Can State-Level Leading Economic Indicators Explain Okun's Law?

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Abstract

Okun's Law is a widely accepted and validated negative relationship between real GDP and the unemployment rate. Researchers have expanded upon the original (1962) specification of Arthur Okun. We add to the literature by incorporating the Leading Economic Index (LEI) to explain changes in the unemployment rate. We build upon previous regional studies within the United States to investigate the magnitude differences for each region established by the Census Bureau. We employ statewide panel data in each region to improve the efficiency of the coefficient estimates for real GDP and the LEI. Pooled and panel seemingly unrelated regression (SUR) are also employed to account for a changing population distribution across time and space. We show that the LEI and real GDP growth have a significant negative relationship with unemployment. We determine that for every 1-unit increase in the LEI results in a regional unemployment rate change between -0.45 and -0.97. Likewise, a 1 percent change in real GDP produces an unemployment rate change between -0.004 and -0.008. Okun's Law is a crucial relationship for policy makers to determine the proper set of actions to mitigate increases in the unemployment rate. Leveraging new data series such as the regional LEI policymaking decision for the macro economy. These findings are consistent with previous research as well as the modern literature on Okun's Law discussing the changes in coefficient magnitudes and the specification of models.

I. Introduction

In 1962, the macroeconomist Arthur Okun published a famous study analyzing the statistical association between changes in the unemployment rate and changes in inflation-adjusted or "real" GDP. Okun uncovered a significant inverse relationship between the unemployment rate and output. Okun (1962) found that there was a 3:1 tradeoff between real GDP and the unemployment rate. In other words, for every three-percentage point increase in real GDP growth the unemployment rate will decrease by 1 percentage point. Okun supports this is in his studies because as output falls firms lay off employees, which thus increases the unemployment rate. Employers may be reluctant to lay off workers at first, however as recessions deepen, they adjust their headcount to reduce variable costs. Since 1962 there have been many technological advances from working on typewriters in offices to now answering all your questions in one simple Google search. Today, many different types of workers can work from anywhere with the internet and are able to contact individuals across the globe.

Although technological changes have transformed the prediction and distribution of goods and services, Okun's law has remained a relatively robust relationship. Researchers have expanded upon Okun's Law over the years, typically focusing on two areas. The first area is how the magnitude and accuracy has changed since 1962. The second area applies different estimation techniques and specifications of Okun's law. These specifications have evolved from first differences to different dynamic forms and different aggregation methods.

The first way Okun's law has become refined is that the intensity of the relationship has weakened. When Okun (1962) originally estimated his model for the period 1947-1960, he found a 3:1 tradeoff between the unemployment rate and real GDP growth. Ball et. al. (2013) determined that it is closer to a 2:1 trade off over the time period 1948-2011. This implies that a 1% growth in output will lead to a 0.5% change in the unemployment rate. This has been confirmed by Gordon (1984); Attfield and Silverstone (1998); and Moosa (1997). Although the magnitude has changed, Okun's law is "strong and stable by the standards of macroeconomics" according to Ball et. al. (2013).

The second area of research into Okun's law has applied new estimation methods and techniques. Some economists estimate Okun's law using different functional forms. One such form is the difference between output and unemployment around their potential values. This assumes that shifts in demand cause GDP to fluctuate around its potential. In turn, this causes employers to hire and release workers as a reaction to changes in demand. As demand falls, firms will lay off workers to cut costs and the unemployment rate will rise as a result. Another functional form is the difference between the unemployment rate between years as well as output. These differences are very useful to remove time-trends which could create spurious associations in the nominal variables. Both of these equation specifications are summarized in Ball et. al. (2013).

This work has motivated economists to test Okun's law in different regions of the United States. Freeman (2000) analyzes this relationship for eight different regions and finds that Okun's coefficient varies from 1.8 to 3.6. Harris and Silverstone (2001) test Okun's Law across multiple different countries and they uncover that unemployment expectedly increases during an economic downturn. However, as the market expands there is a tightening between output and the unemployment rate that is common across most countries. Courtney (1991) investigates this asymmetry in Okun's Law over the course of the business cycle and attributes it to industry inputs. His explanation of factor substitution is evidenced by a non-constant relationship between labor hours, labor force participation, and capital utilization. This implies that the composition of fixed and variable costs change over the course of the business cycle and differ between industries. This cost mixture, such as when the percent of fixed costs increase in an industry, will affect the variation in market rigidities. Courtney (1991) notes these effects on sectoral labor demand are relevant determinants of economic fluctuations. Moosa (1997) delves into a comparative study across countries in which the United States has the highest coefficient and Japan has the lowest. The variation in these coefficients is similarly attributed to labor market rigidities in specific countries.

These are just a few of the different methodologies that have been used to estimate the relationship between GDP and the unemployment rate. Other methods include using smoothing functions like the Hodrick-Prescott or Baxter and King bandpass filter. Both are incorporated to address the trend component of an economic time series, such as GDP (see Freeman (2000) for further detail). These different methodologies and magnitude arguments still make Okun's law an evolving yet stable relationship in macroeconomics.

In this paper, we address the magnitude changes of Okun's Law on a more specialized scale of individual regions within the United States. Regions throughout the United States are reliant on different industries and they react differently to certain stimuli. This is especially seen with the manufacturing sector which is usually the first sector to experience a rising unemployment rate with a decrease in GDP. Instead of focusing directly on one state's specific GDP-unemployment rate relationship this paper focuses on multiple states in their respective regions by paneling and pooling together these states. We will test Okun's law in a different way than previously done with a regional panel analysis in the United States. We estimate the GDP-unemployment rate relationship for the nine census divisions that are established by the BEA. These nine divisions are included in Figure 1 as a reference. Each region or division has economic interactions between them and are reliant on each other. Also, we examine the statistical differences between states in a region to determine if there is strong economic evidence to suggest that there is a different fixed unobservable effect between states based on these economic interactions. In other words, we compare the economic data to determine if the states are uniquely different from one another within a region. Preliminary results suggest that some states have a unique effect based on their region however others are homogeneous within their respective region. In addition, we examine whether the states within a region have a significant underlying economic relationship. Lastly, we not only include GDP as an explanatory variable for the unemployment rate but we use a new series developed in 1982 called the leading economic index (LEI). Results show that the LEI is a significant deterministic factor in explaining the unemployment rate first differences.

