Analysis of Okun's coefficient in California 2010-2019

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Abstract

Okun’s law is an empirical observation indicating that if unemployment decreases, a country’s production, or GDP (Gross Domestic Product), will rise. According to Okun’s theory, a 1% decline in the unemployment rate will result in a 2% rise in GDP. Utilizing our collected data from 58 California counties, we shall attempt to determine Okun’s coefficient for the years 2010 to 2019. The findings of our study concluded that Okun’s law does not hold when data is collected at the county level and thus different parameters should be used to examine its validity.

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I. Introduction

The purpose of our project is to examine if Okun's law can be applicable at the county level. As a result, we have collected data from all 58 California counties for the years 2010 through 2019, using various data sources detailed in the Data Description Table. Due to the fact that based on recent economic reports, the COVID-19 pandemic has shown to decrease GDP and increase the unemployment rate, we have excluded it from our model (United Nations, 2021). The goal of our analysis is to collect data over a 10-year period for unemployment, economic growth, and labor force. Our hypothesis is that a decrease in unemployment would increase GDP. The reason why our question is important is that Okun's law may be used as a guide to plan and invest in infrastructure. Future growth may need to be supported by government and institutional services, such as healthcare, education, and transport. These are long-term projects that rely on good planning and projections to ensure economic growth. However, in a rapidly changing world new industries are being created (e-commerce, digital gaming, artificial intelligence, biotech), and may cause perturbations to the law. People who have been unemployed for a long time drop out of the statistics, as do those taking early retirement and undocumented workers. Needless to note, there is a component of the economy that is not tracked, including but not limited to, black markets or off-the-books accounting, prostitution, and drugs.

A correct analysis between the relationship of economic growth and the rate of unemployment is necessary to effectively assess the validity of Okun's law. A constant change of unemployment and economic growth is a good indicator of their correlation. However, if the effect of unemployment on economic growth is not constant then Okun's law may not be very useful at predicting future changes.

II. Literature Review

In 2017, the study "Estimating Okun's law in Sweden" conducted by researchers Valde Stjernström and Roma Goussakov, who examined Okun's law in Sweden between the years 1980-2015, found that the effect of unemployment on GDP was negative during this time period. Thus, they concluded that Okun's law holds true for the country of Sweden. However, the paper also notes that there were differences in the size of coefficients between males and females. Women showed a weaker relationship between GDP and unemployment. Furthermore, older people's unemployment was affected less by changes in the GDP. Interestingly, in their paper, Mr. Stjernström and Mr. Goussakov also note that the relationship between GDP and unemployment should not be the sole factor for policymakers to rely on when they are attempting to analyze unemployment changes.

Moreover, in "The Validity of Okun's Law: An Assessment of the United Kingdom's Unemployment- Output Relationship", Bucharest University Economics professor, Emmanuel

Olusegun Stober, analyzed Okun's Law in the United Kingdom using quarterly data from 1971-2013. This collected quarterly data suggested that unemployment should be considered as a dependent variable, while GDP should be used as an independent variable. In fact, Dr. Stober's regression equation and graphs show an inverse relationship between these two variables. The results were interpreted that if the unemployment rate falls by 0.074 points, then GDP rises by 1 point. Inversely, if there is a rise in GDP by 0.15%, unemployment is predicted to fall by 1%. Finally, Dr. Stober concluded that Okun's law is a good estimate for policymakers, economists, and the government when they are trying to effectively estimate the effect of unemployment on an economy.

Interestingly, in another study titled "Okun's Law: An Empirical Investigation into Eurozone Growth and Unemployment" and conducted by Stephen Garavan, a consultant at the Center for European Policy Analysis (CEPA), Okun's law was tested by looking at the data for the years 2002-2013 from 19 Eurozone countries: Austria, Belgium, Cyprus, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Portugal, Slovak Republic, Slovenia, and Spain. Similar to the results of Stober's study mentioned above, this paper also concluded that in the short run, there is a negative relationship between GDP and unemployment. This study also used unemployment as the dependent variable and GDP as the independent variable. In his paper, Mr. Garavan suggested that further studies and research should be conducted to accurately analyze Okun's law in an effective manner.

Furthermore, in a robust study titled "A State-Level Analysis of Okun's Law" and conducted by multiple economics experts, Okun's law was estimated separately for each U.S.

state. What is noteworthy is that this group of researchers concluded that Okun's coefficient varies from state to state. For instance, they list California's coefficient as being -2.12, while Florida's is noted as -2.38. The paper also suggested that if state policymakers or state governments wish to create unemployment policies for their specific state, in addition to other factors, they should take into account differences in Okun's coefficient.

