Hospital Closed:

Rural Hospital Closures and their Community Impacts

The Procrastinators

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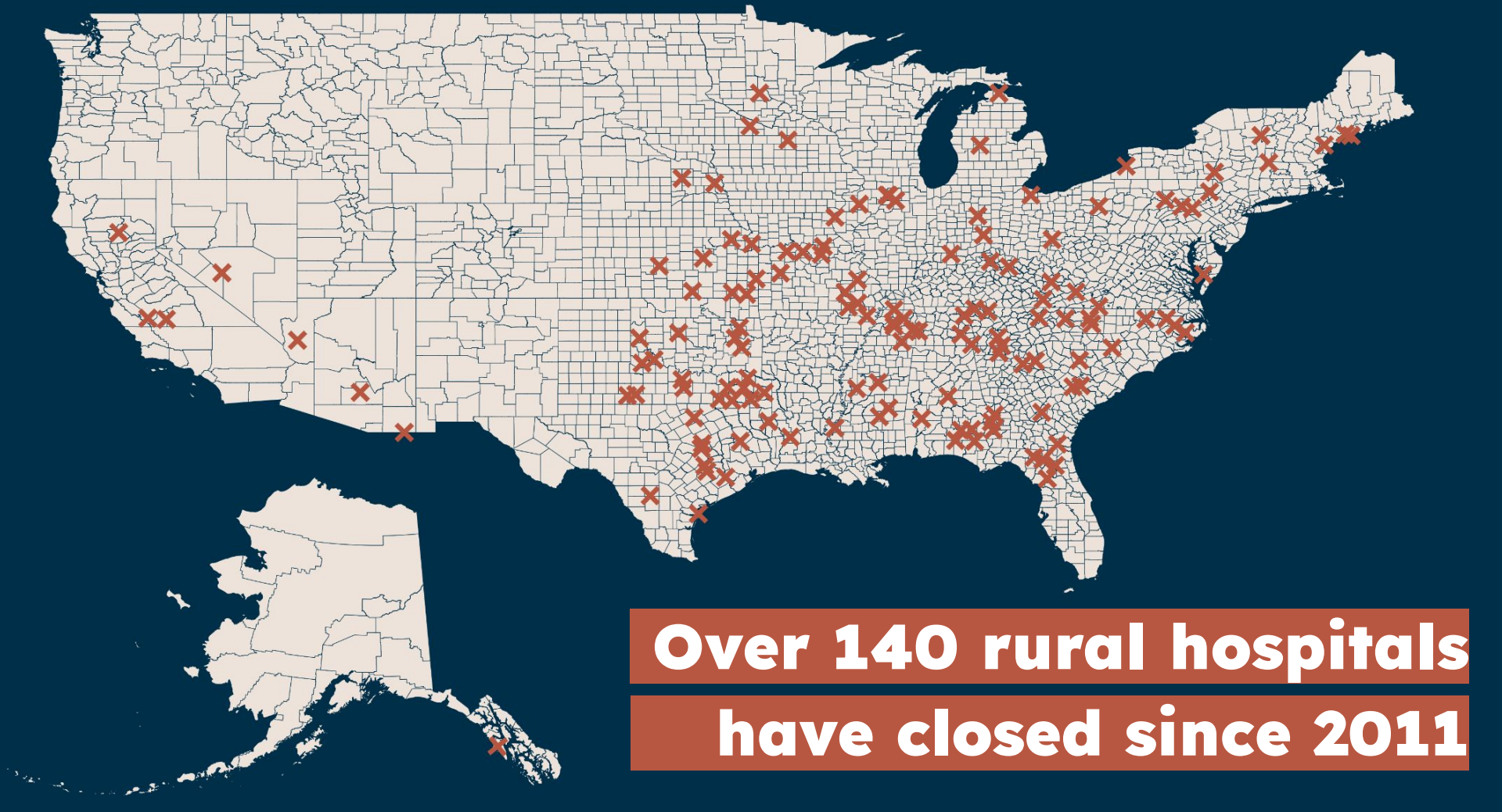

Over 140 rural hospitals
have closed since 2011

Decreases rural access to medical care
[5][6][7]

Harms surrounding economies
[1][2][4]

Increases outmigration pressure
[3][8]

Research Questions

1. **To what extent do rural hospital closures and conversions change prior migration trends?**

2. **To what extent can rural hospital closures be *predicted* based on county and hospital characteristics?**

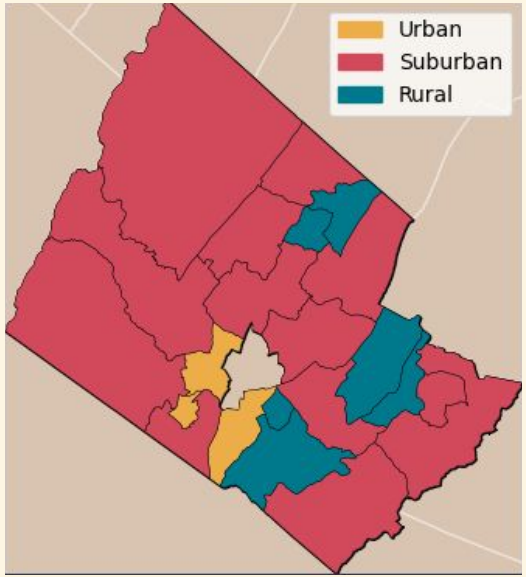
Data Sources

Data Wrangling Note

two datasets at the tract, zip level

Data Wrangling Note

RUCA Rurality Classification of Rockingham County Census Tracts



Rurality	Count	Percentage
Urban	3	3/22
Suburban	13	13/22
Rural	6	3/11
Total	**22**	**1**

RQ1. To what extent do rural hospital closures change prior migration patterns?