Section 2 reviews literature from other researchers that have been analyzing different aspects of Okun's law. Section 3 explains the data and model specification, the preliminary details of the model such as the definition of variables. Section 4 discusses the estimation issues that could be present in the model. Section 5 discusses the summary statistics of the model. Section 5 discusses results of the models and their application. Section 5 discusses the regional model results and their applications. Then section 6 concludes the paper with the policy implications.

II. Background

Okun's Law is a widely accepted macroeconomic relationship that has stimulated extensions in the literature. For example: Harris and Brian (2001) conducted cross-country comparisons between western countries; Guisinger (2018) compared US states; and Freeman (2000) tested Okun's Law on different US regions. There has been extensive research regarding the use of the first difference in the unemployment rate as the dependent variable.

Thirlwall (1969) analyzed the natural rate of growth in GDP in the United States and the United Kingdom. Thirlwall (1969) took Okun's original specification and applied it to both the USA and UK and found that the United States' natural rate to be about 3.6% and the UK's natural rate to be 2.9%. In addition, he confirmed that Okun's law holds for the UK and the US adding to the acceptance of the relationship across countries. He also acknowledged its reliability in measuring past performance even though it may not fit certain portions of history. Ball et. al. (2013) applies Okun's Law across a wider subset of countries such as Spain and Japan.

Ball et. al. (2013) estimated if Okun's model to see if it is still relevant in the 21st century and how it has changed since Okun's initial estimate in 1962. They specify a first difference model quarterly model of unemployment as a function of the growth rate of real GDP, lagged by 2 quarters. The six-month lag is to account for the time to adjust the workforce after a change in demand. Ball et. al. (2013) further evaluate this specification with annual data and include GDP and unemployment in the same time period. In both of these models, the authors found that there is "no evidence of a breakdown in Okun's Law". Okun's law also holds across different countries although the coefficient varies drastically from -0.85 in Spain and -0.16 in Japan.

Okun assumed the shifts in demand would then be followed by firms changing their labor needs by firing or hiring workers, and this would then cause employment and unemployment to change. He decided to put output on the left side of his equation with unemployment on the right. However, some economists differ in their interpretation of output and unemployment and they switch output and unemployment. This is seen in papers such as Prachowny(1993) and Daly et. al. (2012) where they regress unemployment to explain the output levels. They focus on the underlying production function that connects output to the services and goods of an economy. They uncover that changes in capacity utilization, adjustments in the unemployment gap, and weekly hours are significant variables on the changes in output which is the dependent variable.

Courtney (1991) and Harris and Silverstone (2001) delve into the symmetrical assumption between unemployment and real output. Both groups of authors identify contractions as having a bigger impact on the change in the unemployment rate. Courtney (1991) finds that fluctuations in multi-factor productivity and the distribution of output growth across sectors aids in explaining Okun's Law over the business cycle. Harris and Silverstone (2001) analyze the asymmetries and uncover that these should be taken into account in order to not reject the hypothesis that there exists a long-run relationship between unemployment and real GDP across countries. A further area of research is to explain asymmetry in the output-unemployment relationship and why in some periods of history their inverse relationship breaks down but then ultimately returns.

Freeman (2000) conducted regional tests of Okun's law for the years 1977-1997 and incorporated a bandpass filter. His paper estimated the Okun coefficient and analyzed the "trend-cycle of decomposition of economic time series". He develops this model for 8 different economic regions which is a motivating element, for my paper. Freeman (2000) claims that regional data adds evidence to the coefficients magnitude and allows for regional differences in the responsiveness to economic signals. In other words, there may be differences across regions to how labor markets react to changes in production. Economies in different regions may respond differently due to the nature and composition of regional industries. Thus, Freeman highlight regional output and unemployment variation which could lead to more efficient parameter estimation. The estimated coefficients for the regions vary from 1.8 – 3.6 with a weighted average of 2.22 and this aligns with pooled estimate of 2.22.

Guisinger (2018) on the other hand does a state-specific analysis of Okun's Law. A state-level analysis is to determine any variation by state (Guisinger et al. 14). Two of the variables that are used as determinants are labor market flexibility and demographic characteristics. A rigid labor market is defined as one with more employee protections which make it harder to fire employees and makes the employer delay their hiring and firing procedures. Guisinger (2018) finds that the Okun coefficients vary for each U.S state with some regional patterns present. In addition, the difference across state labor market flexibility indicators had the theorized positive effect. A state with more labor market flexibility can adjust their employment operations quicker which results in a faster adjustment of employment to output changes. Education attainment, which is measured by the percent of state's population with a college degree, is one of the indicators that has a statistically significant effect. These results also indicate that monetary policy can have different effects across the states.

