ECONOMY, INDUSTRY AND SUSTAINABILITY

Spatial-Temporal Modeling of the Relationship between Individual Industries and the Economy using Panel Time Series Modeling

Name : Angolla Praveen Goud

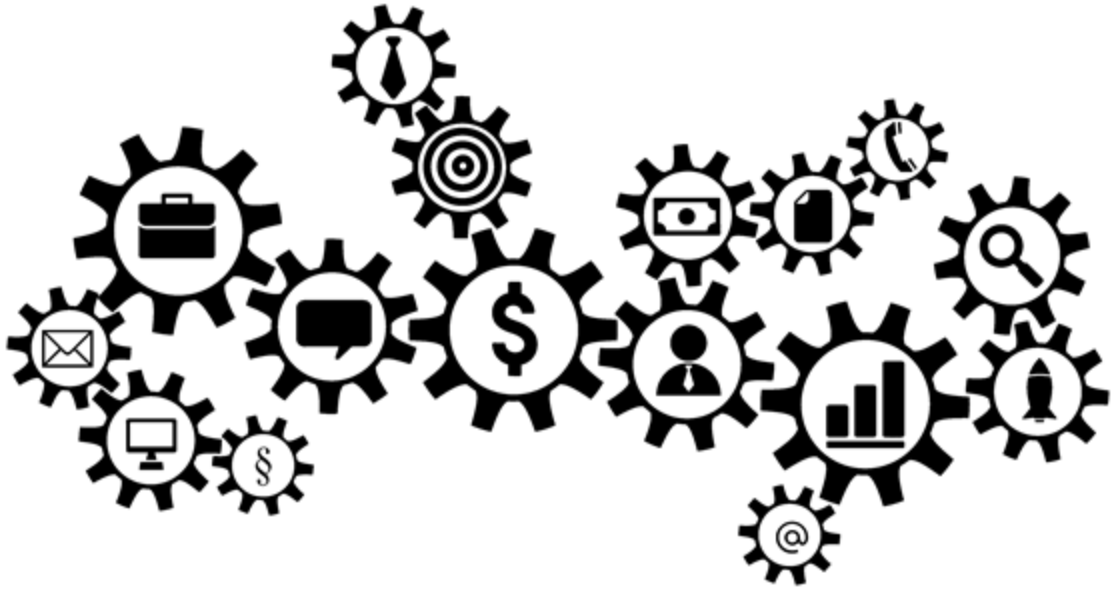
Institution : Regis University

Date : 03/07/2026

Introduction: Economy and Industry

- The economy provides the foundation for the business environment in terms of the consumer purchasing power and access to capital (Karimi & Sugözü, 2025).

- On the other hand, industries contribute to the economy in terms of taxes, salaries and propagation of economic activities through purchases and sales (Karimi & Sugözü, 2025).



Introduction: Sustainability

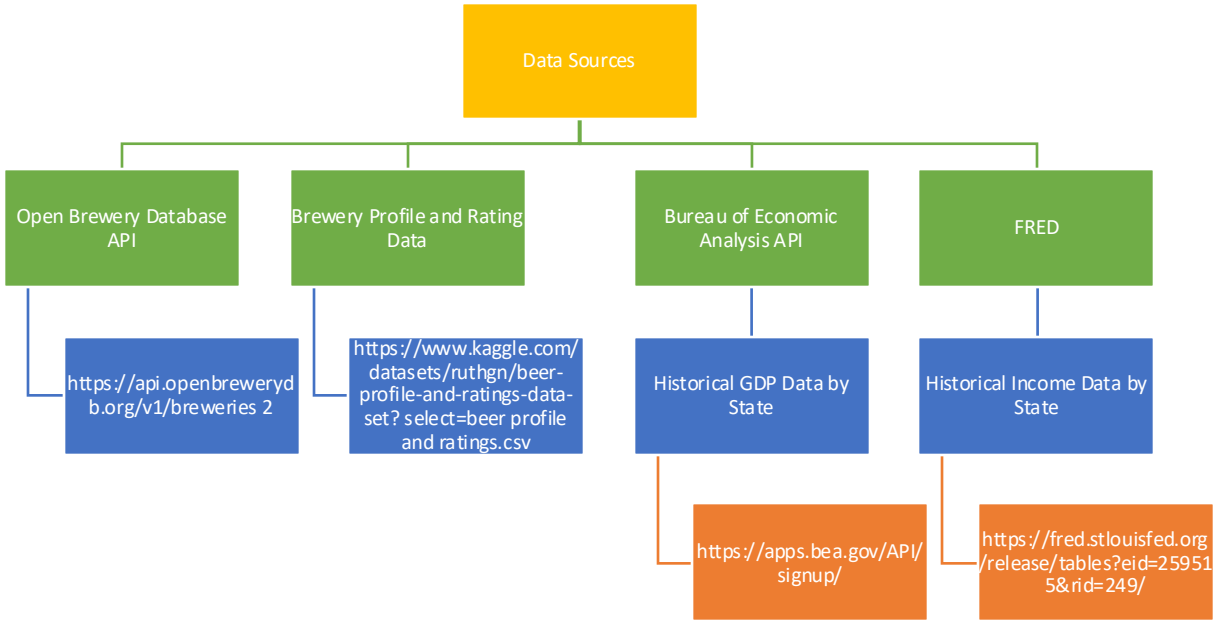
- Sustainability represents a reality for the future, making it a necessity rather than an option.

