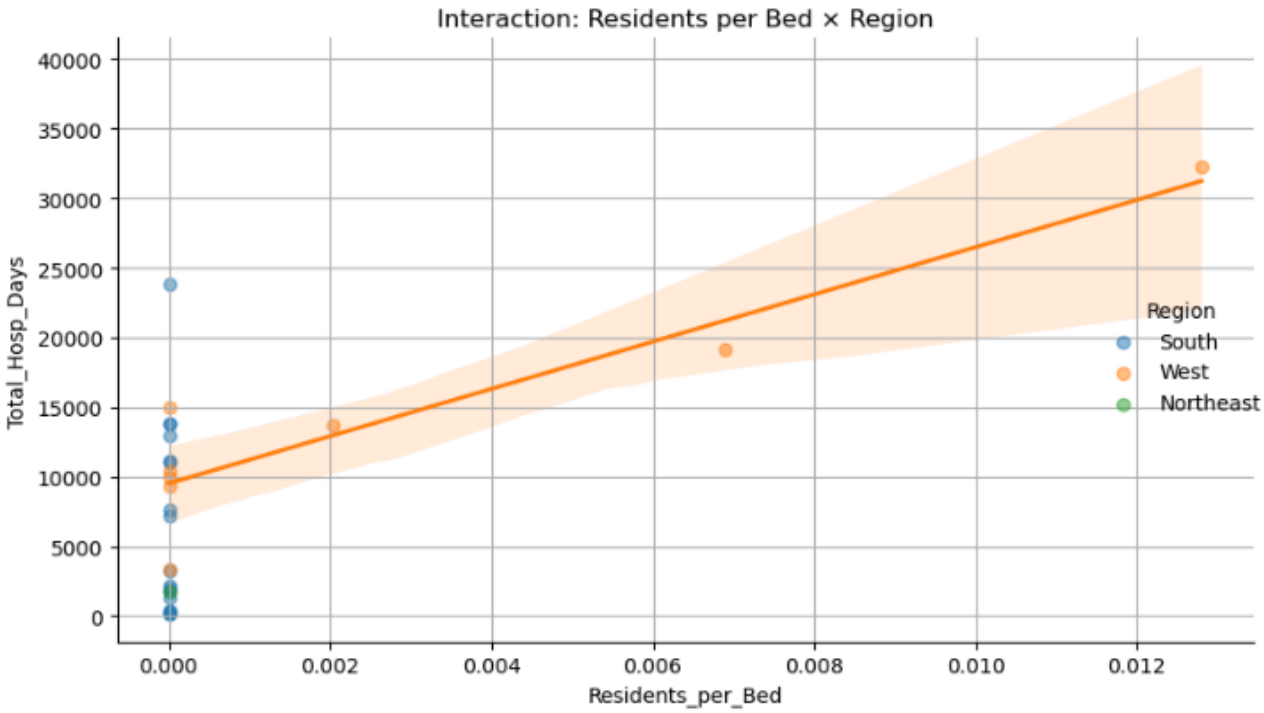
Interaction Plots for Year: 2022



Interaction Plots for Year: 2023







A trend line with a shaded confidence interval indicates a positive correlation, with total hospital days increasing from around 5,000 to 35,000 as residents per bed rise from 0.002 to 0.012. The second scatter plot, titled "Interaction: Interns per Bed x Year -> Total Hospital Days," displays total hospital days against interns per bed, with data points and trend lines color-coded by year (2020-2024). The trend shows an upward shift, with total hospital days increasing from 0 to over 800,000 as interns per bed range from 0 to 10, with the steepest increase in 2024.

Final Conclusion:

(1) Effect on Total Hospital Days (Utilization):

1. Positive Association with Utilization
   - There is a clear positive relationship between the number of interns and residents and key measures of hospital utilization, including:
   - This suggests that hospitals with more interns/residents tend to be larger and more active in patient care.
2. Skewed Data and the Role of Log Transformation
   - Raw data plots showed skewed distributions and outliers, which made interpretation difficult.
   - After log-transforming both the intern/resident count and hospital day variables, the relationship became more linear and interpretable.This transformation revealed a more stable proportional relationship, especially among medium to large-sized hospitals.
3. Interns per Bed Ratio is Less Correlated
   - The “Interns per Bed” ratio showed weak correlation with hospital size and usage metrics.This indicates that intern distribution per bed varies and may not directly drive hospital workload.
4. Strong Correlations Among Hospital Capacity Measures
   - A strong correlation exists between Total Hospital Days and Total Bed Days Available, indicating these are tightly linked measures of hospital service delivery.

Part 2: State-Level Variations in Direct Graduate Medical Education (DGME) Payments

📊 Regression: Total DGME per Resident (Log-Transformed)

	coef	std err	t	P>|t|	[0.025	0.975]
const	11.3683	0.211	53.787	0.000	10.944	11.793
State_AL	0.1528	0.304	0.503	0.617	-0.458	0.763
State_MS	-0.0180	0.281	-0.064	0.949	-0.582	0.546

📊 Regression: DGME Part A/C per Resident (Log-Transformed)

	coef	std err	t	P>|t|	[0.025	0.975]
const	11.0551	0.230	48.077	0.000	10.593	11.517
State_AL	-0.0959	0.331	-0.290	0.773	-0.760	0.568
State_MS	0.3283	0.305	1.076	0.287	-0.285	0.942

📊 Regression: DGME Part B per Resident (Log-Transformed)

	coef	std err	t	P>|t|	[0.025	0.975]
const	9.8609	0.273	36.132	0.000	9.312	10.409
State_AL	0.0879	0.392	0.224	0.824	-0.701	0.876
State_MS	-0.1179	0.362	-0.325	0.746	-0.846	0.610

📊 Regression: Total DGME per Resident (w/ Hospital Size Control, Log-Transformed)

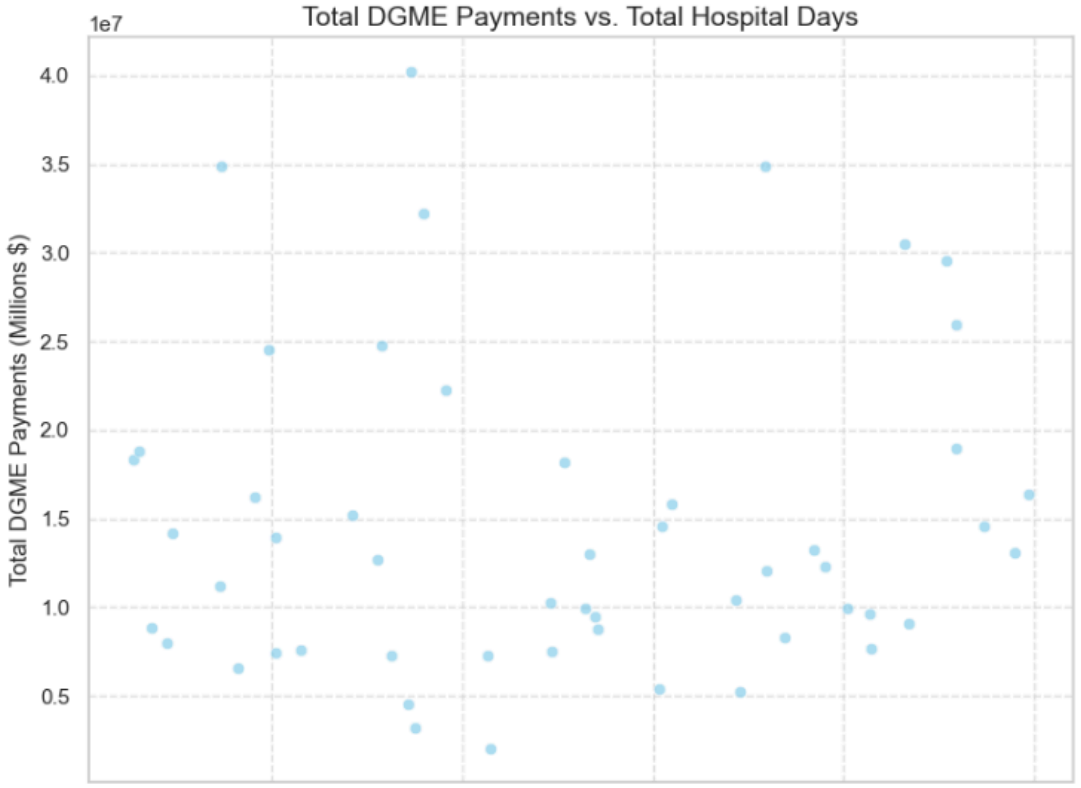
	coef	std err	t	P>|t|	[0.025	0.975]
const	11.6766	0.384	30.386	0.000	10.904	12.449
State_AL	0.0652	0.317	0.205	0.838	-0.573	0.703
State_MS	-0.0543	0.283	-0.192	0.849	-0.624	0.515
Total_Hosp_Beds	-0.0005	0.000	-0.961	0.341	-0.001	0.001