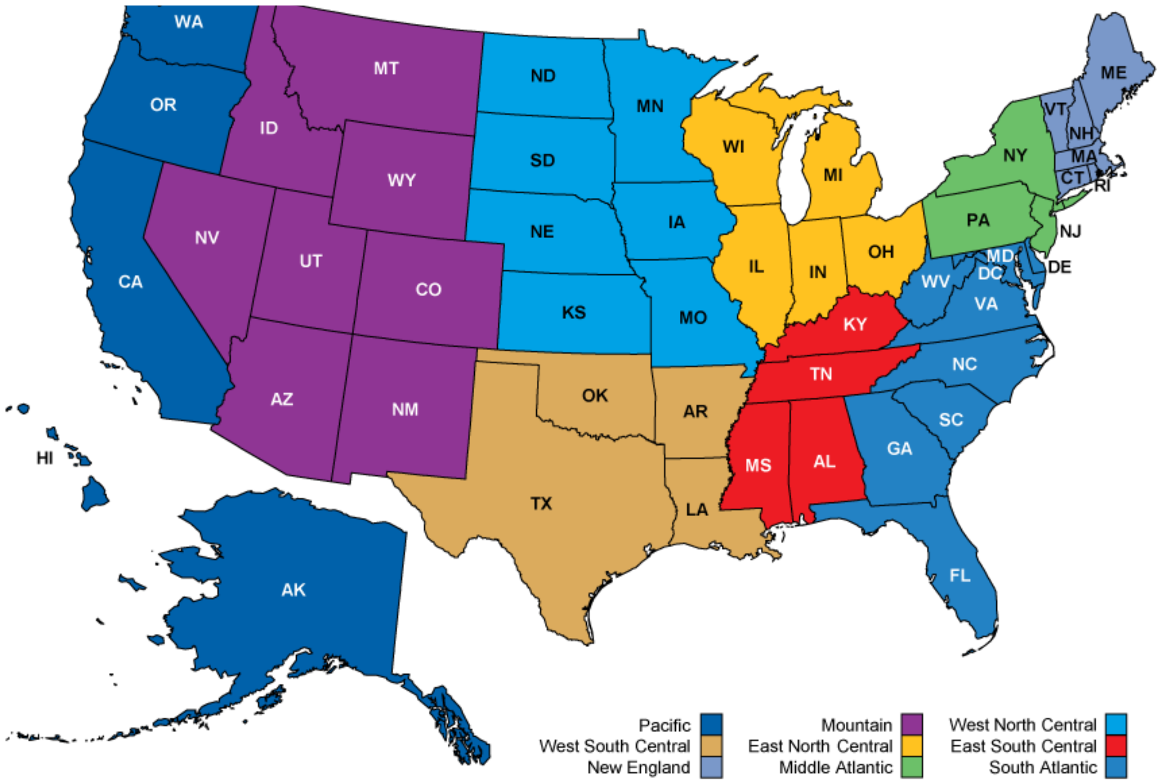
Ultimately Okun's law is a relationship that still holds true even fifty years after Arthur Okun formulated the statistical relationship between changes in the unemployment rate and real GDP. However, it varies in strength depending on the time period and the country in question. There are many factors that also influence changes in the unemployment rate besides changes in real GDP. Additionally, there are numerous methods that can be used to estimate Okun's Law. This paper draws upon this literature to provide more accurate estimates of Okun's law by incorporating additional estimation techniques and economic information.

III. Data and Methodology

The economic data that we use was gathered directly from the Bureau of Economic Analysis (BEA) for the United States of America. For this analysis, we investigate the nine census divisions to see if there are differences in Okun's law. Specifically, we look at differences across each division and within each division. The Census Bureau also analyzes statistical data on a region basis across the United States. They include four regions which are the West, Midwest, Northeast, and South. These regions are further narrowed down into 9 divisions[1]. We focus on the census divisions because state by state differences are more likely to be seen in smaller groups rather than portions of the state effect being averaged out across the large regions. The census bureau (Statistical Groupings of States and Counties) divides the nation into categories based on similar historical development, population characteristics and economies. Lastly, the segments define a geographical framework for aggregating individual states in order to model the economic variation across divisions.

[1] The 9 Census Divisions are defined as: New England (ME, NH, VT, MA, RI, CT); Middle Atlantic (NJ, NY, PA); South Atlantic (DE, MD VA, WV, NC, SC, GA, FL); East North Central (WI, MI, IL, IN, OH); East South Central (KY, TN, MS, AL); West North Central (ND, SD, MN, NE, IA, KS, MO); West South Central (OK, AR, TX, LA); Mountain (MT, ID, WY, NV, UT, CO, AZ, NM); Pacific (AK, WA, OR, CA, HI)

Figure 1 : US Census Divisions



For example, different industries are impacted when consumers tighten up their spending during recessions. The five states within the east north central division are heavily reliant on manufacturing. Manufacturing is one of the top 5 industries by revenue in all those states. Manufacturing output varies differently from the services sector and is known to respond faster to changes in the business cycle. This can be attributed to the market rigidity in manufacturing, which has a higher degree of fixed costs in production. Therefore, how Michigan's unemployment rate changes in respond to output changes is different from New York. These economies have spillover effects into the states around them which is why we will analyze statistical evidence to see if the effects on real GDP and the unemployment rate are different by state within a division as well as different across divisions. Adjacent divisions with similar industries could have different patterns of unemployment than that of their more distant neighbors.

Determining how the economic impact of the business cycle affects each division is critical to know since some divisions take longer to recover during recessions and some are not impacted to the same degree. However, there could be an underlying or prevalent economic relationship between these different divisions. For example, in the middle Atlantic division there are economic interactions between New York and New Jersey that are harder to measure and quantify. People commute from New Jersey to New York City and there are economic interactions that link them together. The entire Middle Atlantic division is heavily reliant on the professional and business services industry. In Pennsylvania, New Jersey, and New York this sector is either the largest or the second largest by revenue (Lang, 2019). The Middle Atlantic division is also heavily unionized, with New York ranked as the second highest percentage of union employment, and New Jersey ranked as the fifth highest percentage (U.S. Bureau of Labor Statistics, 2023). This is in stark contrast to the West South Central division. The four states of Arkansas, Louisiana, Oklahoma, and Texas are all reliant on manufacturing, mining, or both as their top industries (Lang, 2019). Arkansas, Louisiana, and Texas are all in the bottom 10 for unionized employment (U.S. Bureau of Labor Statistics, 2023). The West North Central division contains seven states, four of which are in the top 10 contributors in agriculture (U.S. Department of Agriculture, 2023). The remaining three, South Dakota, Missouri, and North Dakota, are ranked 11, 12, and 14 in that order. This particular division also has a large variation in its unionized employment. We suspect examples like these labor market rigidities and different focus in industry will support the selection of divisions for analysis.