In addition, it is important to note that Investopedia points out that Okun's law is based on the U.S. economy and that other industrialized nations have less flexible labor markets which may cause them to have higher Okun coefficients. The author noted that "Economists broadly support Okun's law, but it's considered to be inaccurate". This comes as numerous variables are involved with changes in GNP and GDP. Economists support an inverse relationship between unemployment and production, believing that when unemployment rises, GNP and GDP will simultaneously fall, and when unemployment declines, GNP and GDP are expected to increase, but the exact amount varies" (Kenton, 2020). The literature studies show "Okun's law, only applies to the U.S. economy and only applies when the unemployment rate is between 3% and 7.5%" (Kenton, 2020).

III. Data

Using our collected dataset, we will evaluate the effect of the unemployment rate on GDP in California's 58 counties from 2010-2019. GDP was collected from BEA.gov and is recorded in thousands of chained 2012 dollars. The population estimate and separate estimates for the male population and female population were collected from Census.gov, with males_per calculated as the estimated male population over the total estimated population.

The education variable includes people aged 25 and over who have high school diplomas, GEDs (General Educational Development), Bachelor Degrees, and Masters Degrees for the years 2015-2019 (from 2010-2015 data was not available for education). Data was collected from Census.gov ACS 5-year estimates, with the variables then divided by total population estimate to provide percentages of the total population, GED_per, AA_per, BA_per, and MA_per.

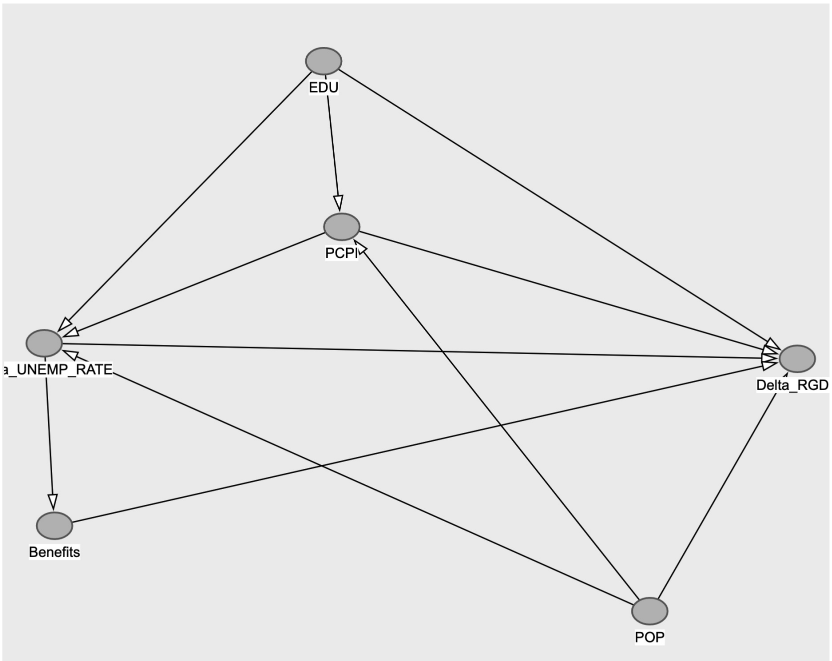
Data for total benefits paid, initial claims, and exhausted claims were collected from Data.CA.gov, with Real_Benefits_paid adjusted to real 2012 dollars using the calculated GDP deflator. Per capita personal income (PCPI) was also calculated to reflect real 2012 dollars (Real_PCPI).

ΔRGDP is the dependent variable in our regression equation, ΔUNEMP_RATE is the independent variable of interest.

This give us our hypothesis:

$\boldsymbol{\Delta} HRGDP_0$: $\boldsymbol{\beta}_1 ==0$, Okun's coefficient can be determined$\boldsymbol{\beta}_0$, Okun's coefficient cannot be determined $+ \boldsymbol{\beta}_1 \times \boldsymbol{\Delta} UNEMPRATE + \varepsilon$ at the county level in this model.at the county level in this model.

H_1: $\boldsymbol{\beta}_1 \neq 0$



Following our directed acyclic graph, we are controlling for education variables (EDU), population estimate (POPESTIMATE), and Real_PCPI (Per Capita Personal Income).