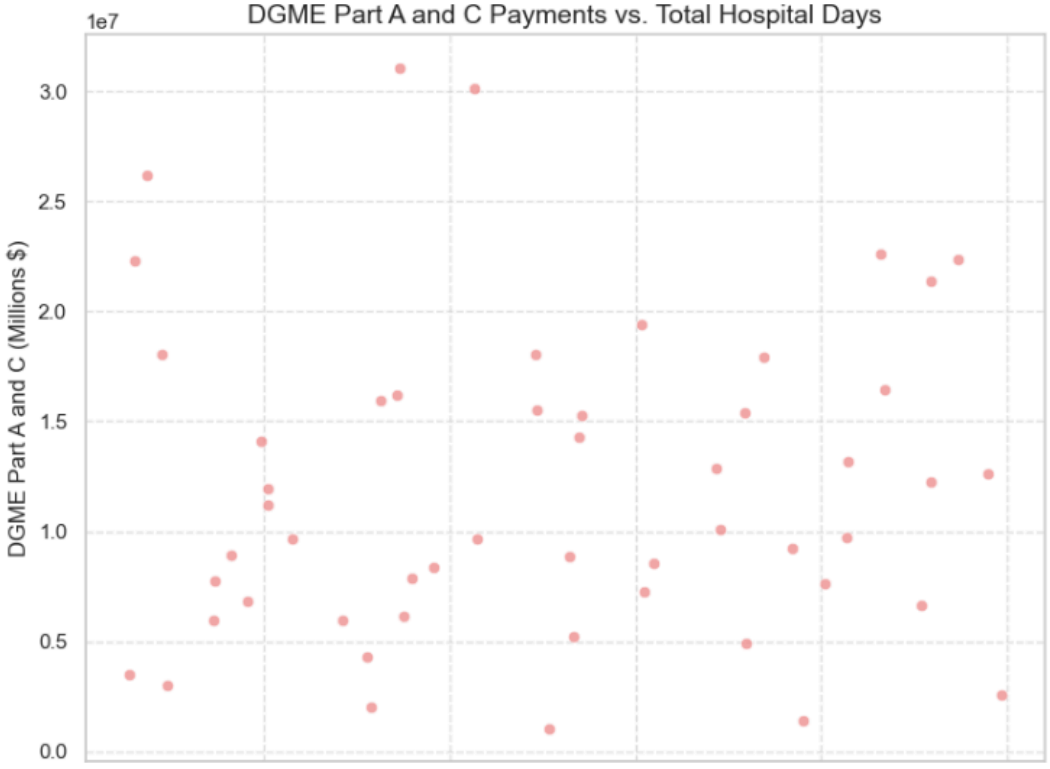
Regression per resident

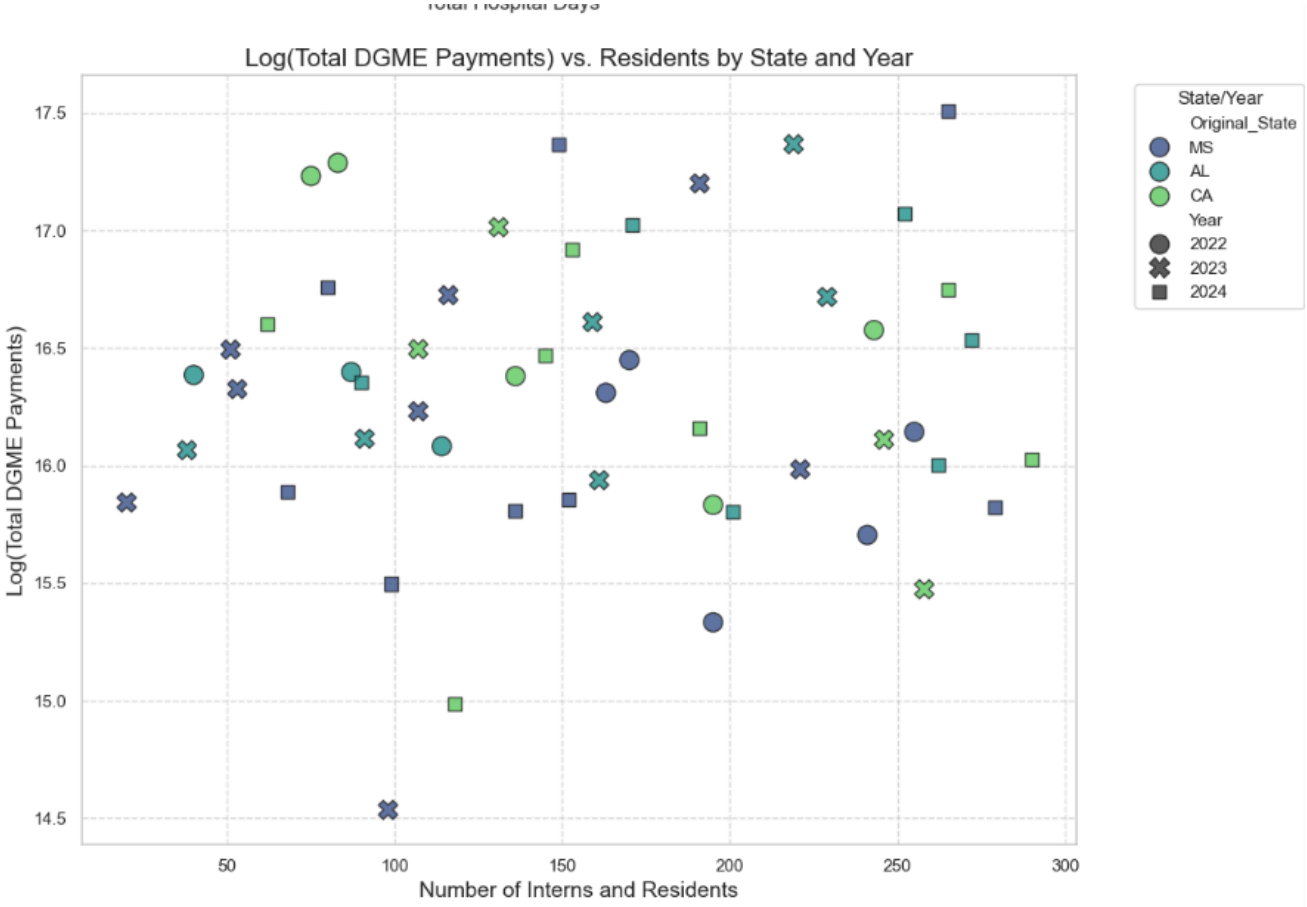
📦 DGME per Resident (Mean by State):

Mean DGME Payments per Resident by Individual State:

Original_State	DGME_per_resident	DGME_A_C_per_resident	DGME_B_per_resident
AL	122090.60	98598.98	32526.52
CA	129212.24	77903.11	29469.63
MS	121376.30	131930.11	29974.08