- Businesses consequently require alignment with sustainability so as to ensure continued profitability into the future (Joseph, 2025; Azizah & Haron, 2025).

Problem Background

- The bi-directional relationship that exists between industries and the economy creates a challenge for business to adjust for a sustainable future.
- A consideration is therefore needed that accounts for how the industries impact the growth of the economy and how the growth of the economy impacts the growth of industries.
- Similar to other industries, the beer industry faces the pressure and reality of sustainability (Fuentes et al., 2025; Ooyama et al., 2025).
- Exploring the economic perspective of sustainability for the beer industry, as explored in Ravanal et al. (2024), in the US will offer the insights into how industries can approach the sustainable future.

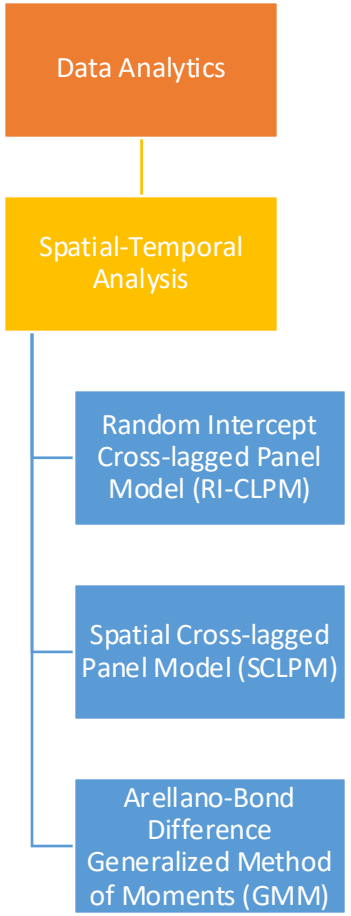
Data Sources and Methodology



- According to Rabbani et al. (2025) and Machmuddah et al. (2025) ,data analytics serve as a tool that can enable easier and faster alignment through anticipation and prediction of possible future scenarios in the transition towards complete sustainability.

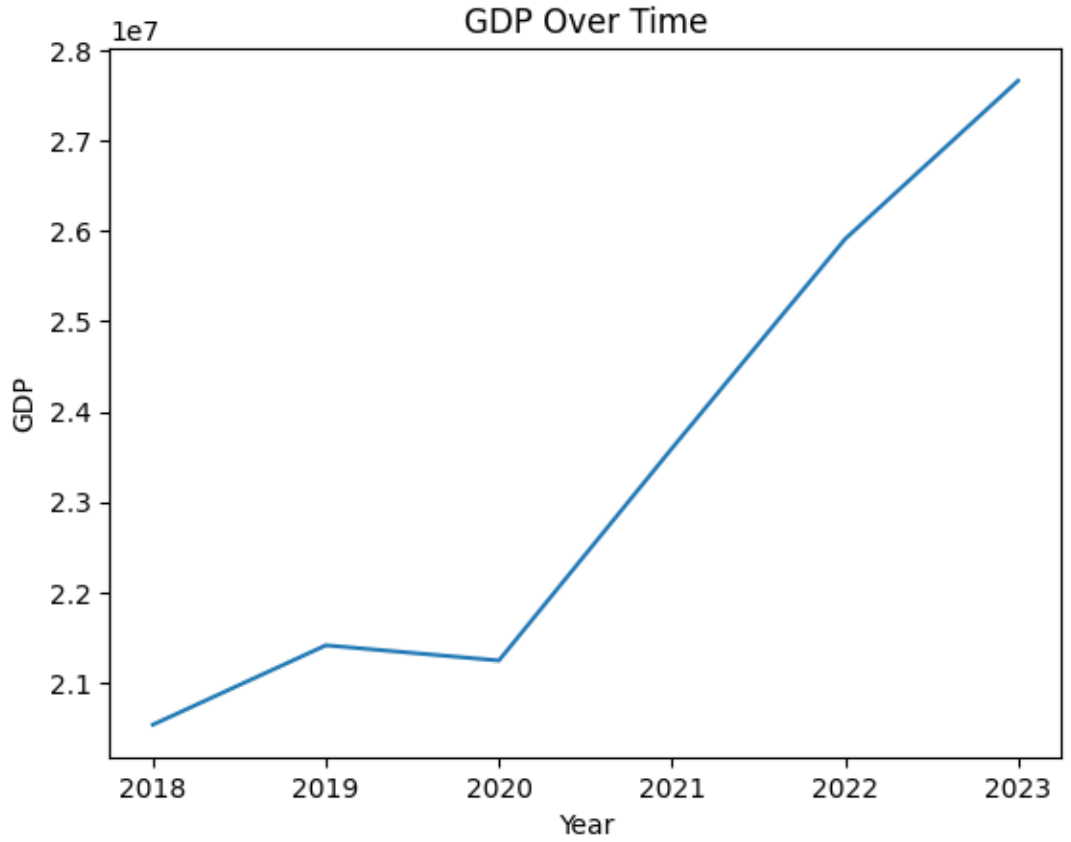
- In the predictive analytics, the bi-directional relationship will be evaluated using GDP for the economy and the number of established breweries across states for the industry.

