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Creating an Economic Resilience Index and an Economic Vulnerability Index for Ohio

By: Puja Gowda, Magie Zheng[1]

Analyzing the resilience and vulnerability of regional economies helps us understand how a community endures and adapts to economic adversity. Economic resilience can be defined as the capability of an economy to rebound from economic shocks while vulnerability signifies how susceptible an economy is to these adverse events. In this article, we discuss the economic resilience and vulnerability of the three major Metropolitan Statistical Areas (MSAs) in Ohio, Cleveland, Columbus, and Cincinnati, examining the factors that contribute to their capacity to weather economic shocks. In order to understand their reactions to specific economic events, we observe the economy during the 2008 Recession and the 2020 COVID-19 Recession.

As the global economy becomes more interconnected, quantifying and comparing these factors is important for policymakers and government entities (Rose 2013). Building these metrics deepens the understanding of economic dynamics and their implications for long-term sustainable developments. In this article, we enter an exploration of economic resilience and vulnerability, and their significance in the context of regional economies.

To assess economic resilience and vulnerability, we employ two metrics: the Resilience Index and the Vulnerability Index (Wu 2020). The Resilience Index quantifies a region's ability to bounce back from economic setbacks, taking into account various economic factors. The Vulnerability Index measures the susceptibility of an economy to external shocks, considering variables such as dependency on specific industries and location quotients. Measuring resilience and vulnerability together provides a more comprehensive understanding of the dynamics and characteristics of an economy.

In our previous research in the Fall 2023 semester, we created an Economic Resilience Index for the major MSAs using the Ohio real GDP, education level, house price index, and unemployment. Now, we aim to include more indicators to further enhance the calculation. The list of indicators can be grouped into three categories.

Economic Indicators	Engineering Indicators	Social Indicators
Ohio Real GDP	Density of Highway Network	Higher Education Rate
Ohio Real GDP Growth Rate	Internet Penetration Rate	Unemployment Rate
House Price Index		
GDP Per Capita		
GDP Per Square Mile		

Resilience Index = $\frac{1}{n}\sum_{i=1}^{n}\omega_i \times \left(\frac{\chi_i - \underline{\chi_i}}{\sigma_i}\right)$

Where:

n = represents the number of indicators

$\omega_i *$ = denotes the weight assigned to each indicator based on its perceived importance

χ_i = the observed value of the respective indicator

$\underline{\chi_i}$ = the mean of the indicator across the 2005-2021 period

σ_i = the standard deviation of the indicator across the 2005-2021 period

**For this calculation, we will be considering all indicators to be at the same weight (~14.286%), however, for future calculations, a regression analysis will be used to determine the relative weights of indicators.*

[1] Thank you, Professor Bogart, and Professor Clingingsmith, for their insights. Additionally, thank you Katie Merritt for her guidance.

Interpretation: A higher resilience index suggests that the MSA's economy was doing better than the Ohio average that year and a lower resilience index implies that the MSA is doing worse.

Additionally, we are including a calculation for the vulnerability index, which is quantified by using location quotients and traded industries (Tuysuz 2022). Location quotients (LQ) are a statistical tool that is used to assess the concentration of a particular industry. It is measured as the proportion of the industry in the MSA, to the proportion of that industry in the entire nation. A LQ greater than 1 indicates that the industry is more concentrated in that MSA than the United States, whereas a LQ less than 1 suggests the opposite. Tradable industries are sectors of the economy that produce goods and generate revenue from outside the local market. Non-tradable industries primarily serve local markets and do not contribute to external sales.

The measurement for the vulnerability index is stated below:

$$\text{Vulnerability Index} = \sum_{i=1}^{n_t} es_i \times \left(\frac{TLQ_i - 1}{Total\ TLQ}\right) - \sum_{j=1}^{n_{nt}} es_j \times \left(\frac{NTLQ_j - 1}{Total\ NTLQ}\right)$$

Where:

n_t = represents the number of tradable industries
n_{nt} = represents the number of non-tradable industries
es_i *= denotes the employment share for the *i*th tradable industry, measured as employment per 1000 jobs
es_j *= denotes the employment share for the *j*th non-tradable industry, measured as employment per 1000 jobs
TLQ_i = the LQ for the *i*th tradable industry in the MSA
Total TLQ = the total number of LQs for all tradable industries in the MSA
NTLQ_i = the LQ for the *j*th non-tradable industry in the MSA
Total NTLQ = the total number of LQs for all non-tradable industries in the MSA

Interpretation:

- A higher vulnerability index suggests a greater dependence on tradable industries, making the MSA more susceptible to economic shocks.
- A lower vulnerability index indicates a greater dependence on non-tradable industries, making the MSA less susceptible to economic shocks.