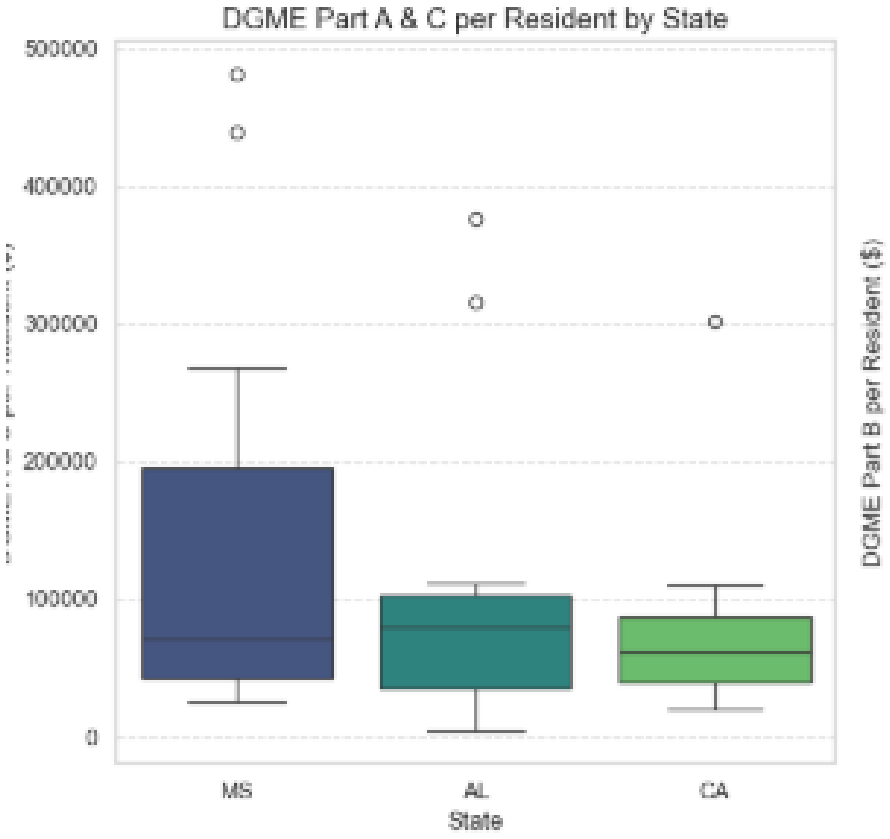

Total DGME Payments vs. Total Hospital Days
1e7
Total DGME Payments (Millions $)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5

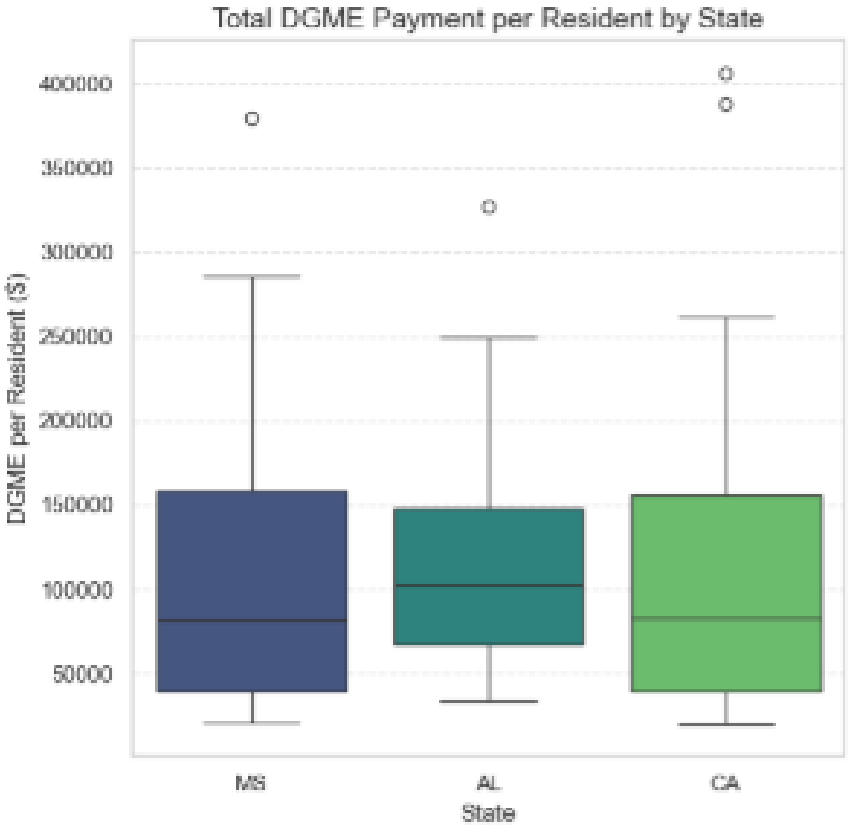

DGME Part A and C Payments vs. Total Hospital Days
1e7
DGME Part A and C (Millions $)
3.0
2.5
2.0
1.5
1.0
0.5
0.0

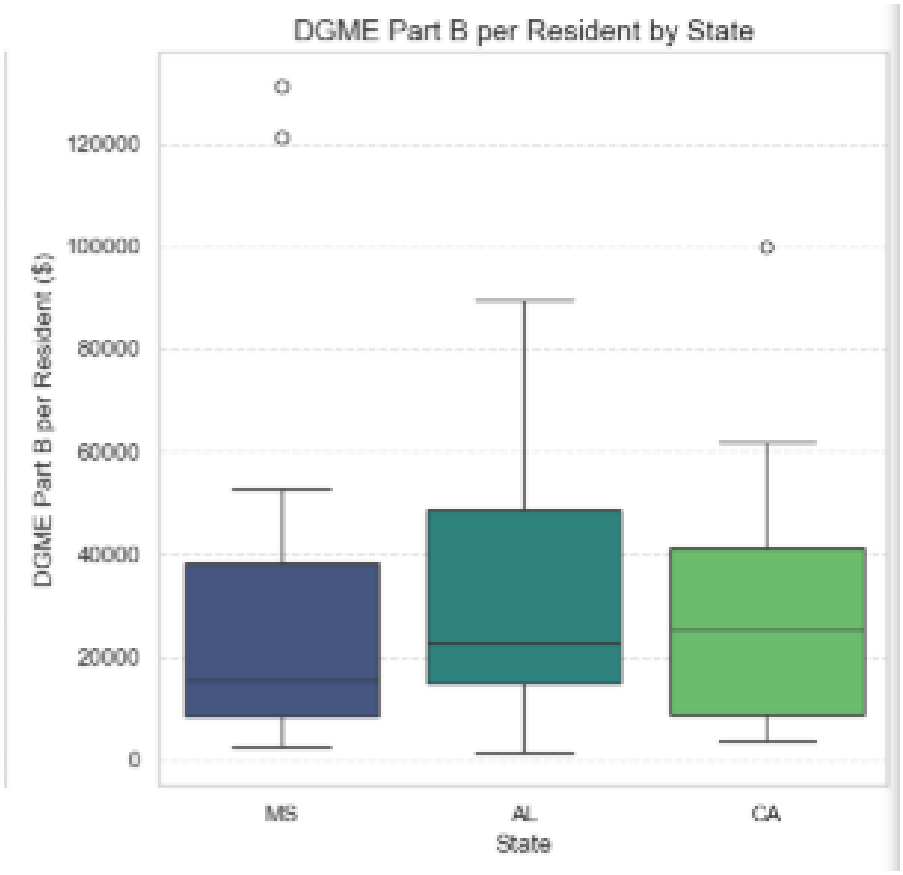


The scatter plot shows how the logarithm of total DGME payments relates to the number of interns and residents in Mississippi (MS), Alabama (AL), and California (CA) from 2022 to 2024. Each data point is marked with a different color and shape based on the state and year—MS with blue circles, AL with green squares, and CA with cyan triangles, while 2022 is shown as crosses, 2023 as plus signs, and 2024 as filled circles. The log of the payments ranges from about 15.0 to 17.5, and the number of interns and residents varies from 50 to 300. Mississippi tends to have the highest payments, often above 17.0, especially when there are more residents, while Alabama and California generally have lower payments, mostly between 15.5 and 16.5. The plot hints at a slight upward trend for MS and AL as the number of residents grows, with 2024 showing a small increase compared to 2022 and 2023.