This gives us our baseline regression:

ΔRGDP = $\boldsymbol{\beta}_0$ + $\boldsymbol{\beta}_1$ x ΔUNEMP_RATE + $\boldsymbol{\beta}_2$ x POPESTIMATE + $\boldsymbol{\beta}_3$ x GED_per + $\boldsymbol{\beta}_4$ x AA_per + $\boldsymbol{\beta}_5$ x BA_per + $\boldsymbol{\beta}_6$ x MA_per + $\boldsymbol{\beta}_7$ x Real_PCPI + ε

IV. Results

Baseline Regression

Model Fit Measures

				Overall Model Test			
Model	R^2	Adjusted R^2	RMSE	F	df1	df2	p
1	0.02074	−0.00357	3.69459	0.85333	7	282	0.544

Model Coefficients - Delta_RGDP

			95% Confidence Interval			
Predictor	Estimate	SE	Lower	Upper	t	p
Intercept	2.03820	1.68936	−1.28716	5.36356	1.20649	0.229
Delta_UNEMP_RATE	1.08407e−4	0.00366	−0.00709	0.00731	0.02965	0.976
POPESTIMATE	−1.12330e−7	1.60544e−7	−4.28345e−7	2.03686e−7	−0.69968	0.485
GED_per	−3.52564	7.51703	−18.32226	11.27097	−0.46902	0.639
AA_per	22.28891	18.52924	−14.18427	58.76210	1.20290	0.230
BA_per	−0.30345	12.51420	−24.93656	24.32965	−0.02425	0.981
MA_per	16.32314	23.42084	−29.77871	62.42500	0.69695	0.486
Real_PCPI	8.90722e−6	1.44258e−5	−1.94887e−5	3.73031e−5	0.61745	0.537

We interpret these results as follows: On average, holding all else constant, a 1 percentage point increase in the Δunemployment rate will increase ΔReal GDP by 0.0001 percentage points (1.08e-4 percentage points). However, we fail to reject the null hypothesis and these results are not statistically significant.

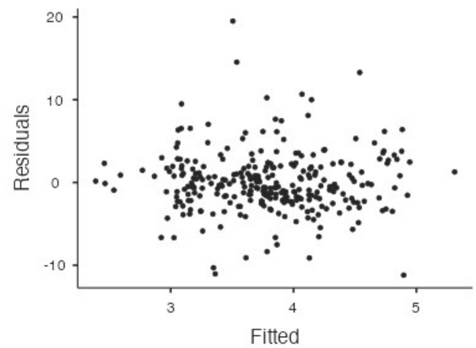
```
Call:
lm(formula = Delta_RGDP ~ Delta_UNEMP_RATE + POPESTIMATE + GED_per +
    AA_per + BA_per + MA_per + Real_PCPI, data = data)

Residuals:
    Min      1Q  Median      3Q     Max
-11.197  -1.975  -0.392   1.796  19.504

Coefficients:
                  Estimate Std. Error t value Pr(>|t|)
(Intercept)       2.04e+00   1.95e+00    1.05     0.30
Delta_UNEMP_RATE  1.08e-04   2.86e-03    0.04     0.97
POPESTIMATE      -1.12e-07   7.91e-08   -1.42     0.16
GED_per          -3.53e+00   9.28e+00   -0.38     0.70
AA_per            2.23e+01   2.41e+01    0.92     0.36
BA_per           -3.03e-01   1.52e+01   -0.02     0.98
MA_per            1.63e+01   3.06e+01    0.53     0.59
Real_PCPI         8.91e-06   1.12e-05    0.80     0.43

Residual standard error: 3.75 on 282 degrees of freedom
  (290 observations deleted due to missingness)
Multiple R-squared:  0.0207,    Adjusted R-squared:  -0.00357
F-statistic: 1.54 on 7 and 282 DF,  p-value: 0.153
```

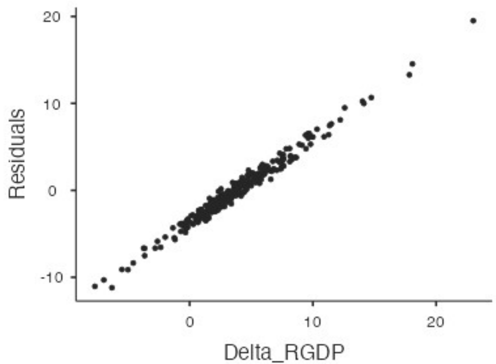
If we look at the Robust Standard Error (SE) results and compare them with our linear regression, we find our estimated result and p-value the same, however, the t-test is different. The Robust SE interpretation is that on average, holding all else constant, when the Δunemployment rate increases by 1%, the ΔReal GDP falls by 1.08e-04 percentage points. However, these results are still not statistically significant, although the relationship between Δunemployment rate and ΔReal GDP is positively related, which is different from Okun's definition.