All the data for these indicators are pulled from the Federal Reserve of Economic Data (FRED), the US Bureau of Labor Statistics, and the US International Trade Administration. We include data from 2005 to 2021 for the MSAs of Ohio to observe how these areas responded to the 2008 Recession. By creating these indexes, we hope to create a complete understanding of Ohio's economy, as well as support further research that can be expanded to other states or regions. Below we have listed the indicators we will be using:

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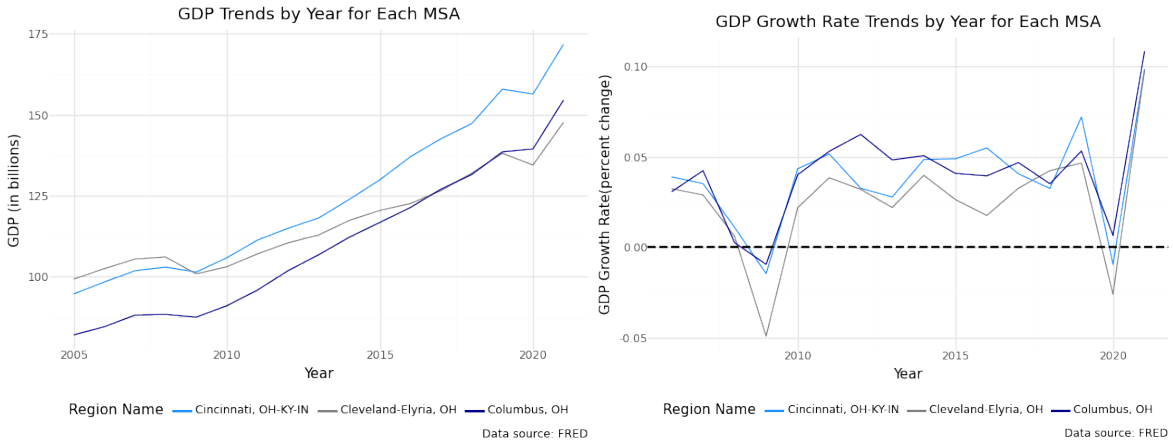
Economic Resilience Index

Economic Indicators

Figure 1. (left) GDP trends by year for Ohio MSAs; **Figure 2.** (right) Ohio real GDP growth rate



The first graph depicts the GDP over time in millions of dollars for the three biggest metropolitan areas in Ohio, Cincinnati, Cleveland, and Columbus, ranging from 2005 to 2021. The GDP steadily increases until 2008, where it then dips in Cleveland until 2009. On the other hand, in Columbus in Cincinnati, it seems to remain more stagnant. This is most likely in response to the Great Recession, which primarily took place between 2008 and 2009. After 2009, all three metros increased steadily until 2019, when they began to dip again, presumably due to the spread of the COVID-19 virus and subsequent lockdown. Also worth noting is that Cleveland had the highest GDP prior to the 2008 Recession, however has gradually fallen behind Cincinnati and Columbus over time.

The second graph shows the growth rate of real GDP for the three MSAs from 2006 to 2021. The fluctuations in growth rate oscillate around a level of 4%. The two exceptions are seen in 2009 and 2020, where in 2009 it reached a change of -5% and in 2020, around -2%. The recovery is also much more pronounced in 2020 as seen in the extreme high following the extreme low, whereas the outlier in 2009-2010 lacks such an obvious rise following the drop. In 2021, the change reached about 11%. The contracting patterns observed in the two recessions highlight differences in their nature and impact on GDP. The slow recovery from the 2008 recession likely reflects the effects of the global financial crisis and its prolonged aftermath. Conversely, the 2020 recession rebound can be explained by fiscal stimulus measures and pent-up demand.