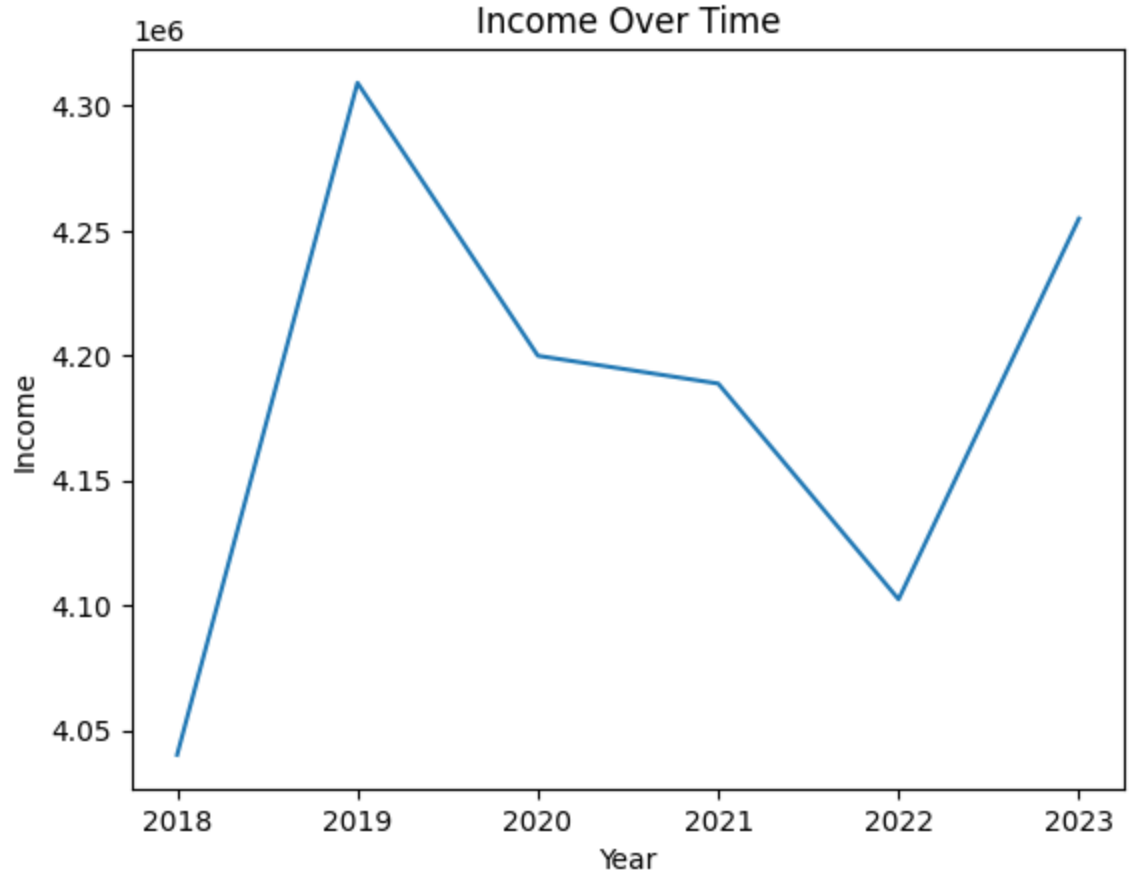
Data Sources and Methodology



- The RI-CLPM is described in Sorjonen and Melin (2025) to employ cross lagging through re-ordering data by spatial and time attributes with significance evaluated for both the cross-lagged effects and the two dependent variables evaluated for mutual effects.
- The SCLPM applies cross lagging through the use of multi-index for the spatial time attributes followed by lagging where spatial weights are employed for the two dependent variables evaluated for mutual effects (Fingleton, 2023).
- The GMM represents a robust approach in handling dynamic panel data where the consistency that results from the differencing to remove spatial effects that are time-invariant or very specific; making the model very sensitive to the attributes included in the modeling (Jula et al., 2026).