Approach: Difference-in-Difference Design

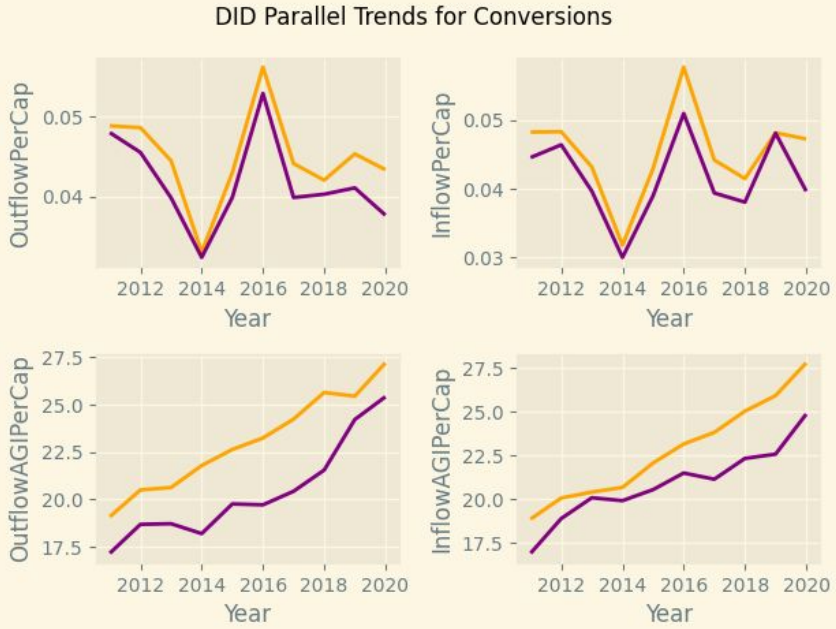
Control for regional effects

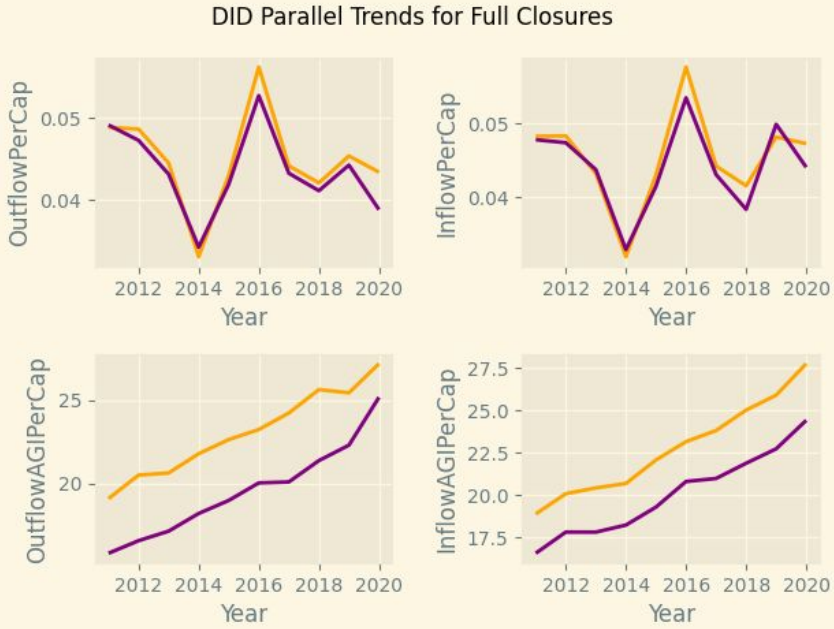
$$Y_{c,t} = \beta + \delta_{\text{DID}} \text{TREAT}_{c,t} + \sum_{k \in \text{Counties}} \alpha_k \text{COUNTY}_{k,c} + \sum_{n=2011}^{2020} \theta_t \text{YEAR}_{n,t}$$

(Indicator)
Has county c had a hospital closure by year t?

Control for temporal effects

Results





Parallel trends assumption appears satisfied

Results

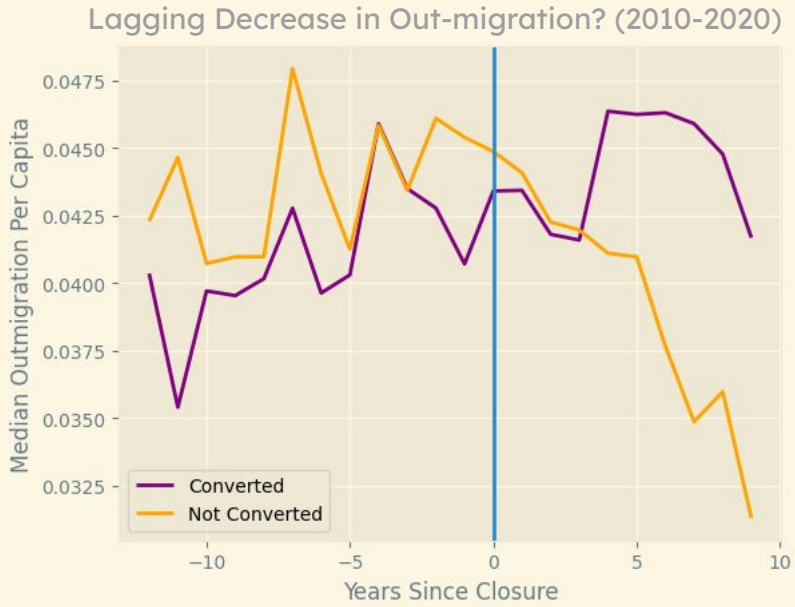
		Out-Flow		In-Flow	
		Individuals Per Capita	AGI Per Capita	Individuals Per Capita	AGI Per Capita
Full Closure	**Coefficient**	0.000	**-1.231**	**0.001**	**-1.416**
	p-value	0.7700	**0.0004**	**0.0197**	**0.0033**
Partial Closure	**Coefficient**	-0.001	-0.863	0.001	-0.425
	p-value	0.4949	0.2659	0.6669	0.7123

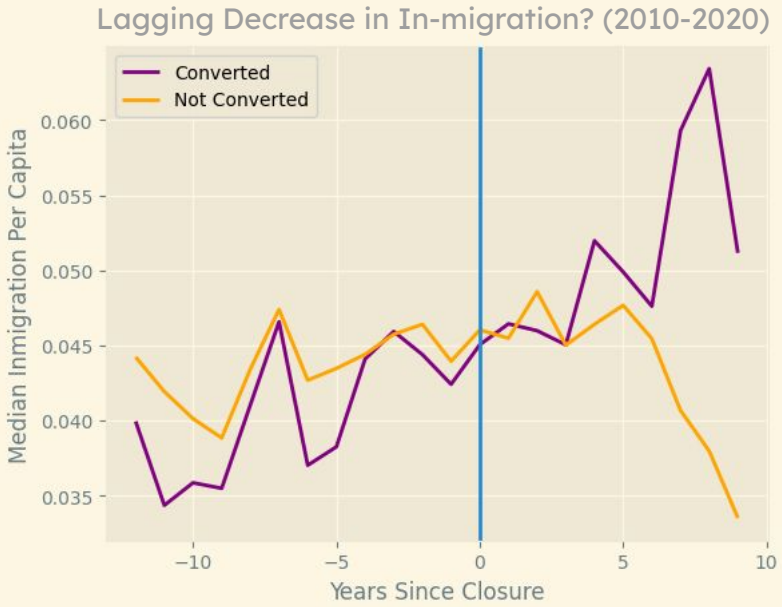
Even when statistically significant, effect sizes are incredibly small.