State-level Leading Economic Indicators are a relatively new measure used to predict the state and local business cycles. Leading economic indicators started in 1979 for the United States as a whole and since 1982 for each state. The Philadelphia Federal Reserve is the organization that produces the Leading Economic Indicator Index. The foundation for this index lies in another index called the coincident index. The 4 variables they use in the coincident index are “nonfarm payroll employment, average hours worked in manufacturing by production workers, the unemployment rate, and wage and salary disbursements deflated by the consumer price index” (State Leading Index 2020). The coincident index is used to analyze the current state of the economy and is calibrated to match the long-term growth rate of GDP.

The LEI is an index of leading indicators that predicts the economic expansion or contraction in the individual states over the next 6 months (State Leading Index 2020). The leading economic index includes “state-level housing permits (1 to 4 units), state initial unemployment insurance claims, delivery times from the Institute for Supply Management (ISM) manufacturing survey, and the interest rate spread between the 10-year Treasury bond and the 3-month Treasury bill” (State Leading Index 2020). These indicators are based on extensive research which demonstrates their validity and reliability in predicting recessions. Thus, the LEI lends itself to using regression analysis to forecast economic downturns. The variables used in this paper are as follows.

- **U_{it}:** Unemployment rate of a specific state or division. For example, a 7.5% will be input as 7.5.
- **ΔUit :** first difference of the unemployment rate for division i for years t and t-1

- **LEI_{it}:** Leading Economic Index values fluctuate around 0 with the negatives indicating that will be a decrease in economic activity over the next 6 months. LEI for division i and year t.
- **Y_{it}:** Real GDP for division or state i in year t. This is measured in dollars.
- **$\%Y_{it}$:** percent change of real GDP for division i for years t and t-1

The Census division variables are constructed by aggregating data from individual states. To get the LEI for each division a weighted average is used based on the state's contribution to GDP for that division. The unemployment rate for each division is also published on the BEA's website however that can also be calculated from the total number of the division's unemployed divided by the division's labor force. These rates are seasonally adjusted which removes the effect of seasonal patterns in unemployment, the LEI is also seasonally adjusted. Annual data back to 1982 is used for the unemployment rate, real GDP, and the LEI. The regression is a balanced panel since there is a complete data set for all the states and divisions from 1982 to 2019.

In order to explain divisional differences using Okun's Law, we expand upon the first-differences specification of Ball. et. al. (2013).

(1) $\Delta U_{it} = \alpha + \beta\ \Delta Y_{it} + \omega_{it}$

Where ΔU_{it} represents the first difference of the unemployment rate in the i^{th} division for the t^{th} year; ΔY_{it} is first difference in real output; and $\omega_{it} = \Delta\ \varepsilon_{it,}$ the change in the error term. Using the first differences model usually removes the issue of autocorrelation. Levels are often autocorrelated in an economic time series due to the increasing nominal amount of those variables. Ball. et. al. (2013) estimate this equation using both annual data and quarterly data. They lag the quarterly data for two periods due to the extended period it takes to adjust employment after changes in output. Thirlwall (1969) also incorporates a first differences model.

Annual data is used for the specification of this paper with a one period lag to GDP which accounts for the time it takes to adjust employment to a drop in output. Employers are hesitant to release employees at first but as the economy contracts, they are forced to reduce headcounts. A decrease in real GDP from 2007-2008 would cause an increase in the unemployment rate from 2008-2009. A lag is not included for the leading economic index because it is a forward-looking index. The value of the index today is meant to predict what will be the 6-month growth rate be in the future.

We estimate this specification using an ordinary least squares model with a balanced panel. A panel model is particularly efficient because it helps explain factors that a cross section or time series model would not. A panel can control for the effects of some missing or unobserved variables. This is particularly important when predicting the change in the unemployment rate because in addition to GDP and the LEI, there are other variables that impact the unemployment rate. A balanced panel has an equal number of times series observations for each division. The panel strengthens the model because some of the effects of missing and unobserved variables can be controlled. When trying to predict how the unemployment rate will change in the future there are a lot of different factors with varying levels of deterministic capabilities.

This paper explains another way to determine the changes in the unemployment rate that uses contemporary modern tools to its advantage. For the specification in this paper, LEI is used as an explanatory variable. The LEI tracks workforce information and follows from Guisinger's (2018) incorporation of labor market flexibility as an explanatory variable. We use the LEI as a tool to explain these changes as opposed to using labor market conditions.. Equation 2 below shows this model specification and is the basis for the rest of this paper. Guinsinger showed that labor market flexibility helped explain the difference in Okun's law between states.

(2) $\Delta U_{it} = \beta_0 + \beta_1 \%Y_{it} + \beta_2 LEI_{it} + \varepsilon_t$

Where ΔU_{ti} is the first difference in the unemployment rate and the $\%Y_{t-1}$ is the percent change in GDP for the previous period or lagged one period. The LEI is the leading economic index and it is published for each state as discussed in the data section. This index is a combination of the leading indicators that were described previously. These indicators give a view into how the economy will perform in the future. The leading economic index is specific to each state in the pool of the division.