Trend Analysis of GDP and Household Income

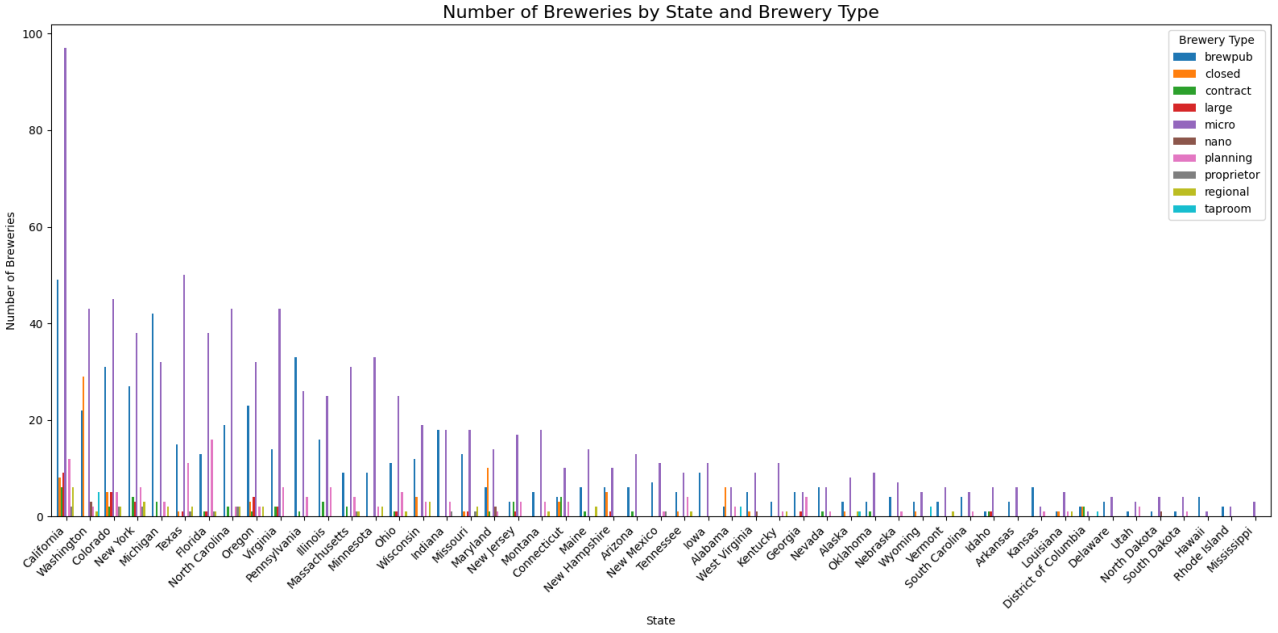




- Trend analysis for the GDP shown in the line chart above indicates that the GDP had a general rising trend between 2018 and 2023 with a slight dip in 2020.

- Trend analysis for the Household Income shown in the line chart above indicates that the Household Income had a series of jumps and falls between 2018 and 2023 and hence had year to year variation.

Spatial Analysis of the Beer Industry

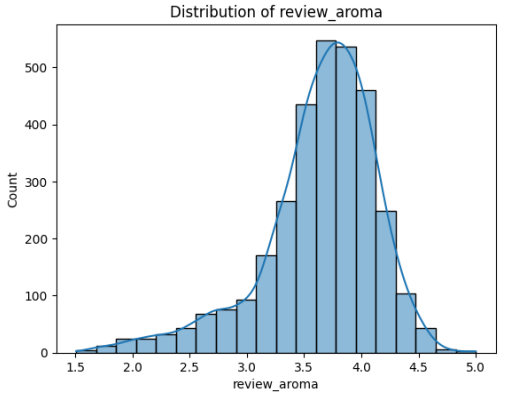


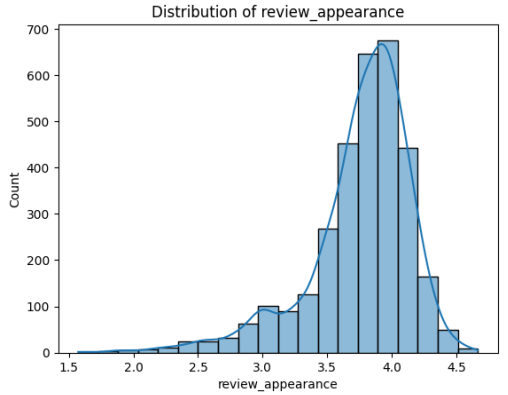
- Above is the map for the distribution of breweries across the US.
- We observed that breweries are predominately located on the East Coast, West Coast and in the states about the Great Lakes.
- We also note that California, Washington State and Colorado lead in the number of breweries.
- Presented on the left is the grouped column chart of the brewery type by state.
- We observe that majority of the states have micro-breweries with the large breweries located in states with the highest number of breweries.