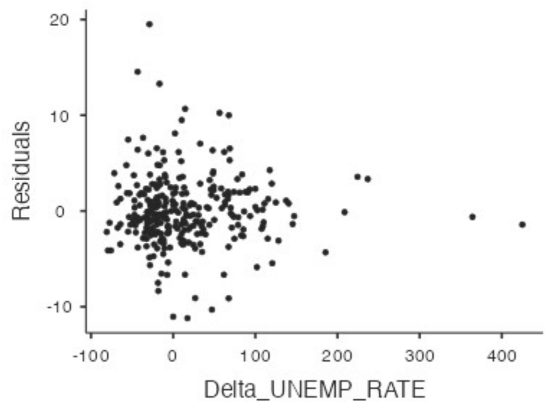
Collinearity Statistics

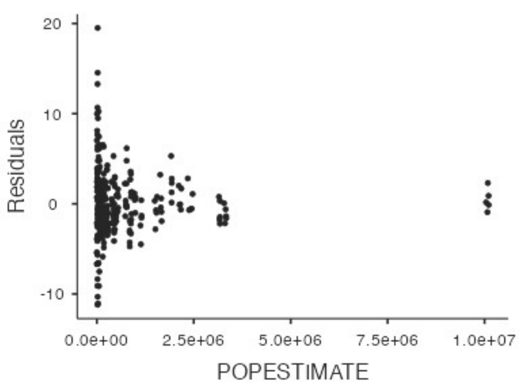
	VIF	Tolerance
Delta_UNEMP_RATE	1.08419	0.92235
POPESTIMATE	1.13011	0.88487
GED_per	1.98934	0.50268
AA_per	1.59275	0.62785
BA_per	6.63673	0.15068
MA_per	6.38920	0.15651
Real_PCPI	1.11288	0.89857

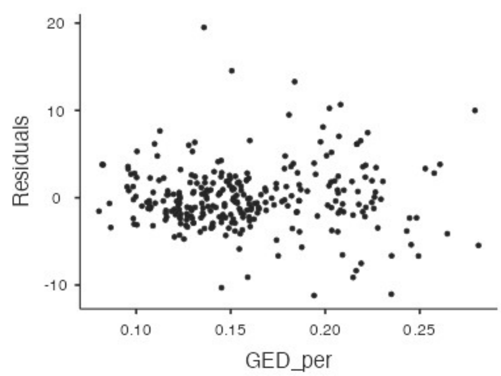
[3]