RQ1. To what extent do rural hospital closures change prior migration patterns?

Approach: Pretty Graphs!

Results


Lagging Decrease in Out-migration? (2010-2020)
Median Outmigration Per Capita
0.0475
0.0450
0.0425
0.0400
0.0375
0.0350
0.0325
Converted
Not Converted
−10
−5
0
5
10
Years Since Closure


Lagging Decrease in In-migration? (2010-2020)
Median Inmigration Per Capita
0.060
0.055
0.050
0.045
0.040
0.035
Converted
Not Converted
−10
−5
0
5
10
Years Since Closure

RQ2: To what extent can rural hospital closures be *predicted* based on county and hospital characteristics?

Overview of Data

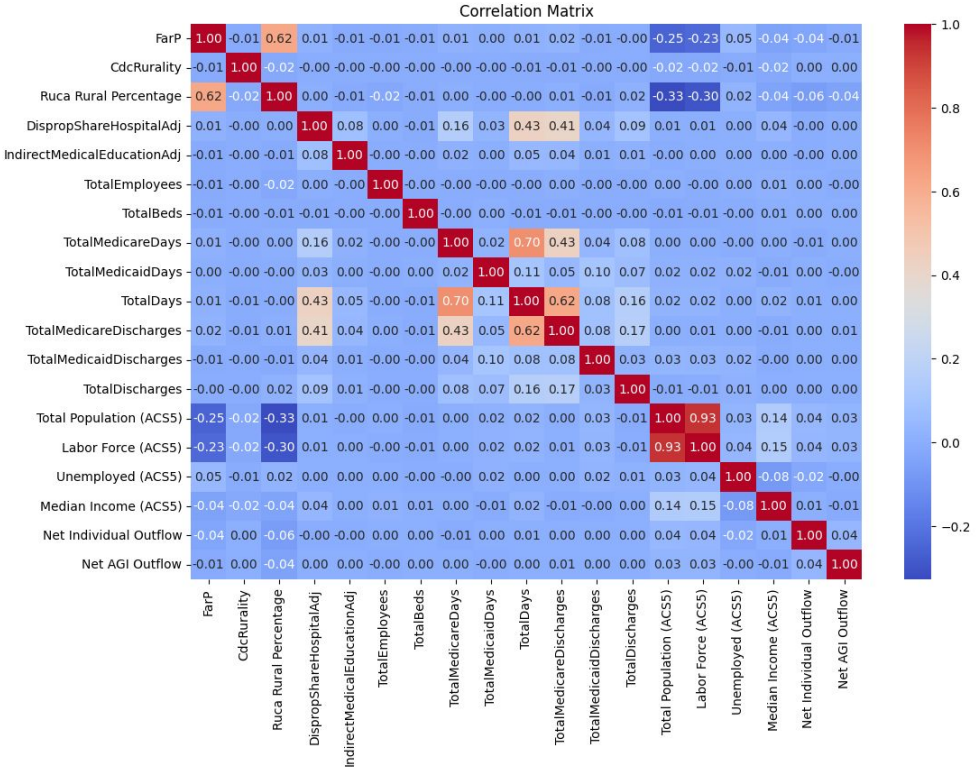
	HID	Year	Name	Address	City	State	Zip	DispropShareHospitalAdj	IndirectMedicalEducationAdj	TotalEmployees	...
61837	H673074	2020	EVEREST REHABILITATION HOSPITAL TEMP	23621 SE HK DODGEN LOOP	TEMPLE	TX	76504	0.0	0.0	59.35	...
61838	H673075	2020	COBALT REHAB HOSPITAL EL PASO	1600 E CLIFF DRIVE	EL PASO	TX	79902	0.0	0.0	33.90	...
61839	H713025	2020	NORTH SHORE REHABILITATION HOSPITAL	64030 HIGHWAY 434	LACOMBE	LA	70445	0.0	0.0	63.50	...
61840	H713025	2020	NORTH SHORE REHABILITATION HOSPITAL	64030 HIGHWAY 434	LACOMBE	LA	70445	0.0	0.0	133.85	...
61841	H713026	2020	BOGALUSA REHABILITATION HOSPITAL	621 S COLUMBIA STREET	BOGALUSA	LA	70427	0.0	0.0	10.16	...

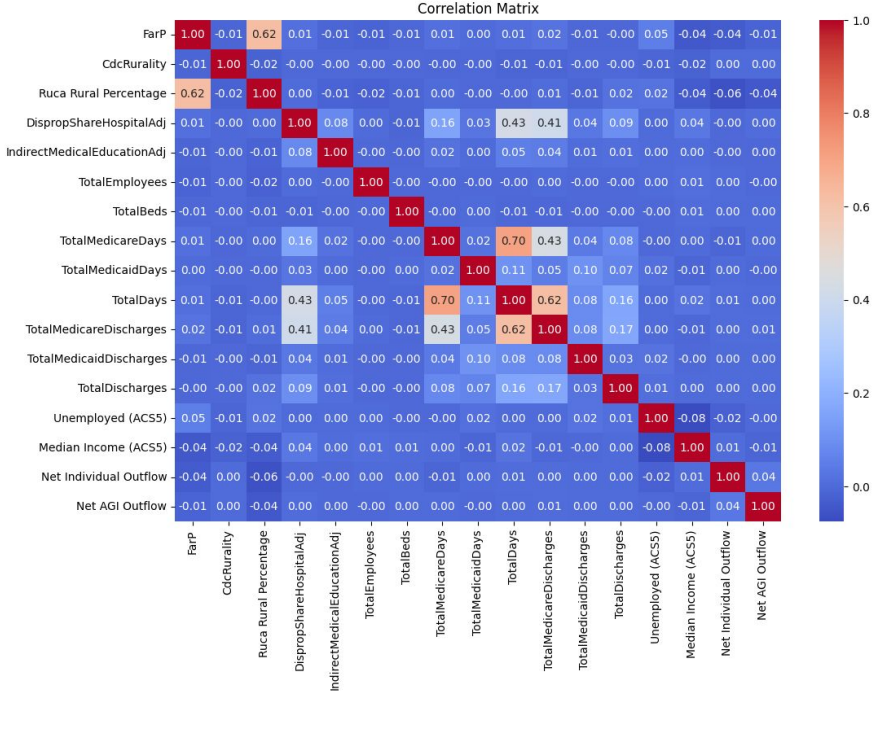
Our data has 61842 rows and 45 columns. We only have about 140 closed hospitals and in total 6787 hospitals. The dataset is very imbalanced.