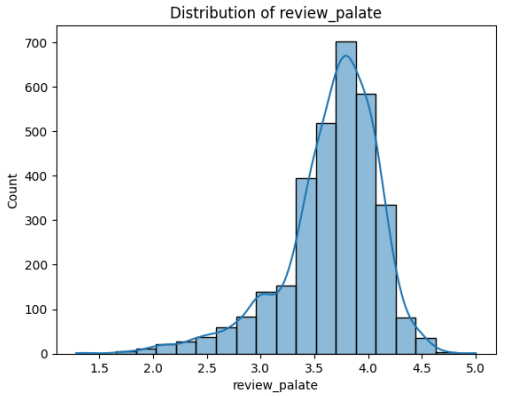
Consumer Review

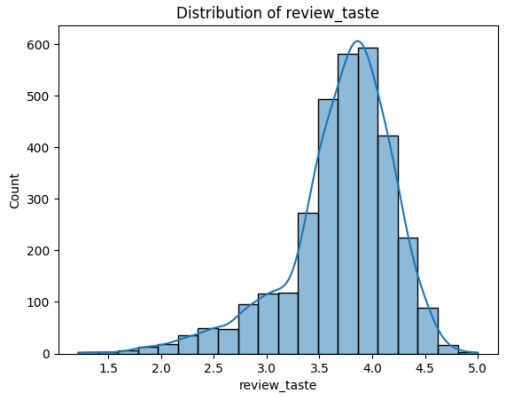
- Consumer review ratings for beer aroma, appearance, palate and taste, and the overall ratings had averages of between 3.64 and 3.75 out of 5. All the ratings also show negative skewness, implying majority of ratings are above average.

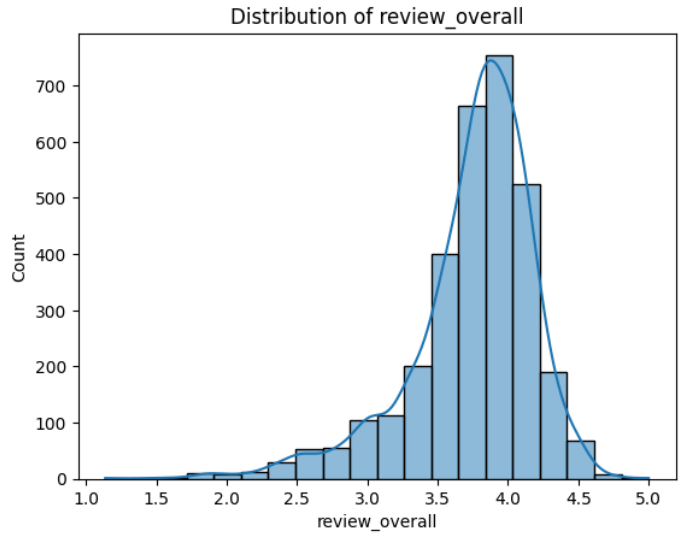
- Beers produced using the IPA – New England style, Wild Ale style and Stout – American Imperial Style had the highest average ratings by the consumers.