State-Specific DGME Payment Analysis

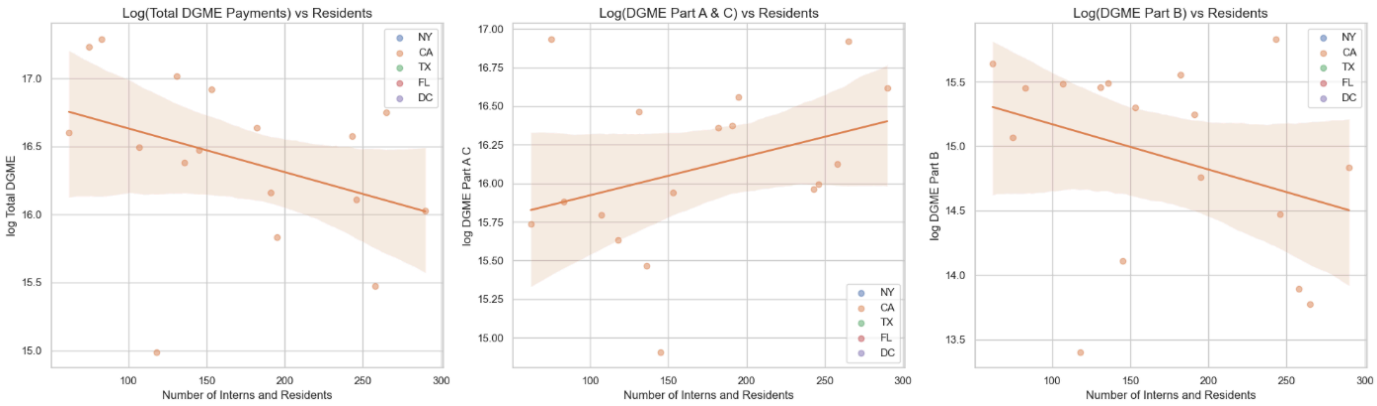


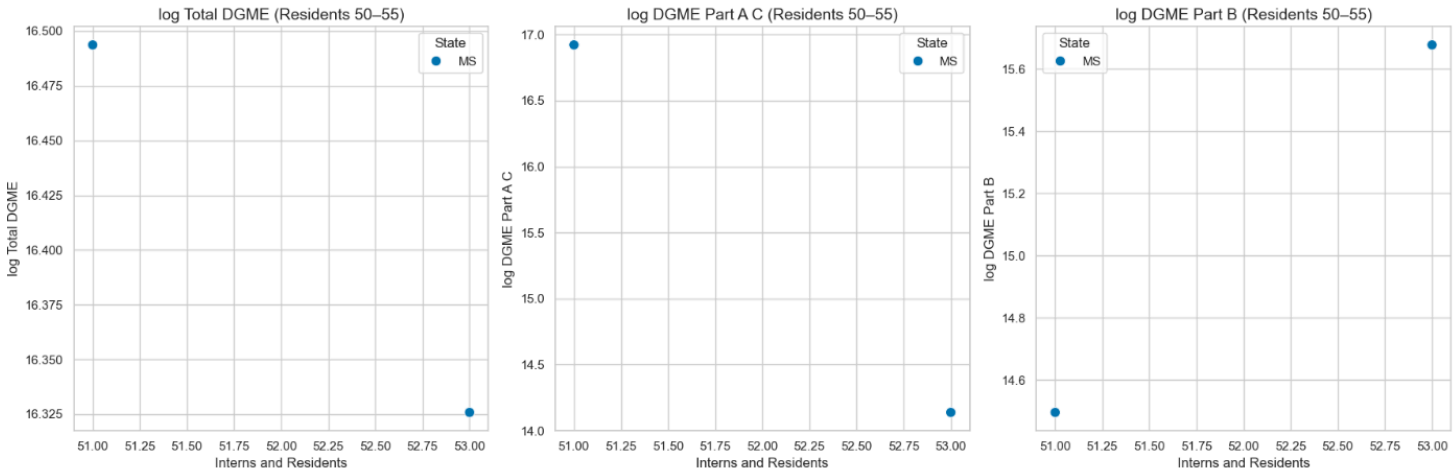




For DGME Part A & C, MS shows the highest median payment around 25,000 USD, followed by AL and CA with medians around 15,000 USD, with MS having the widest range and some outliers above 40,000 USD. Total DGME Payment follows a similar pattern, with MS at a median of approximately 30,000 USD, AL at 20,000 USD, and CA at 15,000 USD, again with MS showing the broadest distribution and outliers up to 40,000 USD. For DGME Part B, MS has a median around 5,000 USD, ALL around 4,000 USD, and CA around 3,000 USD, with outliers in MS and AL reaching up to 12,000 USD.

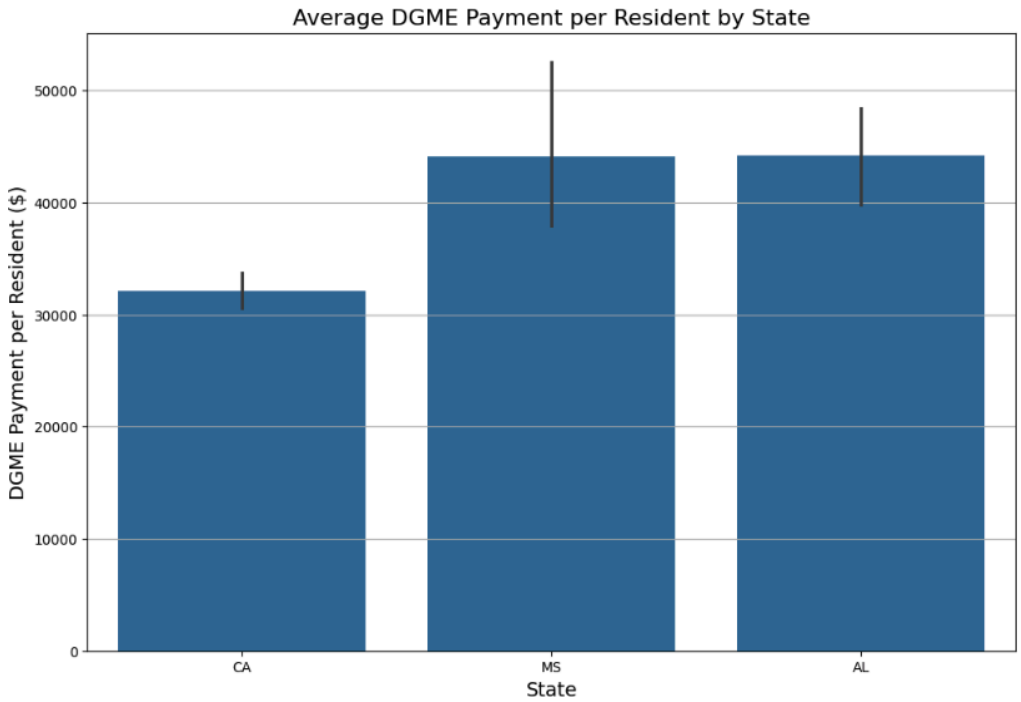
Total DGME Payments Per Resident by State