Figure 3. (left) House Price Index (HPI); **Figure 4.** (right) GDP per capita

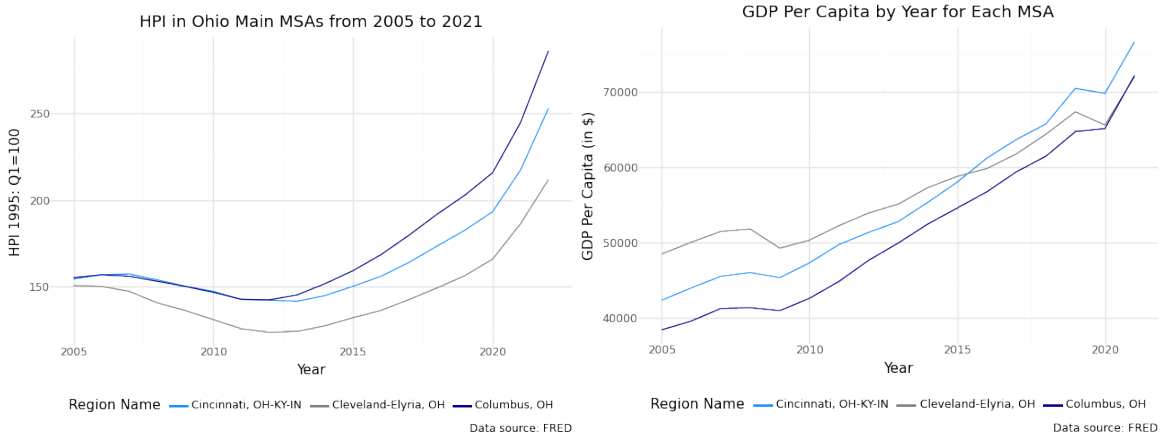


Figure 3 measures the house price index for Cleveland, Columbus, and Cincinnati from 2005 to 2021. The house price index for two of the cities was the lowest in 2012 with Cleveland being at about 125 and Columbus being at around 158, and highest in 2021 at 212 for Cleveland and 285 for Columbus. For Cincinnati, the city saw its lowest HPI at 139 in 2013, and its highest at 252 in 2021. The index has seen an upward trend since 2012. The years between 2007 to 2012 saw a decline in the house price index, and the index only returned to the level it was in 2007 again around 2016 - 2017 and continued to surpass it.

Figure 4 depicts the GDP per capita for the big three metropolitan areas in Ohio. Here we see a decrease after 2008 that continues until 2009, where it then begins increasing at a steady rate. Initially, Cleveland had the highest GDP per capita, however, it was surpassed by Cincinnati in 2015. All three MSAs were no longer increasing in 2019 and began increasing again in 2021. The initial decrease is correlated with the 2008 Recession, and the second change coincides with the COVID-19 pandemic. Compared to the graph depicting GDP over time, we see similar trends, however, we see that Cleveland does not dip far below Cincinnati and Columbus.

Figure 5. GDP per square mile

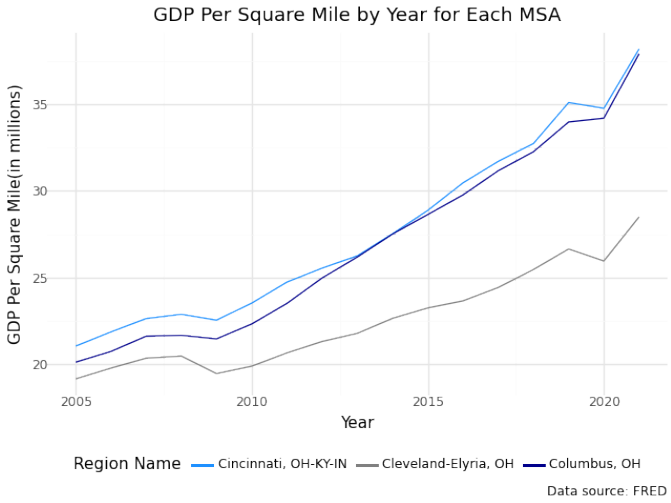


Figure 5 plots the GDP per square mile over time for the three major metropolitan areas, Cleveland, Columbus, and Cincinnati. GDP per square mile measures the economic output within a specific area relative to its size and is calculated by dividing the GDP by the total land area of the MSA. Similarly to the graph of GDP over time, there are dips from 2008-2009 and 2019-2020, with steady increases in the other years. After the Recession, Columbus and Cincinnati grew more steeper than Cleveland, and ended in 2021 with similar measures of GDP per square mile, at around 38-38.5 while Cleveland has a measure of around 29.