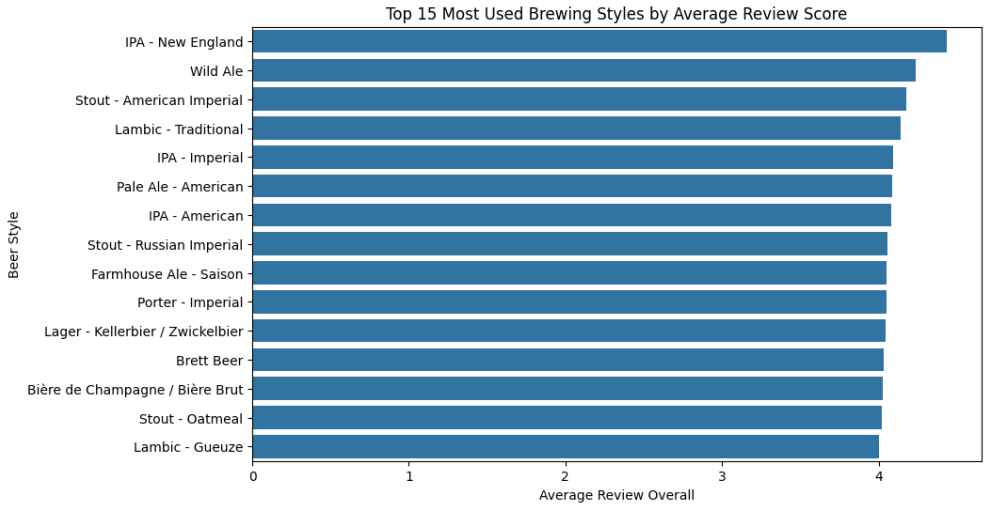




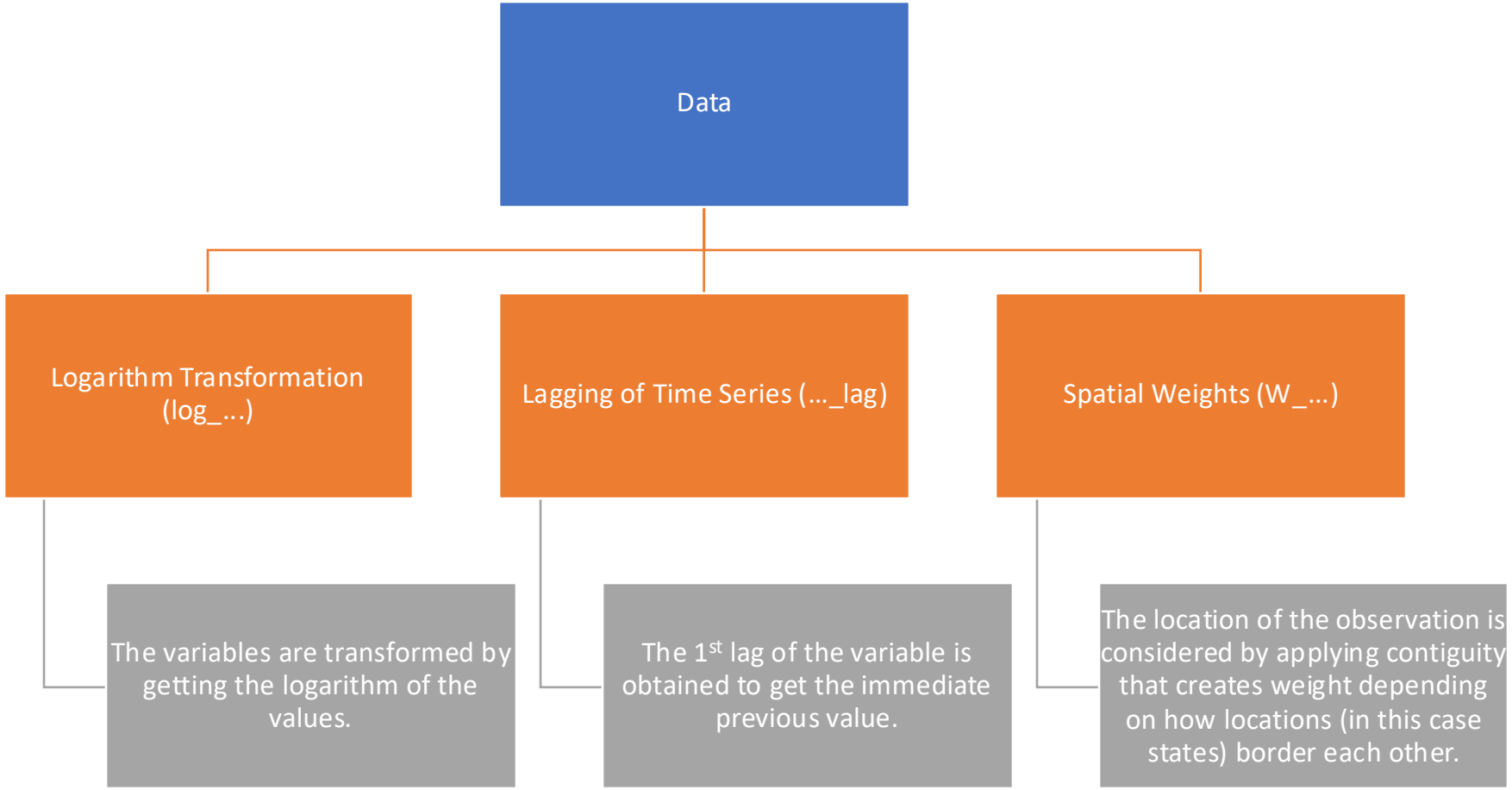




	review_aroma	review_appearance	review_palate	review_taste	review_overall
count	3197.000000	3197.000000	3197.000000	3197.000000	3197.000000
mean	3.638789	3.754393	3.660428	3.702496	3.747522
std	0.503209	0.403416	0.449937	0.510361	0.444288
min	1.509615	1.571429	1.285714	1.214286	1.136364
25%	3.422559	3.604651	3.470021	3.500000	3.566667
50%	3.720183	3.833333	3.741667	3.791667	3.830239
75%	3.978000	4.000000	3.965587	4.033333	4.032847
max	5.000000	4.666667	5.000000	5.000000	5.000000