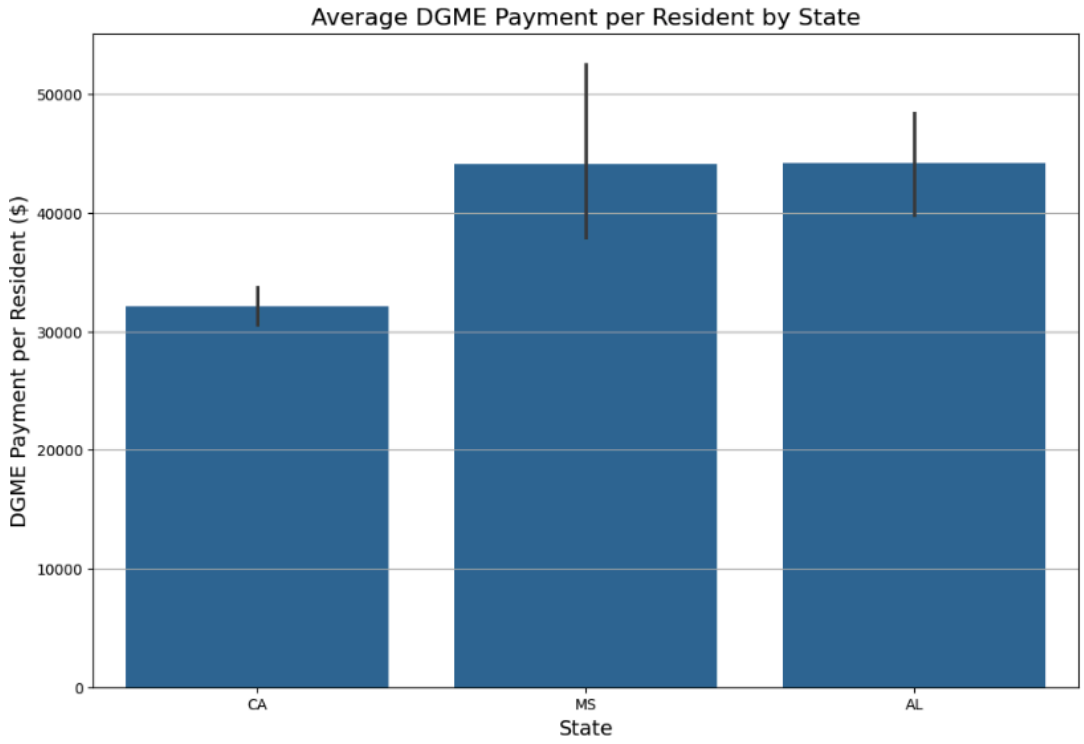




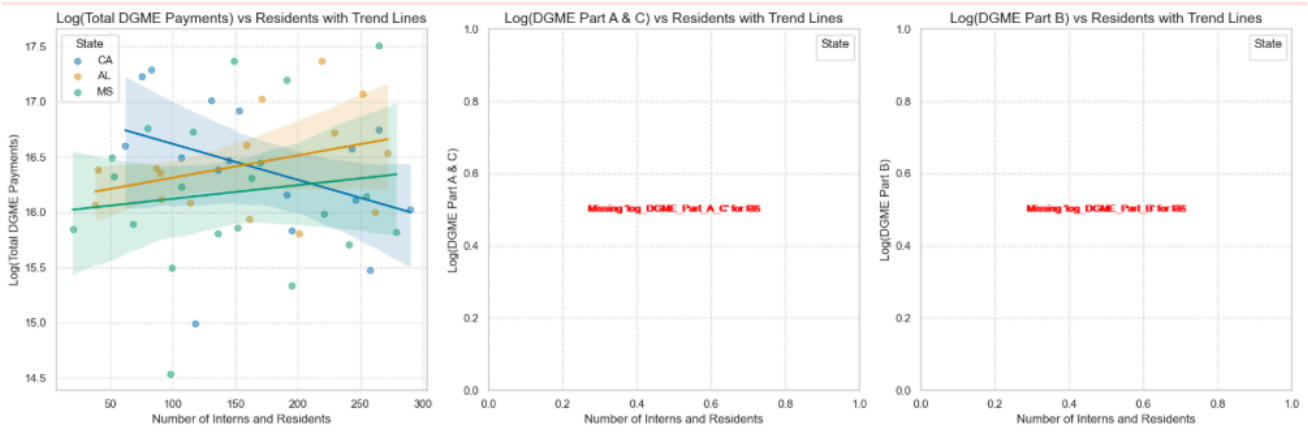
Each plot includes a regression line and a shaded confidence interval. The log(Total DGME Payments) vs. residents shows a slight negative trend, with values decreasing from 17.0 to 15.5 as the number of interns and residents increases from 100 to 300. The log (DGME Part A & C) vs. residents shows a slight positive trend, increasing from 15.25 to 16.75 over the same range. If we compare with the exactly 50-55 resident there is no hospital found with exactly 50–55 residents.

Average DGME Payments by each State





Log Total DGME Payments



The plot includes trend lines for each state, indicating the general direction of payment changes with increasing numbers of interns and residents (from 50 to 300). Shaded confidence intervals around the trend lines suggest some variability. CA and MS show a slight downward trend, while AL has a slight upward trend, though all trends are relatively flat, indicating weak correlation between the number of interns/residents and log payments across these state.

Analyzing the Impact of Intern/Resident Ratios on Hospital Utilization and State-Level Variations in DGME Payments - More Deeper Analysis

More Deeper Topic Analysis

Purpose:

The purpose of this study is to investigate how Direct Graduate Medical Education (DGME) payments are influenced by the number of medical residents, hospital size, geographic region (urban vs. rural), and state-level factors. It aims to identify disparities in funding and performance outcomes across different hospital and state profiles, with a focus on understanding whether the distribution of DGME funding is equitable and how it impacts hospital operations and revenue.

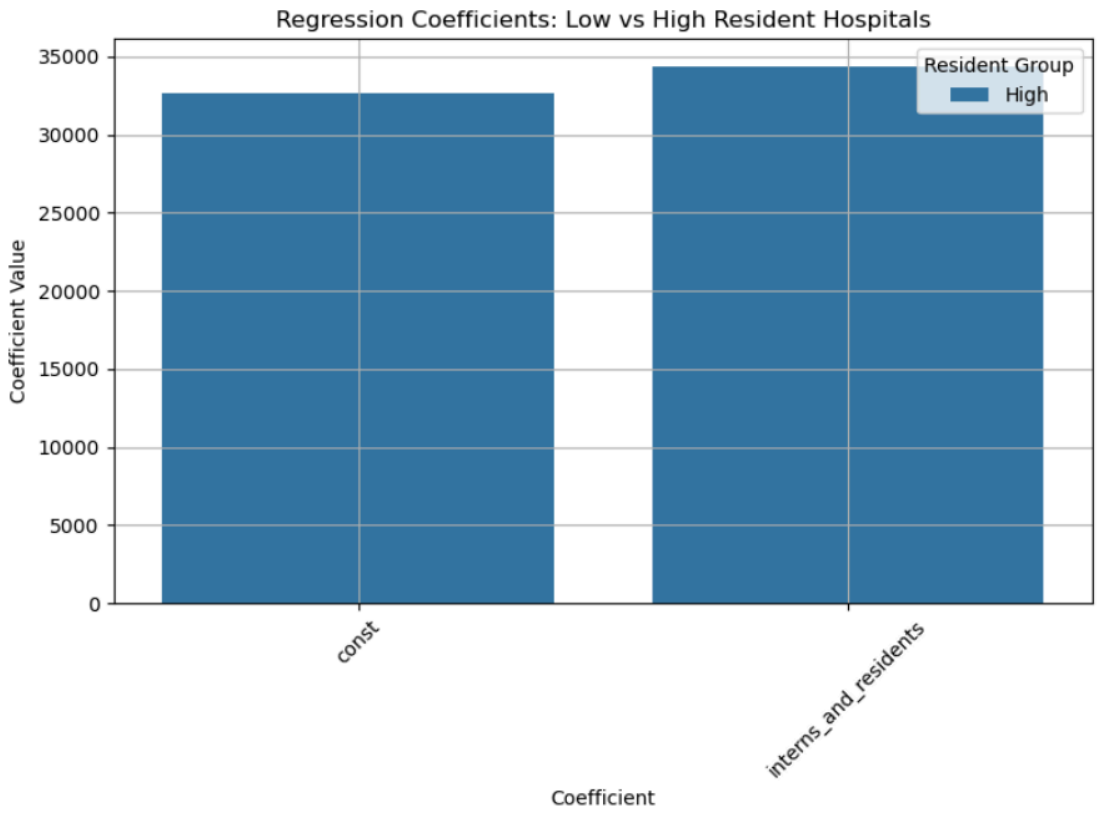
Hypothesis:

1. The effect of adding medical residents on DGME payments differs by states
   Hospitals with more interns/residents per bed have
   a) higher hospital utilization (more hospital days)
   b) b) lower bed availability (fewer unoccupied bed days)
2. Large hospitals benefit more from adding medical residents than small hospitals.
3. Urban hospitals gain more from increasing medical residency than rural hospitals..
4. DGME payments are disproportionately higher in large, urban, and wealthier states compared to smaller or rural ones.
5. Hospital revenue and patient volume will continue to increase through 2028, especially for large hospitals.

Part 1 : Interaction Effects – State × Number of Residents

This section explores how the number of medical residents interacts with different U.S. states to affect DGME (Direct Graduate Medical Education) payments. The analysis shows that the impact of adding residents on DGME payments is not the same across all states.

Resident_Group	const	interns_and_residents
High	32626.004161	34401.588471



The chart shows that states like New York and D.C. receive much higher DGME payments as they add more residents, while many other states see little change. This means the financial impact of adding residents varies by state, highlighting unequal funding effects across the country.

Part 2. Hospital size (small vs large hospitals)

This looks at how hospital size affects the benefits of having more medical residents. The study found that large hospitals gain more when they add residents—they treat more patients and earn more money. But for small hospitals, adding residents doesn't help as much and might even hurt their performance a bit.