IV. Panel Model Estimation

One of the estimation issues that could occur in these models is biased estimates of the slopes. Biasedness is a very serious consequence and leads to an unreliable model. This can be addressed by running the redundant fixed effects test to determine if the separate intercepts should be used for each state-level cross section. Due to the divisional differences in these economies is it highly likely that each state will have different fixed effects because the change in the unemployment rate is likely to differ by state.

A second estimation issue with panel models is cross equation residual correlation. A panel OLS model assumes no cross-equation residual correlation. For example, the unexplained variation in Michigan's unemployment rate should not be correlated with Wisconsin or Illinois. If this is not the case, perhaps due to a common weak or unobservable factor such as political or social factors, then the t-statistics for the explanatory variables will be imprecise. When cross-sections residuals are dependent on each other there can be an overstatement of significance due to bias in the standard errors. This is a hindrance to the model because if cross-section dependence is ignored there is an efficiency loss and test statistics would be invalid.

One of ordinary least squares' assumptions is that the error terms in each equation are independent of the other error term for a different cross section. We expect this to be violated when doing cross sections of different divisions due to the interdependence of the global economy. Our world has become so interconnected with different countries supplying resources to others creating an interlocking web of economic activity. This economic activity is expected to be more influential between each division and definitely between the states with the divisions. The Census classified the divisions together due to their economic similarities so it is clear there will be an unobservable interaction between states that is hard to capture.

The unobservable interaction between states and divisions can be captured to improve the efficiency of the estimators by using seeming unrelated regression. Seemingly unrelated regressions (SUR) is a useful tool to correct for the biased standard errors when the cross section residuals are correlated. Seemingly unrelated regression uses the error term of these multiple different cross section equations to improve the efficiency of the estimators. SUR is used to correct for the biased standard errors and due to the large sample sizes, SUR and OLS estimates will be the same if there is no correlation between the error terms.

V. Summary Statistics

Table 1 below is a balanced panel for the aggregated divisions. To allow time for employment to react to changes in GDP, a one-period lag is implemented for real GDP. This is similar to the model employed by Ball et. al. (2013). This reduces the number of annual periods that are included by 1. Due to the first difference in the unemployment rate and the percent change in RGDP an additional observation is also lost so in total there are 36 periods across 9 different divisions.

Table 1: Panel Regression of Aggregated Divisions

Left Hand Side: $D(U_{it})$	
Constant	1.303***
	(0.078)
$\%Y_{it-1}$	-0.089***
	(0.014)
LEI_{it}	-0.877***
	(0.044)
Periods	36
Cross-sections	9
Total Observation	324
R-squared	0.596
Adj R-squared	0.583
F-statistic	46.085
Durbin-Watson	1.913
*,**,*** indicates significance at the 10%, 5%, and 1% levels	
Standard errors in parentheses	

The regression above confirms that lagged GDP growth is a statistically significant determinant of D(RUNC). The coefficient is -0.0895 which means that for every 1% increase in lagged real GDP growth unemployment will decrease by about -0.0895. If the unemployment rate was 4.0895% in 2018 then it would decrease to 4% in 2019. The usual relationship described in previous literature indicated that unemployment would decline between 0.333 and 0.5 for each one percentage point increase in real GDP. The LEI has taken over some of the explanatory power of GDP in the model, but GDP still has a statistically significant impact. The sign of real GDP aligns with theorized expectations in relation to the unemployment rate.

The slope estimate of -0.8766 for the LEI indicates a much stronger impact on lowering unemployment compared to real GDP growth for an individual state's unemployment rate. One important aspect to test for is if these divisions have different fixed effects which controls for differences in the mean change in the unemployment rate across states given that there was no change in the LEI or real GDP. If the specific fixed effects of different divisions are not accounted for then it could cause a biased estimate of the intercept. This effect is called heterogeneity bias which occurs when the cross sections unique characteristics are not controlled regulating the effects to the error term and these effects correlate with other the explanatory variables (see Pedace (2013) for further detail). Fixed effects are used to control for unobservable variables that impacts an individual state's unemployment rate.

We conduct two auxiliary tests to ensure our specification is appropriate. To test if using fixed effects are necessary, the redundant fixed effects test is used. We further conduct a cross-section dependence test to determine if heteroscedasticity is present. Results are shown in the table below.

Table 2: Auxiliary Tests (Panel)

Redundant Fixed Effects Tests	Statistic	d.f.	Prob
Cross-section F	8.188	8313	0.000
Cross-section Chi-square	61.567	8	0.000
Residual Cross-Section Dependence Test	Statistic	d.f.	Prob
Breusch-Pagan LM	685.884	36	0.000

The redundant fixed effects test result is significant at the 1% level of significance indicating no redundancy amongst the fixed effects. This indicates that each division's fixed effect is unique and therefore it is imperative that they are used to avoid biased slope estimates. The regression in table 1 uses these cross-section fixed effects. The cross-section dependence test shows significance at the 1% level of significance which indicates that there is significant evidence of a cross-section dependence in the residuals which is a violation of the ordinary least squares' assumptions. This indicates that there is strong evidence that there are at least 2 divisions that have a correlated error term. This is not surprising due to the divisional integration of the US, especially the interdependence of state and divisional business cycles. Rejecting this test may imply that the t-statistics are overstated, and the significance of each variable is overstated. This, as stated before, was a potential issue for the model and should be corrected. The simplest method to employ that will help improve estimator efficiency and validity is to use seeming unrelated regressions (SUR) techniques.