Logistic Regression

- Binary Variable
- Assumption: Closure of hospital is not directly correlated with year
- Modify dataframe to find the change of variables
- Calculating percentage change

Logistic Regression of Percentage Change





Logistic Regression of Percentage Change

- From p-value result, FarP, Ruca Rural Percentage, Total Medicare Days, Total Days, and Median Income are significant estimator at 80% confidence interval
- The Pseudo R- Square is 0.1794

	coef	std err	z	P>|z|	[0.025	0.975]
const	-4.9695	0.192	-25.845	0.000	-5.346	-4.593
FarP	-0.0135	0.004	-3.641	0.000	-0.021	-0.006
CdcRurality	-1.453e-05	0.000	-0.065	0.948	-0.000	0.000
Ruca Rural Percentage	2.2666	0.270	8.381	0.000	1.737	2.797
DispropShareHospitalAdj	-0.0048	0.004	-1.354	0.176	-0.012	0.002
IndirectMedicalEducationAdj	5.478e-05	0.001	0.037	0.971	-0.003	0.003
TotalEmployees	-0.0011	0.003	-0.332	0.740	-0.007	0.005
TotalBeds	-6.005e-05	0.001	-0.059	0.953	-0.002	0.002
TotalMedicareDays	-0.0048	0.005	-0.918	0.359	-0.015	0.005
TotalMedicaidDays	0.0002	3.59e-05	4.376	0.000	8.68e-05	0.000
TotalDays	-0.0270	0.004	-6.694	0.000	-0.035	-0.019
TotalMedicareDischarges	0.0065	0.005	1.366	0.172	-0.003	0.016
TotalMedicaidDischarges	-6.233e-05	0.000	-0.235	0.814	-0.001	0.000
TotalDischarges	-0.0001	0.000	-0.345	0.730	-0.001	0.001
Unemployed (ACS5)	-0.0070	0.005	-1.355	0.175	-0.017	0.003
Median Income (ACS5)	-0.1139	0.023	-4.871	0.000	-0.160	-0.068
Net Individual Outflow	0.0002	0.000	1.205	0.228	-0.000	0.001
Net AGI Outflow	-8.072e-06	4.94e-05	-0.163	0.870	-0.000	8.88e-05

RQ2. To what extent can rural hospital closures be predicted based on county and hospital characteristics?

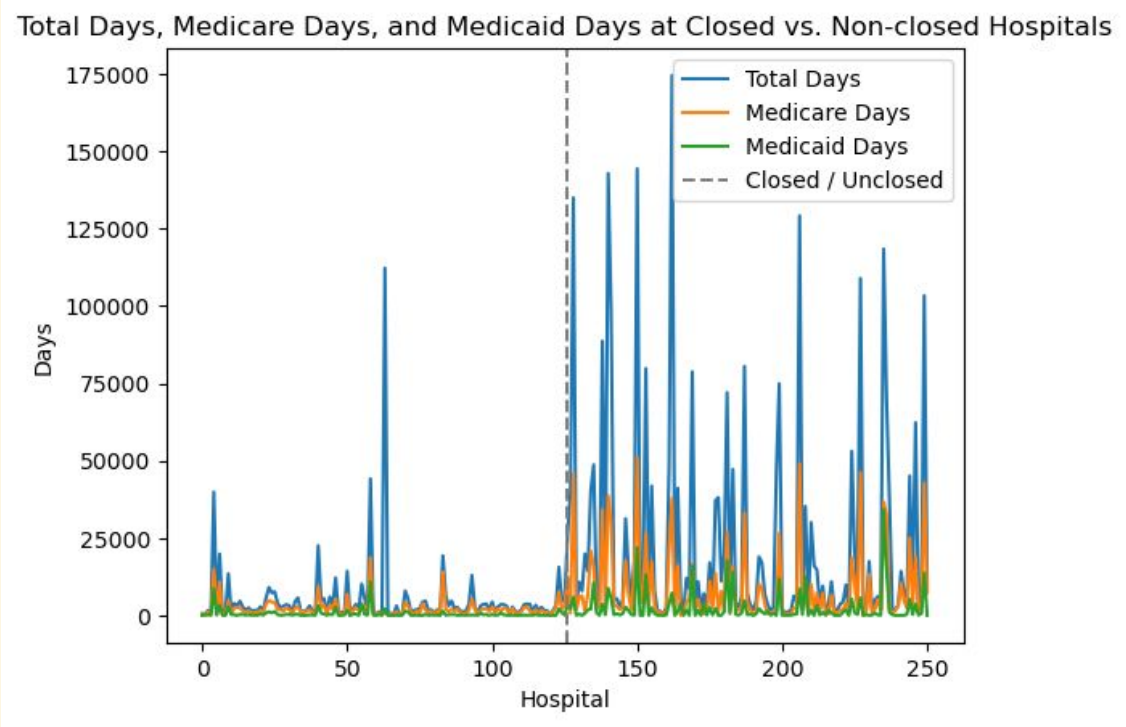
Approach:

balanced data

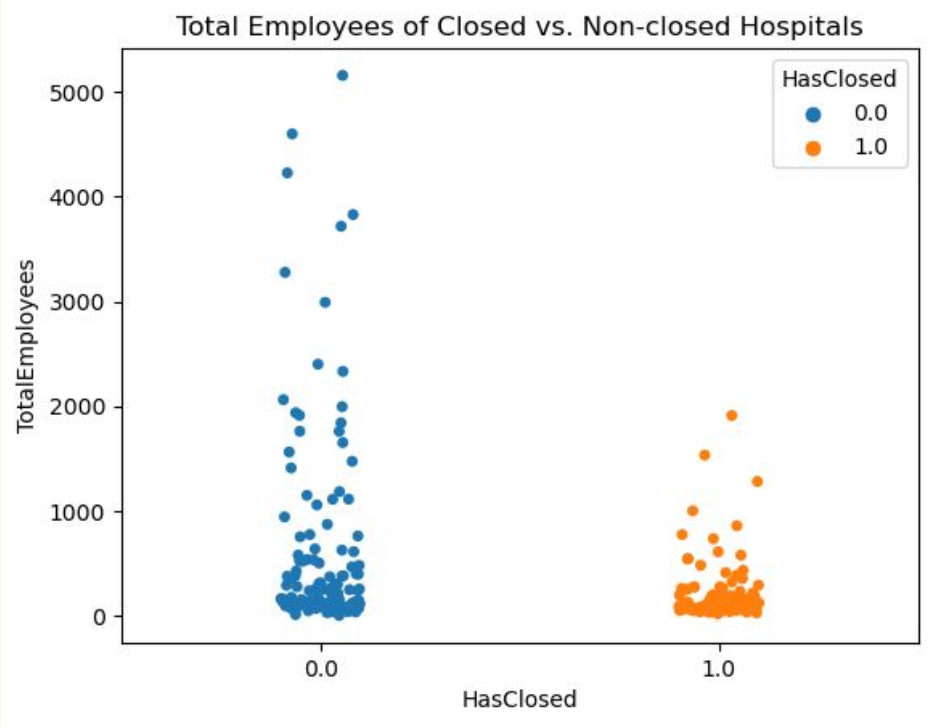
->

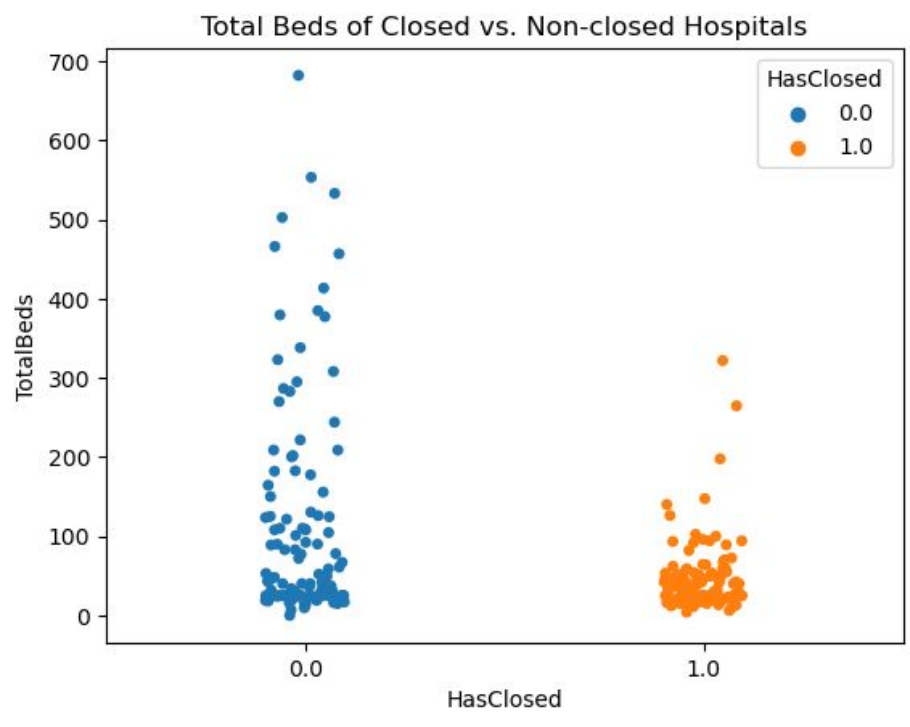
Pretty Graphs!

RQ2. To what extent can rural hospital closures be predicted based on county and hospital characteristics?

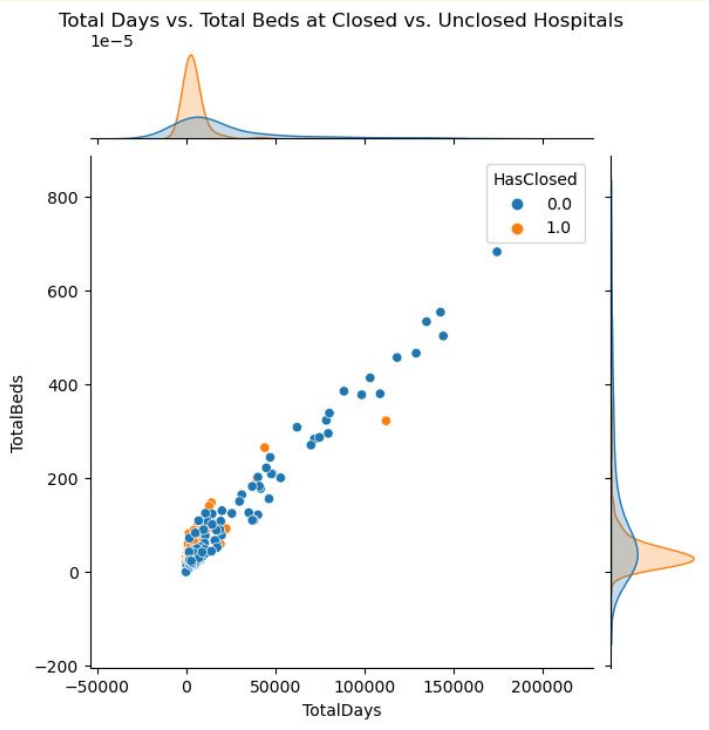


RQ2. To what extent can rural hospital closures be predicted based on county and hospital characteristics?