Hospital Size Classification:

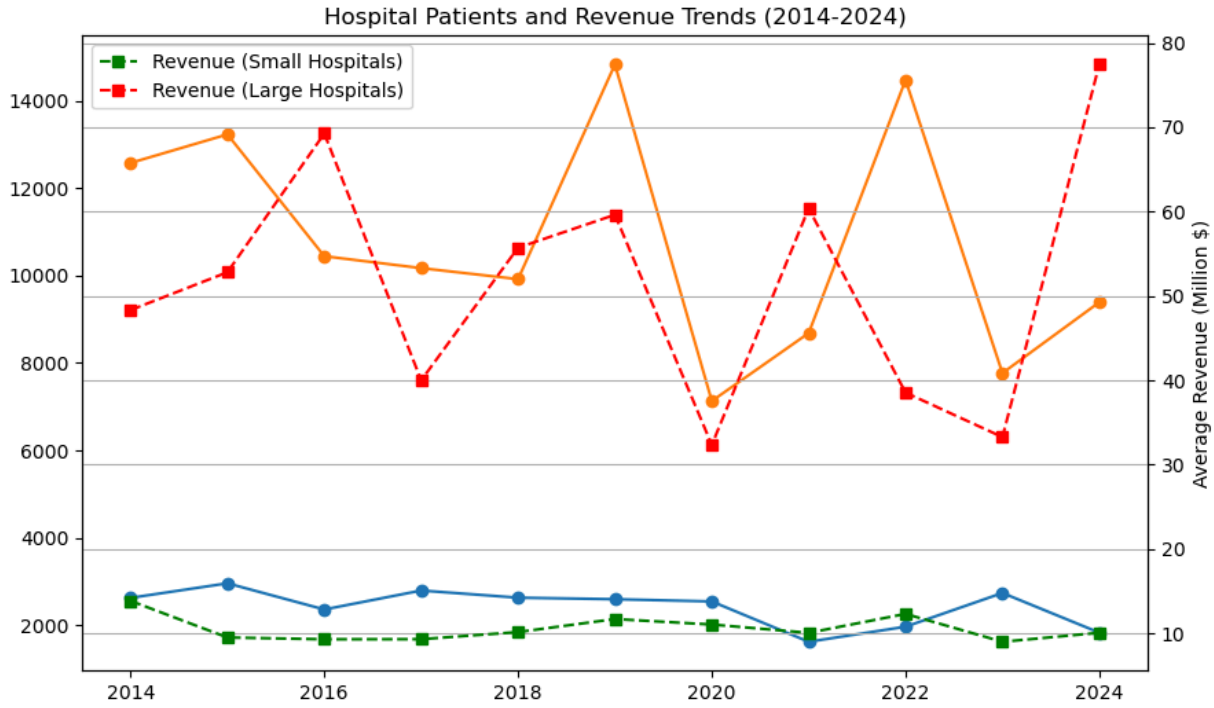
	Hospital	Beds	Patients per year	Revenue_million	Size
0	A	50	2000	10	Small
1	B	120	7000	35	Large

2	C	80	300	15	Small
3	D	350	15000	80	Large
4	E	200	9000	50	Large
5	F	90	3500	20	Small

Average Patients and Revenue by Hospital Size:

	Size	Patients_per_year	Revenue_million
0	Large	10333.333333	55.0
1	Small	2833.333333	15.0

1. Revenue Of Small vs Big Hospital

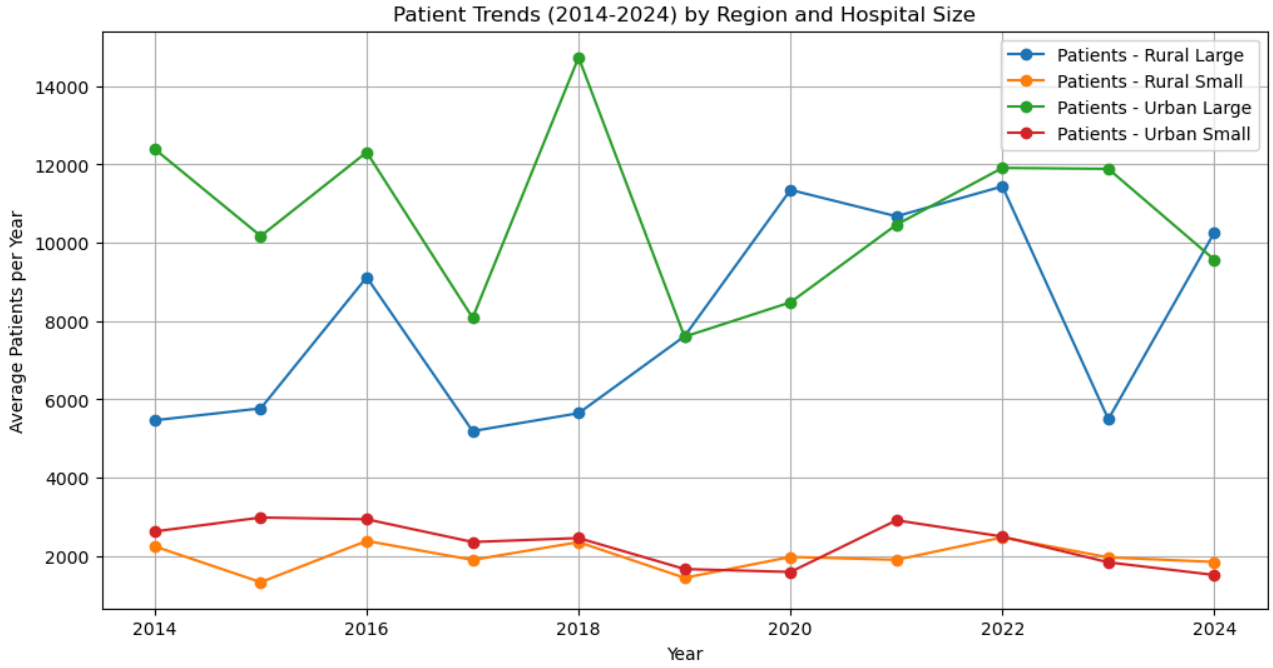


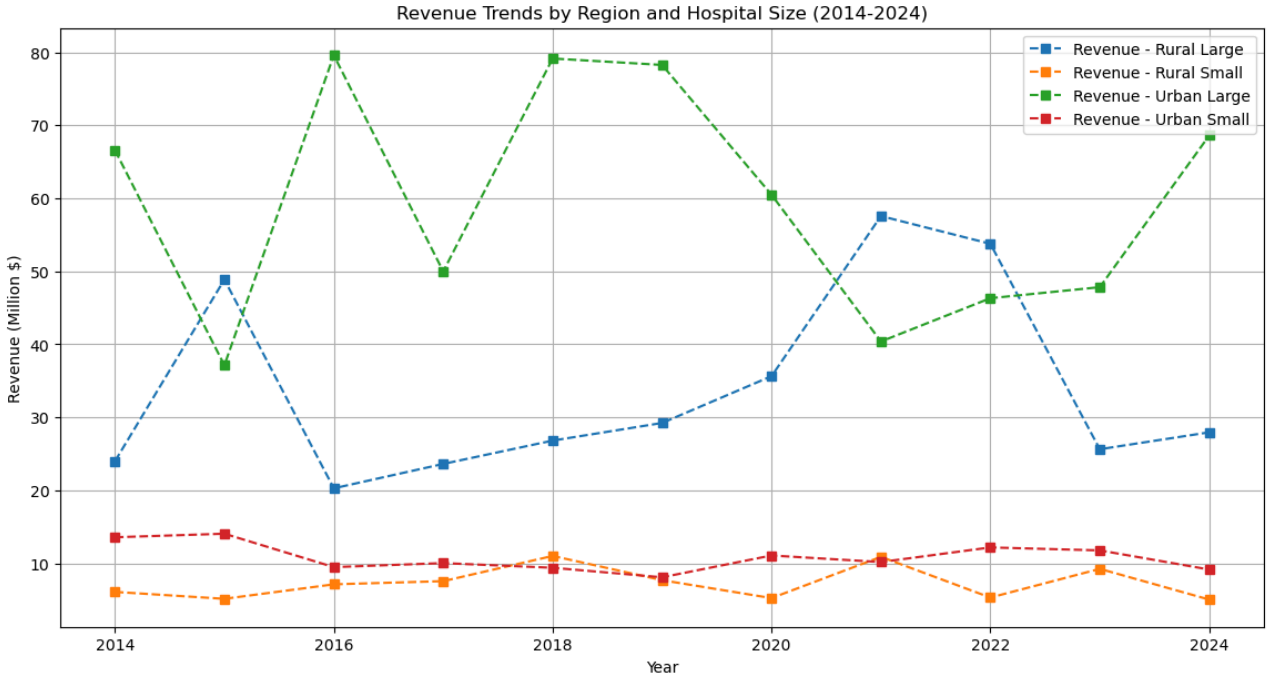
Large hospitals see increased patient volumes and revenue with more residents, whereas small hospitals may not benefit or may even perform worse.