Social Indicators

Figure 6 looks at the overall trend of the percentage of Ohioans with a bachelor's degree from 2006 to 2022. From this graph, we see a continuously positive slope, except from 2007 - 2009 where the slope is 0. This means that there was not a change in the percentage of the population who held a bachelor's degree or higher. This could be explained by the 2008 recession, where for many, education was halted. This trend was not observed during the 2020 recession, where the majority of education was adapted to an online format.

Figure 7 measures the Unemployment Rate in the big three cities in Ohio from 2005 to 2021. There was a rapid increase starting in 2008 and peaking in 2010. It was significantly lower by 2012 and back to its original levels by 2014. This can be attributed to the recession of 2008. The highest recorded rate of unemployment in this time period was in 2020, when the rate rose abruptly in January 2020 to a peak. Unlike the 2008 recession, where recovery spanned over four years, the recovery post-pandemic back to pre-pandemic levels took place in about a year.

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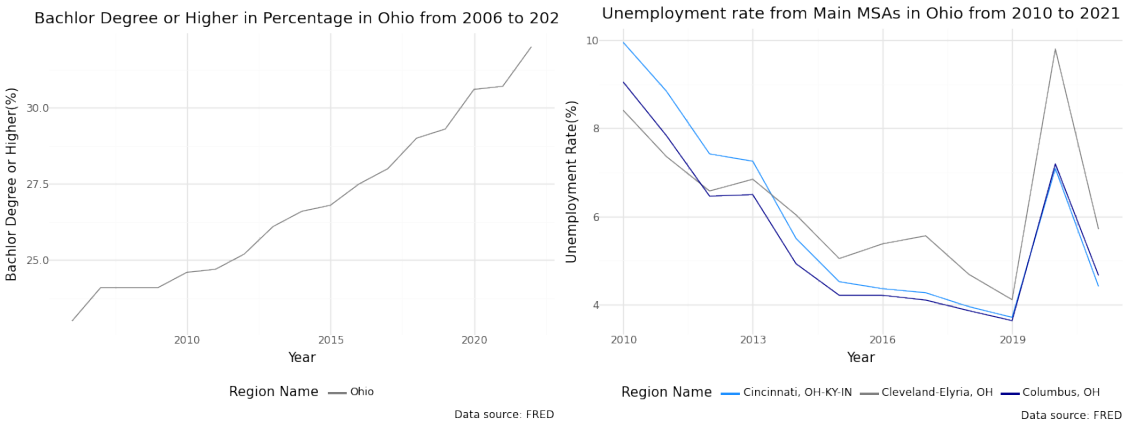
Figure 6. (left) Ohio education level; **Figure 7.** (right) Ohio unemployment rate over time