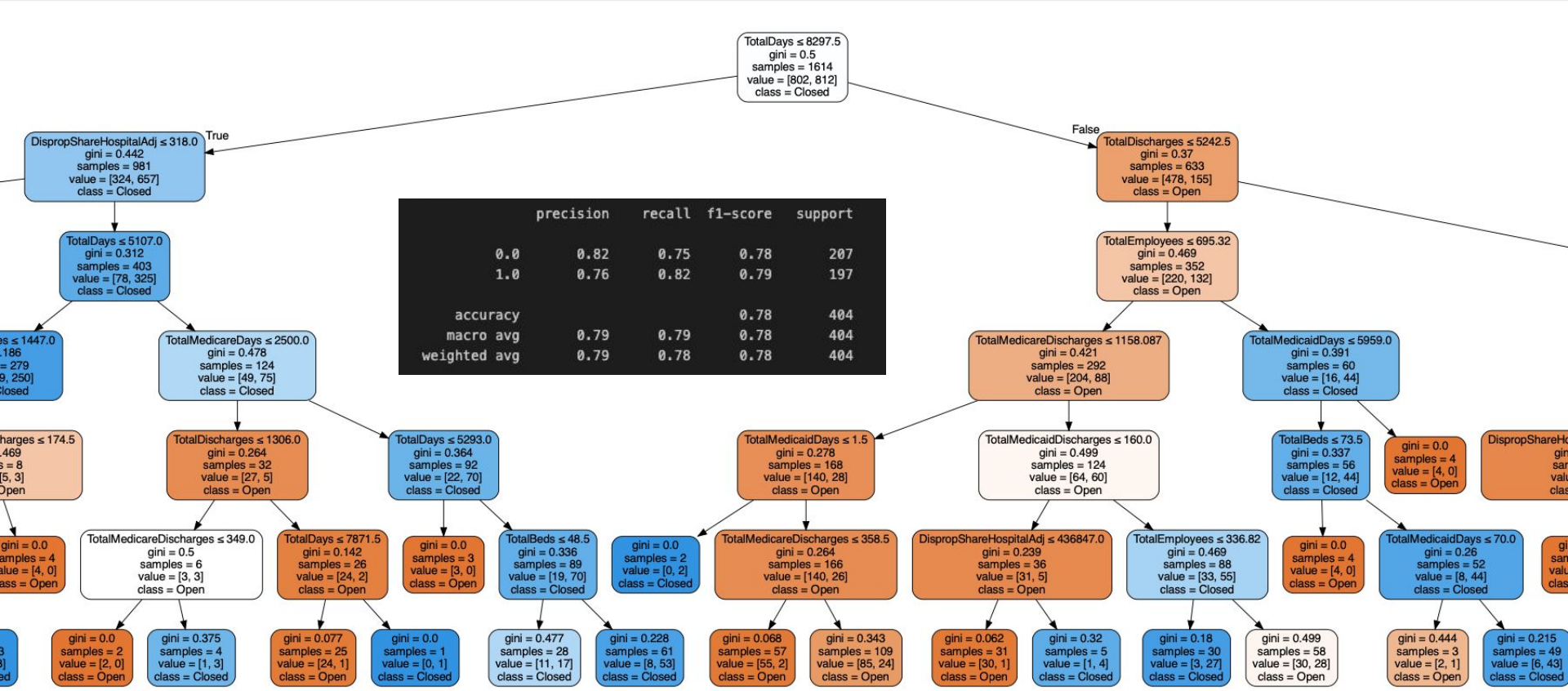
RQ2. To what extent can rural hospital closures be predicted based on county and hospital characteristics?



RQ2. To what exte can rural hos ital cl res be predicted ased co nty an ital characteri s

Machine Learning!

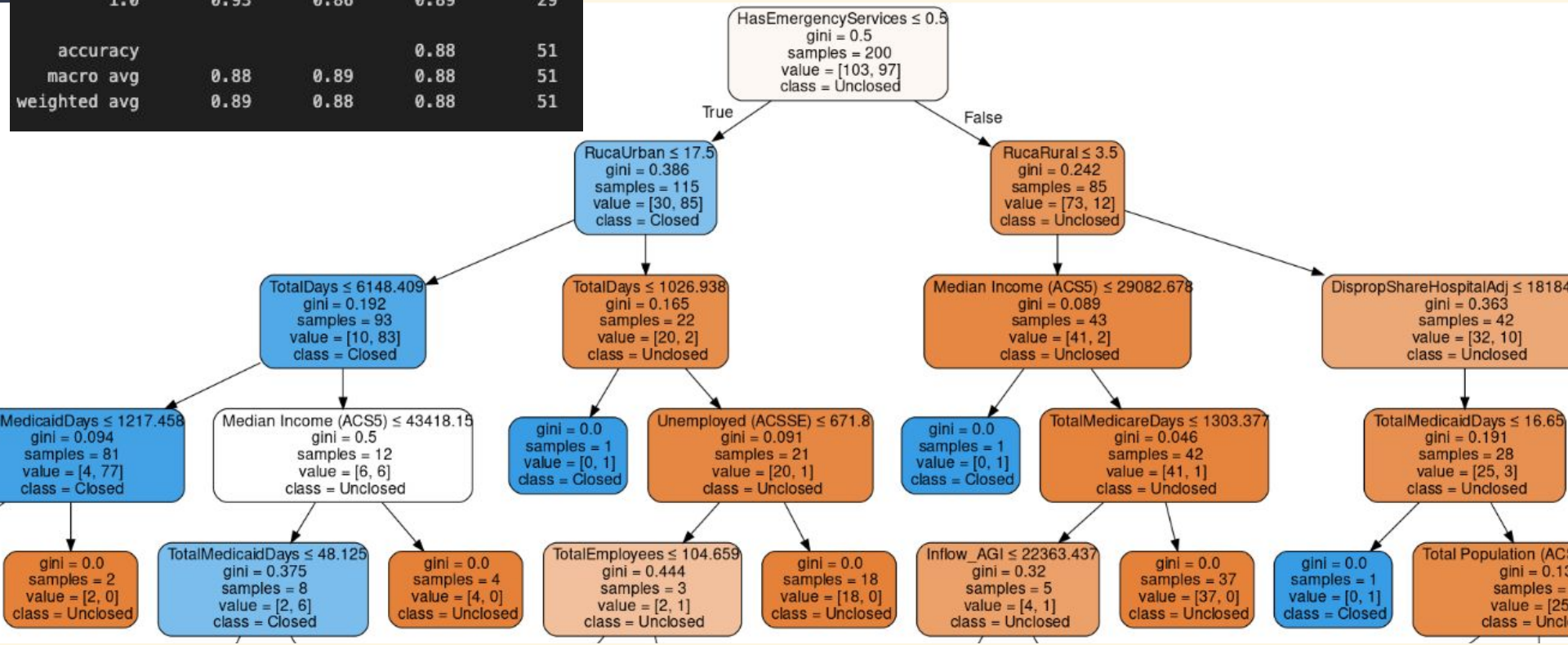
RQ2: Decision tree classifier (hospital data alone)



	precision	recall	f1-score	support
0.0	0.82	0.75	0.78	207
1.0	0.76	0.82	0.79	197
accuracy			0.78	404
macro avg	0.79	0.79	0.78	404
weighted avg	0.79	0.78	0.78	404

RQ2: Decision tree classifier (hospital & county data)

	precision	recall	f1-score	support
0.0	0.83	0.91	0.87	22
1.0	0.93	0.86	0.89	29
accuracy			0.88	51
macro avg	0.88	0.89	0.88	51
weighted avg	0.89	0.88	0.88	51