Running the model using the seeming unrelated regression weights gives the new model below. RGDP and LEI are still significant variables remaining at 1% significance. There was a much larger decrease in the t-statistic for RGDP growth but both variables are ultimately still highly significant. The cross-section dependence test is now insignificant which indicates that SUR assisted in correcting the bias in the standard errors. SUR estimation improved the efficiency of both of these estimators as well.

Table 3: Panel SUR

Left Hand Side: D(U_{it})	
Constant	0.933*** (0.073)
%Y_{it-1}	-0.034*** (0.010)
LEI_{it}	-0.720*** (0.038)
Periods	36
Cross-sections	9
Total Observation	324
R-squared	0.573
Adj R-squared	0.559
F-statistic	41.972
Durbin-Watson	2.001
*,**,*** indicates significance at the 10%, 5%, and 1% levels	
Standard errors in parentheses	

The slopes of both RGDP and the LEI decreased by a sizable amount as well. The adjusted R^2 is still rather high at 0.559 as opposed to 0.583. Only a small amount of the explanatory power was lost due using SUR. The weighted Durbin-Watson test stat is 2.001 which is statistically strong evidence that there is no autocorrelation. That justifies the first difference model and preventing autocorrelation. The F-stat is nearly 42 which is a slight decrease from 46 but there is still statically significant evidence that one of the parameters is different from 0 and they both are significant on their own. Also, there is no longer significant evidence of cross-sectional residual correlation in the Breusch-Pagan LM probability of 0.9799. SUR corrected this assumption violation.

Table 4: Auxiliary Test (SUR)

Residual Cross-Section Dependence Test	Statistic	d.f.	Prob
Breusch-Pagan LM	20.796	36	0.979

VI. Divisional Results

This next section of this paper delves into the divisional panels by state to compare the divisions individually and how each state relates to the others in a particular division. Since the redundancy test determined that each division has different fixed effects, it is a worthwhile endeavor to see how the divisions differ.

Table 5a: Ordinary Least Squares Regression Results

Independent Variable	Division				
	Pacific	**Mountain**	**West North Central**	**West South Central**	**East South Central**
Intercept	1.245***	1.341***	0.795***	1.168***	0.721***
	(0.107)	(0.098)	(0.071)	(0.152)	(0.130)
%Y_{it-1}	-0.030**	-0.023*	-0.036***[a]	-0.049**[a]	-0.163***[a]
	(0.013)	(0.012)	(0.009)	(0.022)	(0.031)
LEI_{it}	-0.963***	-0.833***	-0.610***	-1.037***	-0.420***
	(0.065)	(0.047)	(0.048)	(0.134)	(0.085)
Observations	180	252	259	148	148
R-squared	0.546	0.567	0.439	0.389	0.361
Adj. R-Squared	0.531	0.553	0.421	0.367	0.339
F-Statistic	35.73	39.70	24.46	18.00	16.06
DW Stat	1.92	1.59	1.93	1.75	1.75
Redundant Fixed Effects Prob	0.0000***	0.0000***	0.0001***	0.0000***	0.2787
Cross Section Dependence Test Prob.	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***

*, **, *** indicates significance at the 10%, 5%, and 1% levels

[a] indicates there is no lag in the output variable.

Standard errors in parentheses

Some divisions did not show significance at least a 10% level when Y was lagged for one annual period. Ball et. al. (2013) use a similar specification and lagging structure instead for annual data they used no lag. They used no lag because sometimes it is hard to determine how long it takes employers to adjust their employment levels. Some areas could take longer between 6-12 month when some may have a faster response between 3-6 months. Due to this difference in timing, there is economic evidence to suggest that some divisions in the model do not take a shorter amount of time to adjust their employment. Therefore, the lag is removed and the change in RGDP becomes more significant in explaining the difference in the unemployment rate for the same period. The lag is removed for East South-Central division due to RGDP being insignificant with the lag included. This same methodology is applied to the West South-Central and the West North-Central divisions as well. RGDP is significant with no lag due to the shorter timing difference of employers' responses to changes in output.

The total observations for each division fluctuate based on the number of states included in each cross sections and whether GDP is lagged or not. Paneling data allows for more efficient estimators due to the larger sample size than would be previously possible with only time series models. Every division in Table 5a and 5b have a statistically significant LEI and Y in explaining the change in divisional unemployment rate with most being 1% significant. As in the aggregated model, the LEI is taking away the explanatory power of real GDP due to the stronger correlation between the two variables. LEI is highly significant at the 1% level for every single one of the 5 divisions in Table 4. The coefficients for LEI range from -0.42 to -1.069.

Table 5b: Ordinary Least Squares Regression Results (cont)

	Division			
Independent Variable	**East North Central**	**South Atlantic**	**Middle Atlantic**	**New England**
Intercept	0.987***	1.019***	1.137***	0.904***
	(0.091)	(0.097)	(0.114)	(0.069)
%Y_{it-1}	-0.112***	-0.066***	-0.073***	-0.057***
	(0.018)	(0.017)	(0.025)	(0.013)
LEI_{it}	-0.875***	-0.662***	-1.069***	-0.675***
	(0.062)	(0.051)	(0.085)	(0.037)
Observations	216	288	108	216
R-squared	0.546	0.419	0.636	0.633

Adj. R-Squared	0.531	0.400	0.622	0.620
F-Statistic	35.73	22.29	45.03	151.04
DW Stat	1.92	1.76	2.04	1.89
Redundant Fixed Effects Prob	0.2789	0.0362**	0.6228	0.0002***
Cross Section Dependence Test Prob.	0.0000***	0.0000***	0.0000***	0.0000***
*, **, *** indicates significance at the 10%, 5%, and 1% levels				
Standard errors in Parentheses				

In the four divisions of the eastern United States, they all have highly significant RGDP and LEI variables. They all explain a significant portion of variation in the unemployment rate differences with r-squared of around 0.5. The South Atlantic is the lowest at 0.4 but that is still very strong in relation to economics. The adjusted r-squared follow similar results and have a strong indication that a large part of the variation is explained by LEI and Y. All divisions have at least one variable that is statistically different from 0. This is indicated due to the large F statistics that are all above 22.