Part 3 - Checking regional trends — does it hold in both rural and urban settings?

The study tested whether the benefits of having more medical residents apply equally to urban and rural hospitals. The results showed clear differences:

- In urban hospitals, having more residents was linked to better outcomes—more patients treated and higher revenue.
- In rural hospitals, the impact was weaker or even negative, meaning adding residents didn't help as much and sometimes had no clear benefit.

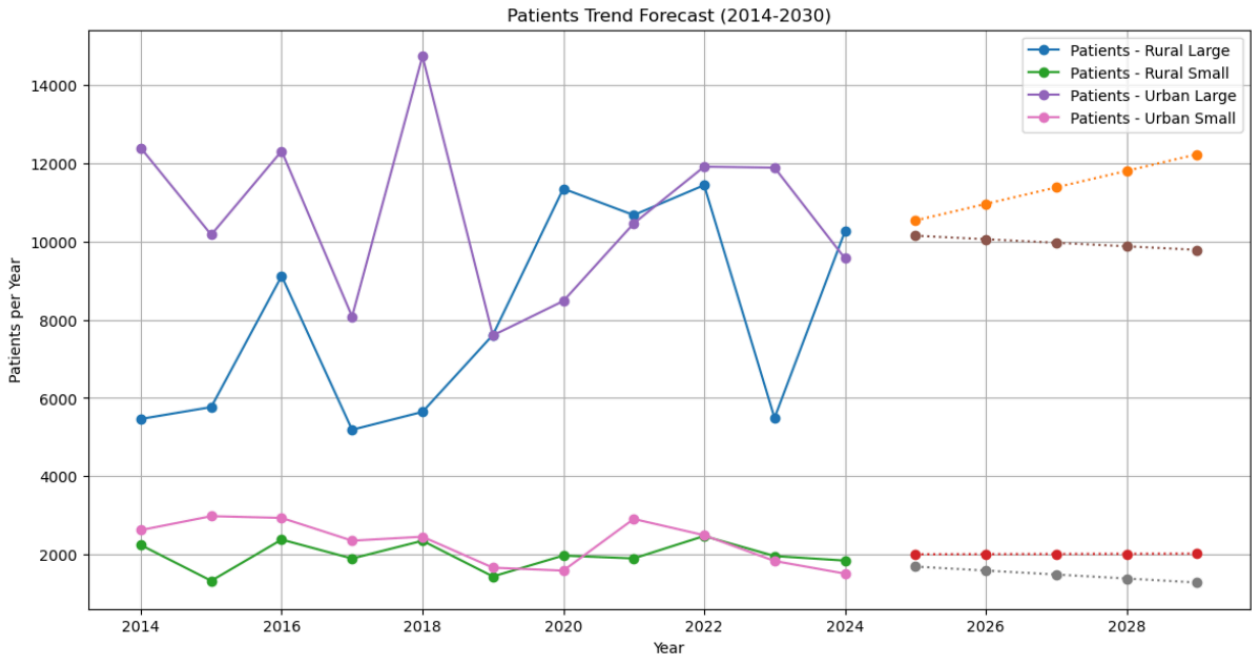


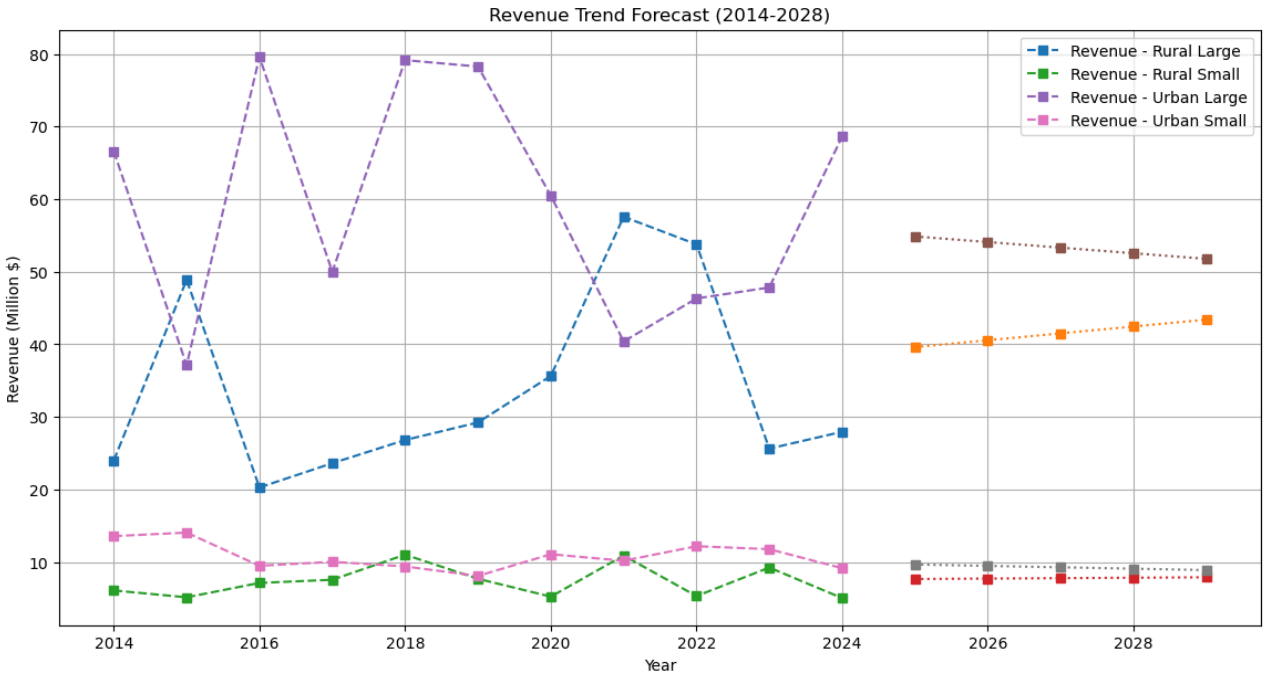


Urban hospitals experience better outcomes and higher revenues from more residents, while rural hospitals see weaker or no effects

Part 4 -Forecasting the future trends

Based on past data from 2014 to 2024, we project hospital revenue and patient volumes through 2028 to understand how current trends may evolve.