RQ2: Time series data

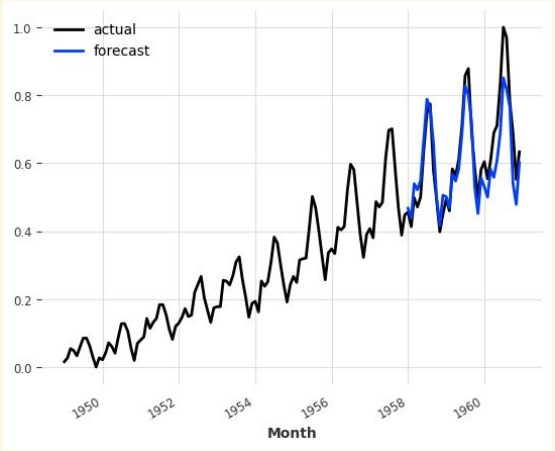
	HID	Year	DispropShareHospitalAdj	IndirectMedicalEducationAdj	TotalEmployees	TotalBeds	TotalMedicareDays	TotalDays	TotalMedicareDischarges
0	H010015	2011	9767.0	0.0	75.03	27.0	295.0	592.0	92.0
1	H010027	2010	103634.0	0.0	97.68	20.0	922.0	1758.0	244.0
2	H010027	2011	48548.0	0.0	159.60	20.0	388.0	714.0	110.0
3	H010027	2012	12764.0	0.0	89.40	20.0	99.0	164.0	28.0
4	H010043	2010	41297.0	0.0	117.98	27.0	1340.0	2724.0	276.0
...	...	...	...	...	...	...	...	...	...
2013	H030087	2019	0.0	665489.0	2146.67	427.0	28488.0	89348.0	6937.0
2014	H030088	2011	2096870.0	0.0	1557.59	318.0	31350.0	81974.0	7428.0
2015	H030088	2012	0.0	0.0	1462.93	318.0	29922.0	79888.0	6998.0
2016	H030088	2013	0.0	0.0	1407.81	318.0	31461.0	79857.0	7158.0
2017	H030088	2014	715957.0	0.0	1504.29	318.0	30013.0	79333.0	6583.0

2018 rows × 27 columns

tsfresh

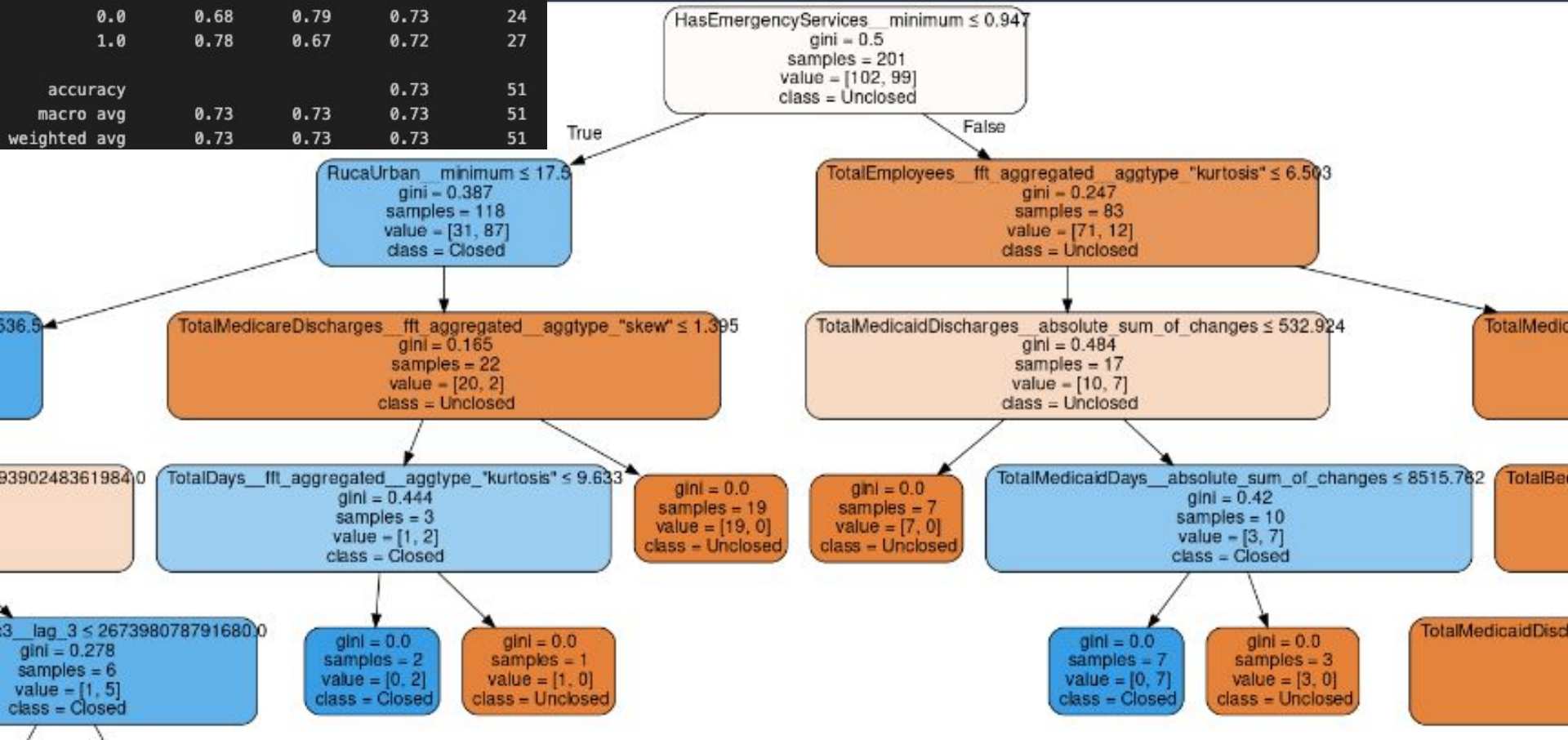
	CdcRurality__abs_energy	CdcRurality__absolute_sum_of_cha...	...rality__c3__lag_1	CdcRurality__c3__lag_2	CdcRurality__c3__lag_3	CdcRurality_
H010001	144.000000	0.000000	64.000000	64.00000	64.000000	
H010005	225.000000	0.000000	125.000000	125.00000	125.000000	
H010006	144.000000	0.000000	64.000000	64.00000	64.000000	
H010007	216.000000	0.000000	216.000000	216.00000	0.000000	
H010011	9.000000	0.000000	1.000000	1.00000	1.000000	
...	...	...	...	...	...	
H491306	252.000000	0.000000	216.000000	216.00000	216.000000	
H510071	250.000000	0.000000	125.000000	125.00000	125.000000	
H510077	324.000000	0.000000	216.000000	216.00000	216.000000	
H670004	409.186322	3.901743	192.537262	192.58954	185.900838	
H670052	12.000000	0.000000	8.000000	0.00000	0.000000	