All the coefficients for each parameter align as expected. Y and LEI are both negative as expected with increases in both indicating a decrease in the unemployment rate. Output impacts the unemployment rate the most in the East North Central division. This is most likely due to that division's reliance on manufacturing. Since manufacturing is known to have higher fixed costs in production, we expect these states to be more sensitive to changes in output and employment. The LEI again took explanatory power away from Y for these divisions which aligns with theorized expectations. LEI is a more significant indicator than Y, but they are both statistically significant to the model.

Tables 5a and 5b show the results of both the redundant significant fixed effects test. For the majority of the divisions there is statistically significant evidence that the states within the divisions have a different fixed effect. However, four of the divisions specifically ENC, ESC, and the Middle Atlantic do not have significant evidence the fixed effects are different between states. These can still be run with fixed effects because there is inconclusive evidence to determine if the constant is redundant.

Every division from both tables above rejects the cross-section dependence test so there is significant evidence of a correlation between at least one state in every division and another state in that division. This was expected to occur due to the economic dependencies between states and between divisions as well. Economies are more interconnected due to the advance in technologies and supply chains so that people in one state can order products from across the country and expect it to get there is a reasonable amount of time. As in the divisional model, this is a violation of one of the ordinary least squares assumptions that the errors terms must be uncorrelated with each other. The rejection of this test indicates that the significance of each variable may be overstated and that the test statistics are too high. There is biasedness in the standard errors and this must be corrected. Seemingly unrelated regression can be used to correct this and give validity back to the estimators. Table 6a summarizes the results of the SUR estimation method for the first 5 divisions.

SUR solved the overstatement of significance in the variable and the biasedness of these variables as shown with the cross-section dependence test now. All 5 divisions in table 6a do not reject cross section dependence test using the Breusch Pagan LM method. This signifies that there is no evidence that the cross-section residuals are correlated and there is no evidence of a violation in the ordinary least squares' assumptions. The r-squared for every division fluctuated but it is still very strong for most divisions around 0.5 however the East South Central division's r-squared dropped to 0.246. This has a significantly lower relationship than other divisions which indicates there may be other factors that explain the difference in the unemployment rate better.

Although SUR correctly adjusted for the test statistics, it changed the significance to the correct level which made some of the Y's insignificant with a one period lag. Due to this, the lag was removed to determine if the current year change in RGDP would explain the current year change in the unemployment rate. However, in the Mountain division Y become insignificant altogether. This signals that the LEI explains way more in proportion to Y and that it is a better indicator of predicting future changes in the unemployment rate. In addition, the East South Central division now does include a lag due to the efficiency gain that using SUR provided. Output lagged is now a statistically significant variable in explaining the difference in the unemployment rate.

Table 6a: Seemingly Unrelated Regression Results

Independent Variable	**Division**				
	Pacific	**Mountain**	**West North Central**	**West South Central**	**East South Central**
Intercept	0.972***	1.061***	0.626***	1.045***	0.500***
	(0.104)	(0.105)	(0.060)	(0.131)	(0.168)
%Y_{it-1}	-0.014*$_a$	-0.004	-0.016***$_a$	-0.030*$_a$	-0.050*
	(0.008)	(0.008)	(0.005)	(0.016)	(0.026)
LEI_{it}	-0.795***	-0.705***	-0.521***	-0.966***	-0.484***
	(0.057)	(0.045)	(0.035)	(0.103)	(0.080)
Observations	180	252	259	148	144
R-squared	0.540	0.490	0.520	0.468	0.246
Adj. R-Squared	0.524	0.483	0.504	0.450	0.219
F-Statistic	33.80	39.70	33.80	25.00	9.02
DW Stat	2.09	1.88	1.96	1.90	2.13
Cross Section Dependence Test Prob.	0.997	1.000	1.000	1.000	0.756

*,**,*** indicates significance at the 10%, 5%, and 1% levels

$_a$ indicates there is no lag in the output variable.

Standard errors in parentheses

The signs of LEI and Y continue to be the same as expected. No sign flipped in significance when using the SUR method. SUR also improves the Durbin-Watson stats by moving them closer to 2 for most of the divisions compared to what they were with OLS.

In the four divisions of the eastern United States, they all still have highly significant RGDP and LEI variables. The only ones that are not significant at the 1% level is the South

Atlantic and the Middle Atlantic's Y. These two variables are significant at the 10% and 5% respectively. They all explain a significant portion of the variation the unemployment rate differences with r-squares varying from 0.378 to 0.595. The F statistics show that every division in table 6a and 6b has at least one explanatory variable that is statistically different from 0. The cross-section dependence test indicates that the problem of invalid test statistics has been addressed using SUR estimation. The four eastern divisions have p-values close to 1 for the cross-section dependence test.

Table 6b: Seemingly Unrelated Regression Results (cont)

	Division			
Independent Variable	**East North Central**	**South Atlantic**	**Middle Atlantic**	**New England**
Intercept	0.470***	0.717***	0.711***	0.706***
	(0.086)	(0.105)	(0.146)	(0.094)
$\%Y_{it-1}$	-0.083***[a]	-0.021*	-0.048**[a]	-0.050***
	(0.016)	(0.012)	(0.020)	(0.011)
LEI_{it}	-0.441***	-0.545***	-0.688***	-0.533***
	(0.048)	(0.041)	(0.096)	(0.033)
Observations	222	288	111	216
R-squared	0.378	0.378	0.386	0.595
Adj. R-Squared	0.358	0.358	0.363	0.581
F-Statistic	18.61	18.76	16.66	43.6
DW Stat	2.02	1.97	2.02	2.05
Cross Section Dependence Test Prob.	0.998	1.000	0.974	0.989

*,**,*** indicates significance at the 10%, 5%, and 1% levels

[a] indicates there is no lag in the output variable

Standard errors in Parentheses

All the coefficients for each parameter align as expected with a negative relationship between U and Y, plus U and LEI. The Middle Atlantic Division's Y became insignificant when it was lagged with SUR, so the lag has been removed as done previously. This is another division that the unemployment rate takes less time to adjust as changes in output occur.