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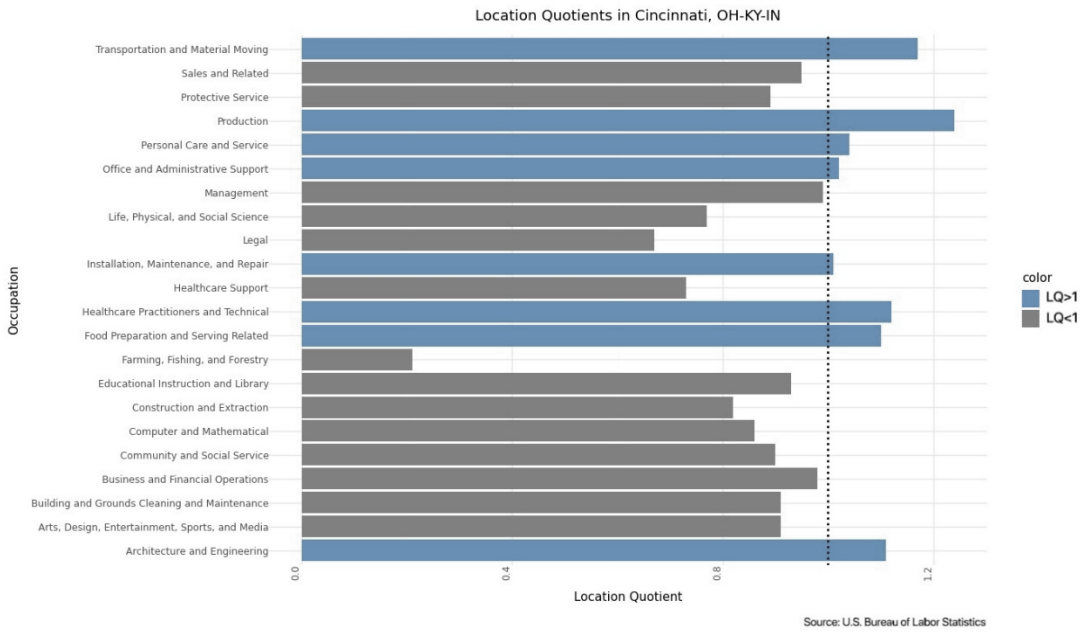
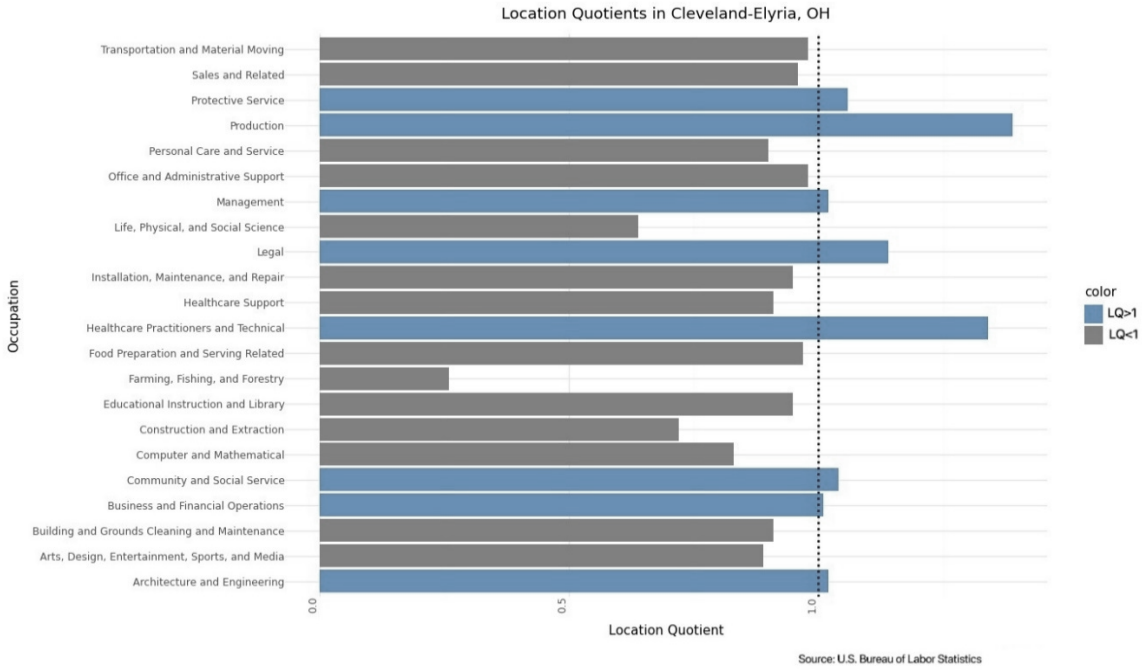
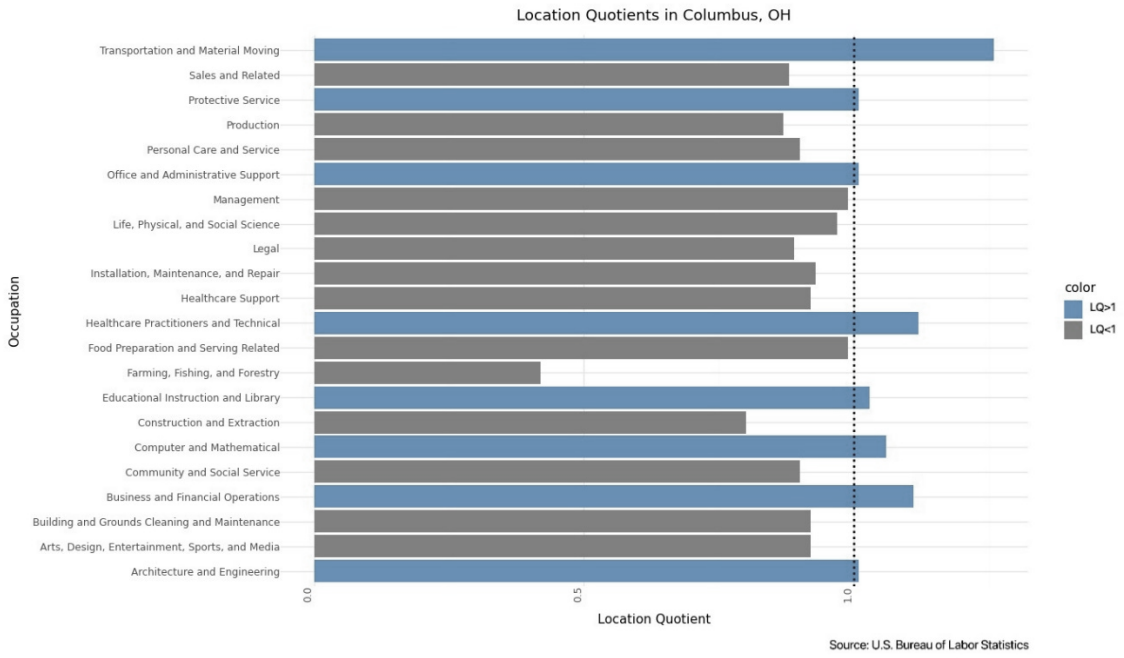
Economic Vulnerability:

Figures 8-10. LQs for Cincinnati, Cleveland, and Columbus







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Analysis

Resilience Index:

To begin the calculations, the mean and standard deviation of each indicator must be calculated:

Table 1. Mean and standard deviation of each indicator used in the Resilience Index.

Indicator	**Mean ($\underline{\chi_i}$)**			**Standard Deviation (σ_i)**		
	Cincinnati	Cleveland	Columbus	Cincinnati	Cleveland	Columbus
Real GDP	124468.6	116859.8	109853.3	21200.58	14651.91	22500.89
Real GDP Growth Rate	0.0383	0.0256	0.0407	0.0277	0.0319	0.0269
House Price Index	165.33	146.23	173.5	29.783	22.108	36.377
GDP Per Capita	0.0744	0.0658	0.0747	0.0115	0.0085	0.0085
GDP Per Square Mile	25.888	42.528	34.663	4.966	5.332	7.100
Higher Education Rate	26.800	26.800	26.800	2.719	2.719	2.719
Ohio Unemployment Rate	5.953	6.317	5.554	4.083	1.560	1.743

Using these measures for the three MSAs combined, we measure the economic resilience of Ohio in any given year during this time period. Below, we will compare the MSA's during the year 2009 and 2021:

2009:

$$\textbf{Cincinnati Resilience Index}_{2009} = \frac{1}{n}\sum_{i=1}^{n}\omega_i \times \left(\frac{\chi_i - \underline{\chi_i}}{\sigma_i}\right)$$
$$= \frac{1}{7}\sum_{i=1}^{7} 1/7 \times \left(\frac{\chi_i - \underline{\chi_i}}{\sigma_i}\right)$$
$$= \frac{1}{49}(-0.9643 + 0.1836 + -0.51147 + -1.001 + -0.9643 + -0.993 + 0.4083) = \textbf{-0.078}$$

$$\textbf{Cleveland Resilience Index}_{2009} = \frac{1}{n}\sum_{i=1}^{n}\omega_i \times \left(\frac{\chi_i - \underline{\chi_i}}{\sigma_i}\right)$$
$$= \frac{1}{7}\sum_{i=1}^{7} 1/7 \times \left(\frac{\chi_i - \underline{\chi_i}}{\sigma_i}\right)$$
$$= \frac{1}{49}(-1.091 + -0.1175 + -0.689 + -1.077 + -1.091 + -0.993 + 0.501) = \textbf{-0.093}$$

$$\textbf{Columbus Resilience Index}_{2009} = \frac{1}{n}\sum_{i=1}^{n}\omega_i \times \left(\frac{\chi_i - \underline{\chi_i}}{\sigma_i}\right)$$
$$= \frac{1}{7}\sum_{i=1}^{7} 1/7 \times \left(\frac{\chi_i - \underline{\chi_i}}{\sigma_i}\right)$$
$$= \frac{1}{49}(-0.9917 + -0.0229 + -0.646 + -1.153 + -0.9917 + -0.993 + 1.116) = \textbf{-0.083}$$