Data Preparation for Modelling



Random Intercept Cross-lagged Panel Model (RI-CLPM) – Model Summary

	lval	op	rval	Estimate	Std. Err	z-value	p-value
0	GDP	~	RI_GDP	1.000000e+00	-	-	-
1	brewery_count	~	RI_brewery_count	1.000000e+00	-	-	-
2	GDP	~	brewery_count	1.426594e+01	0.000721	19788.104223	0.0
3	GDP	~	GDP_lag	1.063477e+00	0.047428	22.42308	0.0
4	GDP	~	Household_Income	-1.845893e-01	1.954302	-0.094453	0.924749
5	brewery_count	~	GDP	-2.449459e-05	0.000003	-8.750762	0.0
6	brewery_count	~	GDP_lag	7.545488e-05	0.000004	20.640231	0.0
7	brewery_count	~	Household_Income	3.212835e-04	0.000087	3.679145	0.000234
8	GDP	~~	brewery_count	9.298159e-08	0.000001	0.100541	0.919915
9	GDP	~~	GDP	1.836277e+11	0.0	1825186145449600771686 40.0	0.0
10	RI_GDP	~~	RI_GDP	4.999804e-02	0.0	49696055233.757072	0.0
11	RI_GDP	~~	RI_brewery_count	9.298159e-08	0.000001	0.100541	0.919915
12	RI_brewery_count	~~	RI_brewery_count	3.568833e-03	16.234471	0.00022	0.999825
13	brewery_count	~~	brewery_count	3.666223e+02	16.234471	22.582951	0.0

- The table on the left gives the model summary for the RI-CLPM.
- The estimated cross-lagged effects for the GDP were:
  - Brewery Count: 1.427
  - GDP_lag: 1.064
  - Household Income: -0.1846
- The estimated cross-lagged effects for the Brewery Count were:
  - GDP: -0.000025
  - GDP_lag: 0.000076
  - Household Income: 0.00032

Spatial Cross-lagged Panel Model (SCLPM) – Model Summary

	lval	op	rval	Estimate	Std. Err	z-value	p-value
0	log_GDP	~	log_GDP_lag	0.988748	0.007791	126.903443	0.000000
1	log_GDP	~	log_income_lag	-0.015848	0.033873	-0.467862	0.639883
2	log_GDP	~	W_GDP_lag	0.004552	0.005642	0.806808	0.419777
3	log_GDP	~	W_brewery_count	-0.011001	0.018247	-0.602891	0.546582
4	log_GDP	~	log_brewery_count	0.011598	0.008867	1.308024	0.190865
5	log_GDP	~~	log_GDP	0.006471	0.000573	11.291590	0.000000

- The table on the left gives the model summary for the Spatial Cross-lagged Panel Model (SCLPM).

- The results of the effects on the GDP were such that the estimated effects were:
  - log_GDP_lag: 0.99
  - log_income_lag: -0.016
  - W_GDP_lag: 0.005
  - W_brewery_count: -0.011
  - log_brewery_count: 0.012

Arellano-Bond Difference Generalized Method of Moments (GMM) – Model Summary

Parameter Estimates

	Parameter	Std. Err.	T-stat	P-value	Lower CI	Upper CI
log_income	-0.6635	0.7838	-0.8466	0.3972	-2.1996	0.8726
W_GDP_lag	-20.492	23.163	-0.8847	0.3763	-65.891	24.906
log_GDP_lag	21.531	23.439	0.9186	0.3583	-24.408	67.470

Endogenous: log_GDP_lag
Instruments: log_GDP_lag2
GMM Covariance
Debiased: False
Robust (Heteroskedastic)

- The table on the left gives the model summary for the Arellano-Bond Difference Generalized Method of Moments (GMM).

- The results showed the estimate for the parameters were;
  - log_GDP_lag: 21.531
  - log_income: -0.6635
  - W_GDP_lag: -20.492

Key Findings: RI-CLPM

- The estimated cross-lagged effects were such that the estimated magnitude of effect on GDP was 1.427 for brewery_count, 1.064 for GDP_lag and -0.1846 for Household_Income.

- The estimated cross-lagged effects were such that the estimated magnitude of effect on brewery count was -0.000025 for GDP, 0.000076 for GDP_lag and 0.00032 for Household_Income.

- Results from the RI-CLPM showed the estimated temporal aspect was significant at alpha = 0.05 since;
  - GDP had GDP_lag and brewery count as significant predictors.
  - Brewery count had GDP_lag, GDP and household income as significant predictors.

- The findings are however limited in terms of the interpretability of the RI-CLPM model.