VII. Conclusion

Okun's Law is a relationship that originally identified that a 3% increase in GDP would accompany a decrease in the unemployment rate by 1%. This inverse relationship has been tested in literature since Okun's original paper in 1962. Since then, research has expanded on Okun's law by focusing on the changes in magnitude and the mathematical specification of the relationship. A better understanding of this relationship aids policymakers in determining the overall health of the economy. The overall conclusion from previous researchers is the relationship can have large magnitude shifts depending on the division or country in question.

In this paper we focused on the intersection between different specifications and divisional selections. We built upon past research done by Freeman and Guisinger (2000) in their concentrated analysis of specific subsections in the United States. We also incorporated the Leading Economic Index. The index is used to forecast the 6-month growth rate and has indicators that have a more precise relationship with the unemployment rate. The data we used in the model was gathered from the BEA and based on the 9 divisions established by the Census Bureau.

We found a highly significant relationship for the changes in real GDP and the LEI in the aggregated 9- division panel model. In addition, there was a significant fixed effect difference between the 9 divisions. Real GDP aligned with expectations and had a negative impact of -0.089. In other words, for every 1% increase in RGDP, the unemployment rate will decrease by 0.09 of a percentage point. This is a lot less than the 3 to 1 tradeoff and the 2 to 1 tradeoff that researchers have validated. This is due to the addition of the LEI which takes the explanatory power away from real GDP. The LEI is also significant and for every 1 unit increase in the LEI the unemployment rate decreases by about 0.9 of a percentage point. There is one assumption violation that occurred with the ordinary least squares model, which is cross equation residual correlation, however using seemingly unrelated regression corrected this issue.

The results of each divisional panel with their states proved to have similar results but also had a variation between the divisions. Most divisions had highly significant real GDP parameters with a one-year lag, however there were three divisions that used the current value of real GDP growth. Fixed effects were insignificant for three divisions which means those divisions were very interconnected and did not have a separate state influence. These divisions have some unknown economic interactions that link the states together compared to the other six divisions. Using the original OLS models, all the divisions had real GDP and LEI variables with a negative coefficient aligning to expectations. The coefficients varied from -0.023 to -0.163 for real GDP and -0.42 and -1.069 for LEI. All divisions had the issue of cross equation residual correlation and it was corrected by employing SUR models for every division.

The SUR results still had a highly significant LEI variable for every division at the 1% significance level. The LEI coefficients varied from -0.466 to -0.966. Almost all divisions had lower LEI coefficients using SUR estimation than using ordinary OLS in absolute value terms except for the East South-Central division. These drops across all divisions demonstrates the importance of using panel models to improve not only the precision, but also suggests that OLS estimates may have an element of bias. RGDP growth estimates ranged from -0.004 to -0.083 with varying levels of significance. The Mountain division become insignificant at all alpha levels and a majority of the other divisions became less significant. This further supports that the LEI has a much stronger impact that the change in the unemployment rate compared to GDP. This strongly suggests a modification to the first-difference specification of Okun's Law.

One area for extension in this paper is why the fixed effects are not significant for the East South Central, East North Central, and Middle Atlantic. These divisions could have very dependent economies or similar industries that lead to a high economic dependency between states in these divisions. Out of the 12 states in this cohort, finance is a top industry for six them, while professional and business services is a top industry for all of them. On average, these states are more unionized and less involved in agriculture (U.S. Department of Agriculture, 2023). Another area to examine is why the West South Central, East South Central, and the West North Central divisions are all quicker to respond to changes in output. This was indicated due to the lag in output being insignificant when in all the other divisions it is not. Dropping the lag on the growth in real GDP improved its significance. Out of the 15 states in this cohort, manufacturing is the single top industry for 11 of them, while mining is the top industry for two states. This group is very low in the unionization rankings, and is much more involved in agriculture. Five out of the top 10 agriculture states are in this group (U.S. Department of Agriculture, 2023) The reduction in the time between changes in aggregate supply and demand must be due to both supply chain management and improvement in communication times due to the emergence of other technologies.

This leads to additional questions about how dependent each of these divisions are to one another, to what degree the role of labor rigidities play, and if certain industries create greater asymmetry. The magnitude of dependency would give valuable insight to policy makers and enable them to enhance the efficiency of these economic interactions. We can hypothesize that a higher focus in agriculture and lower unionization hastens the connection between GDP and unemployment; whereas a higher focus in professional and financial services increases the magnitude. However, further research could explain a why these divisions have these unique responses at greater depths.

Ultimately, we extended Okun's Law into the divisional sphere with the LEI to explain changes in the unemployment rate. These results show that LE.I and real GDP are highly significant indicators of future changes in the unemployment rate and could be leveraged by state officials to slow down decreases in GDP and the ensuing increase in the unemployment rate. These officials can use policies to limit the impact of downturns in the business cycle by using LEI indicators and real GDP to predict the next change in the unemployment rate. As the LEI decreases, they can enact pro spending policies to get consumers to increase their demand and improve economic health. Okun’s law remains a stable relationship that can used for policy making on a divisional basis to limit the impact of declines in the business cycle.

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