2020:

$$\textbf{Cincinnati Resilience Index}_{2020} = \frac{1}{n}\sum_{i=1}^{n}\omega_i \times \left(\frac{\chi_i - \underline{\chi_i}}{\sigma_i}\right)$$
$$= \frac{1}{7}\sum_{i=1}^{7} 1/7 \times \left(\frac{\chi_i - \underline{\chi_i}}{\sigma_i}\right)$$
$$= \frac{1}{49}(1.335 + 2.176 + 1.802 + 1.317 + 1.335 + 1.342 + -0.241) = \mathbf{0.185}$$

$$\textbf{Cleveland Resilience Index}_{2020} = \frac{1}{n}\sum_{i=1}^{n}\omega_i \times \left(\frac{\chi_i - \underline{\chi_i}}{\sigma_i}\right)$$
$$= \frac{1}{7}\sum_{i=1}^{7} 1/7 \times \left(\frac{\chi_i - \underline{\chi_i}}{\sigma_i}\right)$$
$$= \frac{1}{49}(1.201 + 2.274 + 1.708 + 1.232 + 1.201 + 1.342 + -0.139) = \mathbf{0.180}$$

$$\textbf{Columbus Resilience Index}_{2020} = \frac{1}{n}\sum_{i=1}^{n}\omega_i \times \left(\frac{\chi_i - \underline{\chi_i}}{\sigma_i}\right)$$
$$= \frac{1}{7}\sum_{i=1}^{7} 1/7 \times \left(\frac{\chi_i - \underline{\chi_i}}{\sigma_i}\right)$$
$$= \frac{1}{49}(1.313 + 2.519 + 1.911 + 1.197 + 1.313 + 1.342 + -0.255) = \mathbf{0.206}$$

In 2009, all three resilience indexes were negative, indicating that the MSA's were lower than the average values from 2005 to 2021. This coincides with the fact that the United States was facing a recession from 2008 to 2010, worsening the economy. However, in 2021, we see that all the indexes are positive, signifying that the three MSA's were doing better than average, even in the face of the COVID-19 pandemic, which started a year prior. Between the three MSA's in 2009, we see that Cleveland had the lowest value, meaning that it was affected the most by the Recession. Cincinnati had the highest, showing it was able to recover quicker from the Recession than the other two MSA's. In 2021, we see that Columbus had a higher index, meaning it was able to bounce back quicker than the other two MSA's during the pandemic. We also see that Cleveland had the lowest index, which could be attributed to its inability to recover fully after the 2008 Recession up until 2021.

Vulnerability Index:

In order to perform the calculations for the Vulnerability Index, the LQs and employment shares of the three MSA's must be listed for both tradable(T) and non-tradable industries (NT). Table 2 provides a list of the industries and data points included. We use 2023 data from the Bureau of Labor Statistics.

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Table 2. Location quotients (LQ) and employment shares (ES) for tradable (T) and non-tradable (NT) industries for the Vulnerability Index.