Key Findings: SCLPM

- The temporal effects on the log_GDP from the SCLPM model were such that estimated magnitude of effect were 0.99 for log_GDP_lag -0.016 for log_income_lag.

- The spatial effects on the log_GDP from the SCLPM model were such that estimated magnitude of effect were 0.005 for W_GDP_lag and -0.011 for W_brewery_count.

- The brewery count had an estimated magnitude of effect on the log transformation at 0.012.

- In terms of the significance, the temporal effects for the GDP, log_GDP_lag, was significant at alpha = 0.05.

Key Findings: GMM

- The spatial temporal effects on the log_GDP were estimated by the GMM to be -20.492 for W_GDP_lag.

- The temporal effects of log_GDP_lag on log_GDP was estimated by the GMM to be at 21.531 while the effects of log_income was estimated by the GMM to be at -0.6635.

- GMM did not identify any of the effects as significant predictors of the log_GDP.

Conclusion

- The results show that there is a time-based relationship between brewery activity and economic performance across states.
- In the RI-CLPM, the strongest evidence came from changes over time, suggesting that year-to-year patterns matter more than simple differences between states.
- In the SCLPM, a state's own previous GDP was the strongest predictor, while the effects from neighboring states were weak.
- In the GMM robustness check, the predictors were not statistically significant, so the stricter model did not confirm strong effects.

Conclusion

- Overall, the project suggests that economic patterns are explained more by a state's own past values than by neighboring state effects.
- Brewery activity seems to be related to economic change over time, but this relationship appears stronger in the temporal models than in the robustness model.
- This means the findings should be interpreted carefully, because the relationship is visible in some models but not equally strong in all of them.
- In summary, the study suggests a possible connection between brewery presence and economic outcomes, but there is only limited evidence for spatial spillover effects.

References

Al Azizah, U. S., & Haron, R. (2025). The sustainability imperative: evaluating the effect of ESG on corporate financial performance before and after the pandemic. *Discover Sustainability, 6*, Article 529. https://doi.org/10.1007/s43621-025-01401-8

Fingleton, B. (2023). Estimating dynamic spatial panel data models with endogenous regressors using synthetic instruments. *Journal of Geographical Systems, 25*, 121–152. https://doi.org/10.1007/s10109-022-00397-3

Fuentes, O. P., Vásquez, S., Trujillo, D. M., Sánchez, M. E., & Cruz, J. C. (2025). Sustainability assessment in craft beer production: Environmental, economic, and exergetic analyses. *ACS Sustainable Resource Management*, *acssusresmgt.4c00374*. https://doi.org/10.1021/acssusresmgt.4c00374

Joseph, E. K. (2025). *Planning sustainable futures: Critical drivers of success in the global context. Discover Sustainability, 6*, 399. https://doi.org/10.1007/s43621-025-01126-8

Jula, D., Jula, N.-M., & Aivaz, K.-A. (2026). *Quantitative modeling of investment–output dynamics: A panel NARDL and GMM-Arellano–Bond approach with evidence from the circular economy. Mathematics, 14*(3), 463. https://doi.org/10.3390/math14030463

Karimi, R., & Sugözü, İ. H. (2025). The Relationship Between Industrial Production and Economic Growth: The Case of Kyrgyzstan, Kazakhstan and Russia. Uluslararası Ekonomi Ve Siyaset Bilimleri Akademik Araştırmalar Dergisi, 8(20), 20-35. https://doi.org/10.58202/joecopol.1577569

Machmuddah, Z., Winarsih, W., & Yuesti, A. (2025). The ESG disclosure and sustainable growth: Does profitability matter? *Journal of Innovation in Business and Economics, 9*(01 B). https://doi.org/10.22219/jibe.v9i01.40759

Ooyama, S., Seo, Y., & Maesako, K. (2025). Assessing sustainability trade-offs in craft beer production through life cycle and costing analysis scenarios. *Sustainability*, *17*(24), 11003. https://doi.org/10.3390/su172411003

Rabbani, M. R., Kiran, M., & Shaikh, Z. H. (2025). *Financing the future: Insights into sustainable energy investments through scientific mapping and meta-analysis. Discover Sustainability, 6*, 34. https://doi.org/10.1007/s43621-024-00788-0

Ravanal, M. C., Doussoulin, J. P., & Mougenot, B. (2024). *Does sustainability matter in the global beer industry? Bibliometrics trends in recycling and the circular economy. Frontiers in Sustainable Food Systems, 8*, Article 1437910. https://doi.org/10.3389/fsufs.2024.1437910

Sorjonen, K., & Melin, B. (2025). *Using triangulation to evaluate findings from random-intercept cross-lagged panel models: An application with data on curiosity and creativity*. *PLOS ONE, 20*(12), e0337928. https://doi.org/10.1371/journal.pone.0337928