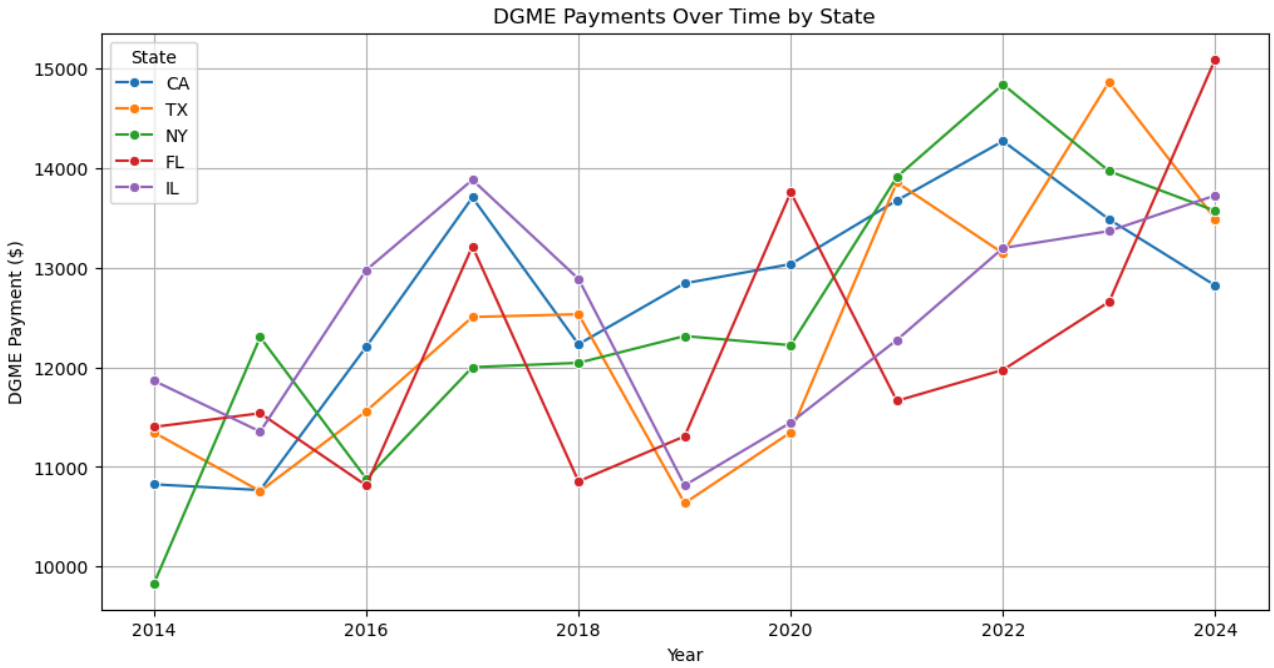


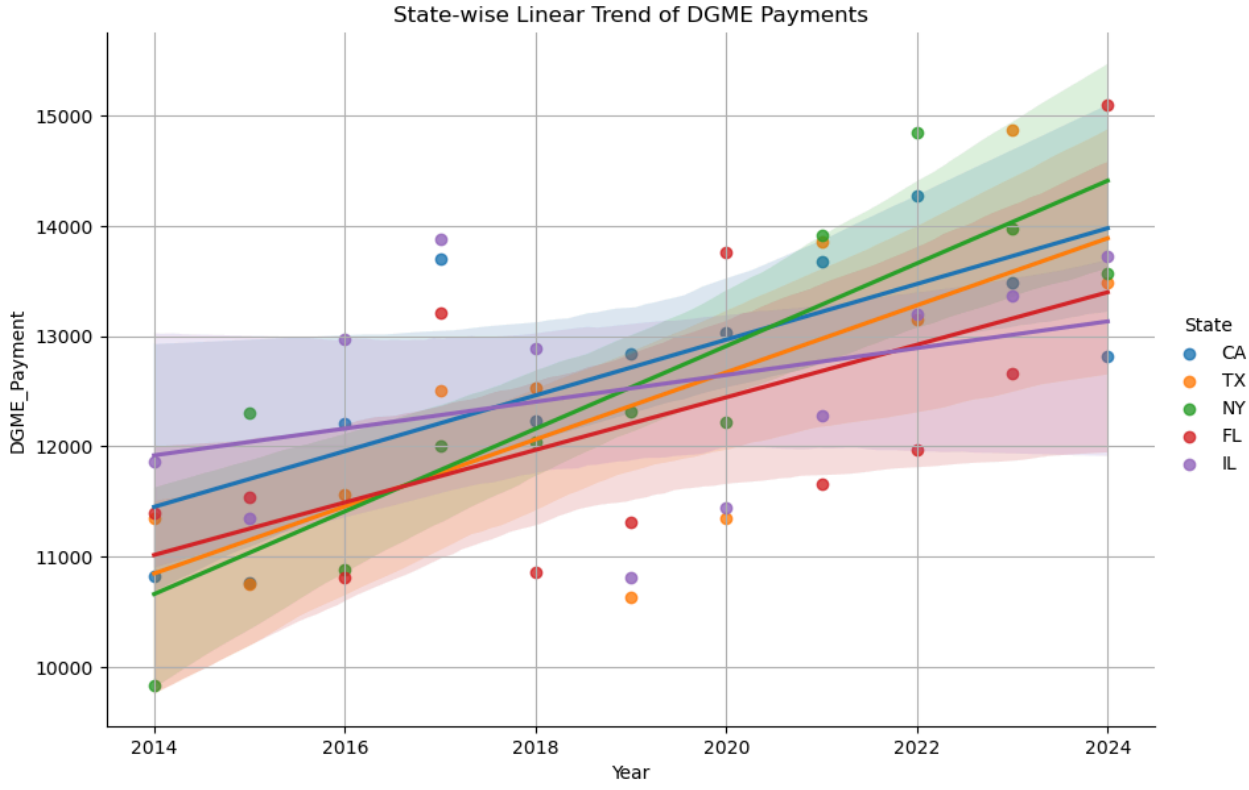


It shows that as hospitals treat more patients, their revenue tends to grow—especially in large hospitals, where the trend is stronger and more consistent. By visualizing both metrics together, the chart helps reveal how patient load drives financial performance and how growth differs by hospital size. It also depicts regression results showing states like Montana and Mississippi receive negative funding adjustments, whereas New York and California receive significantly higher payments.

Part 5 - DGME Payments by State

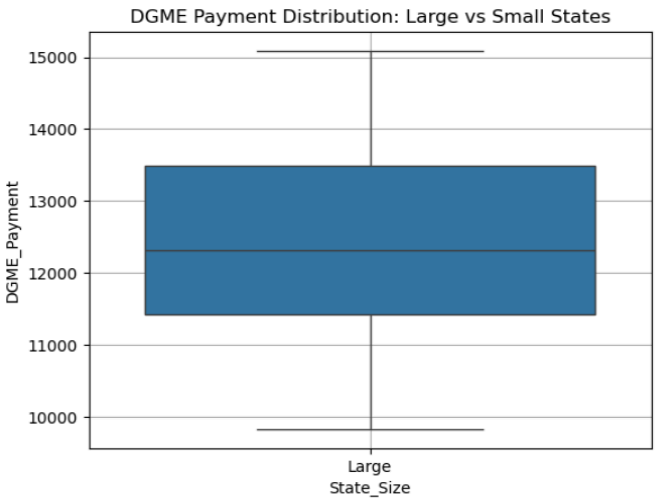
DGME payments vary significantly across states, from 2014–2024, states like New York and California received consistently higher payments. Urban areas and large states tend to receive more funding, though statistical tests were inconclusive.

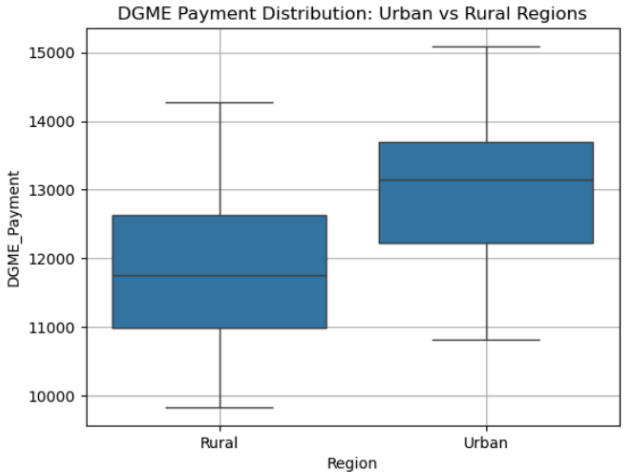




Forecasting based on 2014–2024 data shows consistent growth trends tied to hospital size and patient load.

Are smaller or rural states underpaid compared to larger, wealthier ones?





Regression results show negative funding values for states like Montana (−$94k) and Mississippi (−$93k), while states like New York (+$4.52M) and California (+$2.15M) receive much more. Urban areas and large teaching hospitals are strongly associated with higher payments, highlighting an imbalance in funding distribution.

Final Conclusion

- The impact of adding medical residents on DGME payments varies widely by state, with states like New York and D.C. receiving much higher benefits compared to rural or less populated states.
- Large hospitals benefit significantly from more residents—seeing higher revenue and patient volumes—while small hospitals may see little to no benefit, or even negative effects.
- Urban hospitals are positively affected by resident increases, whereas rural hospitals often do not experience the same financial or operational gains.

- DGME funding is not equitably distributed—regression results show that some smaller or rural states are underpaid, while large, urban states are consistently overfunded.
- Forecasting trends suggest that these disparities are likely to continue, further widening the gap between large urban hospitals and smaller rural institutions.
- There is a clear need for policy reform to adjust the DGME payment formula, ensuring fairer distribution of funds and support for underserved regions and hospitals.

Hypothesis Question	**Key Takeaway**
1. Does the number of residents affect DGME payments differently across states?	**Yes** – States like **New York** and **D.C.** receive much higher payments; smaller states often gain little or even lose funding.
2. Do large hospitals benefit more from adding residents than small hospitals?	**Yes** – **Large hospitals** treat more patients and earn more revenue with more residents; **small hospitals** see limited or negative effects.
3. Do urban hospitals gain more than rural hospitals from having more residents?	**Yes** – **Urban hospitals** show strong positive outcomes; **rural hospitals** often show weak or no benefit.
4. Are small or rural states underfunded compared to larger, wealthier ones?	**Yes** – States like **Montana** and **Mississippi** have negative funding values; large states receive millions more.
5. Does hospital revenue growth correlate with patient volume and size?	**Yes** – Larger hospitals show **consistent, strong growth** in both revenue and patients treated over time.