Industry	**Cincinnati LQ(ES)**	**Cleveland LQ(ES)**	**Columbus LQ(ES)**
Management Occupations (T)	0.99 (.0682)	1.02 (.0702)	0.99 (.0681)
Business and Financial Operations Occupations (T)	0.98 (.0649)	1.01 (.0671)	1.11 (.0739)
Computer and Mathematical Occupations (T)	0.86 (.0293)	0.83 (.0282)	1.06 (.0361)
Architecture and Engineering Occupations (T)	1.11 (.0186)	1.02 (.0171)	1.01 (.0169)
Life, Physical, and Social Science Occupations (T)	0.77 (.0071)	0.64 (.0058)	0.97 (.0089)
Transportation and Material Moving Occupations (T)	1.17 (.1058)	0.98 (.0887)	1.26 (.1138)
Protective Service Occupations (T)	0.89 (.0206)	1.06 (.0244)	1.01 (.0233)
Sales and Related Occupations (T)	0.95 (.0841)	0.96 (.0846)	0.88 (.0778)
Office and Administrative Support Occupations (T)	1.02 (.1242)	0.98 (.1201)	1.01 (.1238)
Construction and Extraction Occupations (T)	0.82 (.0337)	0.72 (.0296)	0.80 (.0326)
Installation, Maintenance, and Repair Occupations (T)	1.01 (.0400)	0.95 (.0375)	0.93 (.0368)
Production Occupations (T)	1.24 (.0716)	1.39 (.0800)	0.87 (.0505)
Healthcare Support Occupations (NT)	0.73 (.0341)	0.91 (.0422)	0.92 (.0428)
Community and Social Service Occupations (NT)	0.90 (.0143)	1.04 (.0165)	0.90 (.0143)
Legal Occupations (NT)	0.67 (.0055)	1.14 (.0093)	0.89 (.0041)
Educational Instruction and Library Occupations (NT)	0.93 (.0535)	0.95 (.0545)	1.03 (.0591)
Arts, Design, Entertainment, Sports, and Media Occupations (NT)	0.91 (.0126)	0.89 (.0123)	0.92 (.0128)
Healthcare Practitioners and Technical Occupations (NT)	1.12 (.0682)	1.34 (.0818)	1.12 (.0684)
Food Preparation and Serving Related Occupations (NT)	1.10 (.0959)	0.97 (.0848)	0.99 (.0865)
Building and Grounds Cleaning and Maintenance Occupations (NT)	0.91 (.0265)	0.91 (.0264)	0.92 (.0269)
Personal Care and Service Occupations (NT)	1.04 (.0208)	0.90 (.0180)	0.90 (.0180)
Farming, Fishing, and Forestry Occupations (NT)	0.21 (.0006)	0.26 (.0007)	0.42 (.0012)

Cincinnati Vulnerability Index $= \sum_{i=1}^{12} es_i \times \left(\frac{TLQ_i - 1}{12}\right) - \sum_{j=1}^{10} es_j \times \left(\frac{NTLQ_j - 1}{10}\right)$
$= (0.00125) - (-1.584 \times 10^{-4})$
$=$ **0.0014**

Cleveland Vulnerability Index $= \sum_{i=1}^{12} es_i \times \left(\frac{TLQ_i - 1}{Total\ TLQ}\right) - \sum_{j=1}^{10} es_j \times \left(\frac{NTLQ_j - 1}{Total\ NTLQ}\right)$
$= (8.73 \times 10^{-4}) - (0.00146)$
$= -0.000593 =$ **-5.93×10^{-4}**

Columbus Vulnerability Index $= \sum_{i=1}^{12} es_i \times \left(\frac{TLQ_i - 1}{Total\ TLQ}\right) - \sum_{j=1}^{10} es_j \times \left(\frac{NTLQ_j - 1}{Total\ NTLQ}\right)$
$= (0.00130) - (-1.861 \times 10^{-4})$
$=$ **0.0015**

All three values for the vulnerability indexes are close to zero, meaning that there is no heavy reliance on tradable or non-tradable industries. Both Cincinnati and Columbus have a positive vulnerability index, which signifies that they have more reliance on tradable industries. The industries with the highest LQs are Production Occupations and Transportation and Material Moving Occupations respectively, which are tradable. Comparatively, Cleveland has a negative vulnerability index, meaning that there is a stronger reliance on non-tradable industries. While their highest LQ is for Production Occupations, they also have LQs over 1 for Healthcare Practitioners and Technical Occupations, Community and Social Service Occupations, and Legal Occupations. Cleveland's lower vulnerability index can be a reflection of a number of factors, such as industry diversification and the strength of community resources.

Conclusion

The development of an Ohio Economic Resilience Index and Ohio Economic Vulnerability Index is important for understanding the state's economic stability and vulnerability. By assessing these aspects of Ohio's economy, policymakers can determine the factors shaping regional economic performance and the potential risks facing communities statewide. Further research can strengthen the Resilience Index by adding indicators that span economic, engineering, and social dimensions. Economic indicators could include measures of industry diversity. Engineering indicators cover infrastructure quality and energy usage. Social indicators might have measures of social capital and equity. With the development and application of Ohio's Economic Resilience and Vulnerability Indexes, Ohio can navigate future uncertainties and create a more resilient future for all its residents.

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