275 rows × 450 columns



RQ2: Decision tree classifier (hospital & county data as time series)

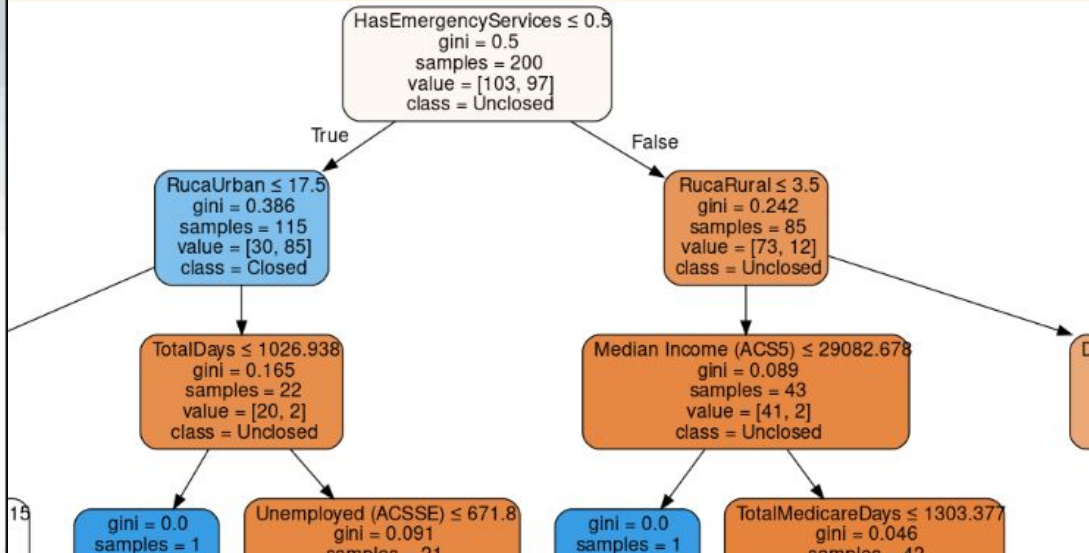
	precision	recall	f1-score	support
0.0	0.68	0.79	0.73	24
1.0	0.78	0.67	0.72	27
accuracy			0.73	51
macro avg	0.73	0.73	0.73	51
weighted avg	0.73	0.73	0.73	51



RQ2: Decision tree classifier features (model 2)

Weight	Feature
0.2039 ± 0.0314	HasEmergencyServices
0.1333 ± 0.0576	TotalDays
0.1059 ± 0.0637	TotalMedicaidDays
0.1059 ± 0.0532	RucaUrban
0.0627 ± 0.0457	Outflow_AGI
0.0549 ± 0.0157	RucaRural
0.0549 ± 0.0384	TotalMedicareDays
0.0431 ± 0.0457	Median Income (ACS5)
0.0275 ± 0.0192	Outflow_Individual
0.0196 ± 0.0248	Inflow_AGI
0.0157 ± 0.0157	TotalEmployees
0.0078 ± 0.0400	DispropShareHospitalAdj
0 ± 0.0000	HasBirthingFriendlyDesignation
0 ± 0.0000	Labor Force (ACSSE)
0 ± 0.0000	TotalDischarges
0 ± 0.0000	TotalMedicaidDischarges
0 ± 0.0000	CdcRurality
0 ± 0.0000	GEOID
0 ± 0.0000	FarP
0 ± 0.0000	TotalMedicareDischarges
	... 16 more ...

-Most important predictor: having emergency services
-Second: total days spent by patients
-Third: rurality
-Fourth: AGI outflow



Conclusions

- RQ1: Results support hypothesis that conversions do not change county level migration behavior, while full closures may have mild effects.
- RQ2: Both hospital and county characteristics can predict rural hospital closure with a reasonable degree of accuracy. Smaller hospitals lacking emergency departments in more rural counties experiencing AGI outflow are most likely to close.

Future Directions

- More robust causality tests and investigations for RQ1
- Find better machine learning algorithms that deal with largely imbalanced dataset, e.g. Support Vector Machine Classifier.
- Use data from a longer time period to provide more closure cases
- Predict which hospitals will close in the future

References

[1] Alexander, D., & Richards, M. R. (2023). Economic consequences of hospital closures. *Journal of Public Economics*, *221*, 104821. https://doi.org/10.1016/j.jpubeco.2023.104821

[2] Edmiston, K. D. (2019). *Rural Hospital Closures and Growth in Employment and Wages*.

[3] King, S., & Dabelko-Schoeny, H. (2009). "Quite Frankly, I Have Doubts About Remaining": Aging-In-Place and Health Care Access for Rural Midlife and Older Lesbian, Gay, and Bisexual Individuals. *Journal of LGBT Health Research*, *5*(1–2), 10–21. https://doi.org/10.1080/15574090903392830

[4] Malone, T. L., Planey, A. M., Bozovich, L. B., Thompson, K. W., & Holmes, G. M. (2022). The economic effects of rural hospital closures. *Health Services Research*, *57*, 614–623. https://doi.org/10.1111/1475-6773.13965

[5] McCarthy, S., Moore, D., Smedley, W. A., Crowley, B. M., Stephens, S. W., Griffin, R. L., Tanner, L. C., & Jansen, J. O. (2021). Impact of Rural Hospital Closures on Health-Care Access. *Journal of Surgical Research*, *258*, 170–178. https://doi.org/10.1016/j.jss.2020.08.055

[6] Miller, K. E. M., James, H. J., Holmes, G. M., & Van Houtven, C. H. (2020). The effect of rural hospital closures on emergency medical service response and transport times. *Health Services Research*, *55*(2), 288–300. https://doi.org/10.1111/1475-6773.13254

[7] Rosenbach, M. L., & Dayhoff, D. A. (1995). Access to Care in Rural America: Impact of Hospital Closures. *Health Care Financial Review*, *17*(1), 15–37.

[8] Sørensen, J. F. L. (2008). The potential migration effect of rural hospital closures: A Danish case study. *Scandinavian Journal of Public Health*, *36*, 460–466. https://doi.org/10.1177/1403494808089554