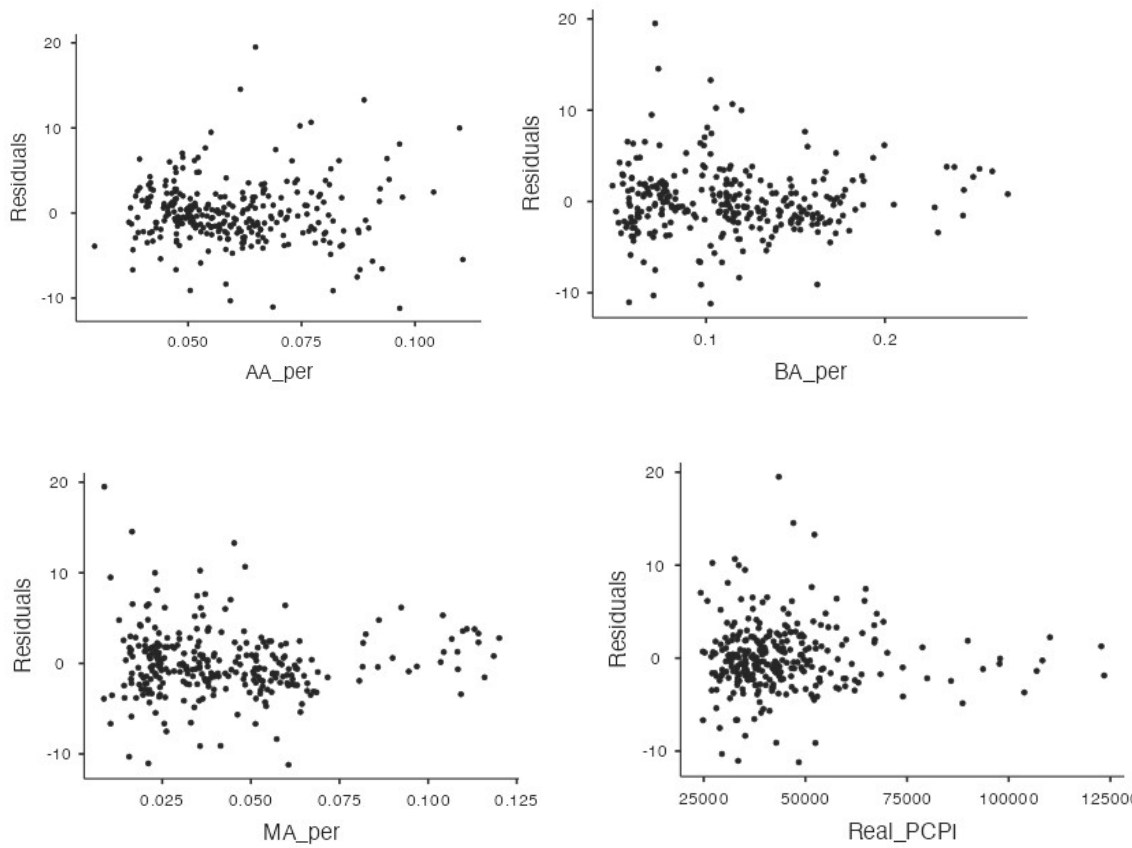











Residuals
AA_per
0.050
0.075
0.100
Residuals
BA_per
0.1
0.2
Residuals
MA_per
0.025
0.050
0.075
0.100
0.125
Residuals
Real_PCPI
25000
50000
75000
100000
125000
20
10
0
-10

Adjusted Baseline Regression

Model Fit Measures

				Overall Model Test			
Model	R^2	Adjusted R^2	RMSE	F	df1	df2	p
1	0.10154	0.06599	3.53890	2.85609	11	278	0.001

Model Coefficients - Delta_RGDP

			95% Confidence Interval			
Predictor	Estimate	SE	Lower	Upper	t	p
Intercept [a]	1.62646	1.68983	−1.70003	4.95294	0.96250	0.337
Delta_UNEMP_RATE	−4.89090e−4	0.00354	−0.00745	0.00648	−0.13823	0.890
POPESTIMATE	−1.02401e−7	1.54903e−7	−4.07332e−7	2.02531e−7	−0.66107	0.509
GED_per	−1.40574	7.26559	−15.70829	12.89682	−0.19348	0.847
AA_per	25.33529	17.90235	−9.90609	60.57667	1.41519	0.158
BA_per	−3.86908	12.10822	−27.70452	19.96635	−0.31954	0.750
MA_per	28.10716	22.75117	−16.67929	72.89361	1.23542	0.218
Real_PCPI	1.34663e−5	1.40619e−5	−1.42151e−5	4.11477e−5	0.95764	0.339
y2016:						
1 – 0	−0.48258	0.67514	−1.81162	0.84646	−0.71478	0.475
y2017:						
1 – 0	−1.13670	0.67320	−2.46191	0.18852	−1.68850	0.092
y2018:						
1 – 0	−1.78525	0.67744	−3.11881	−0.45169	−2.63530	0.009
y2019:						
1 – 0	1.37422	0.67262	0.05015	2.69829	2.04309	0.042

[a] Represents reference level

```
Call:
lm(formula = Delta_RGDP ~ Delta_UNEMP_RATE + POPESTIMATE + GED_per +
    AA_per + MA_per + Real_PCPI + y2016 + y2017 + y2018 + y2019,
    data = data)

Residuals:
    Min      1Q  Median      3Q     Max
-10.344  -1.966  -0.214   1.467  19.337

Coefficients:
                  Estimate Std. Error t value Pr(>|t|)
(Intercept)       4.67e-01   1.89e+00    0.25    0.805
Delta_UNEMP_RATE -4.89e-04   2.74e-03   -0.18    0.859
POPESTIMATE      -1.06e-07   7.85e-08   -1.35    0.178
GED_per          -9.06e-01   8.67e+00   -0.10    0.917
AA_per            2.35e+01   1.96e+01    1.20    0.231
MA_per            2.17e+01   1.35e+01    1.61    0.108
Real_PCPI         1.40e-05   1.14e-05    1.23    0.222
y2016.L          -3.38e-01   4.28e-01   -0.79    0.430
y2017.L          -7.97e-01   4.80e-01   -1.66    0.098 .
y2018.L          -1.25e+00   5.23e-01   -2.39    0.017 *
y2019.L           9.74e-01   4.80e-01    2.03    0.043 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 3.61 on 279 degrees of freedom
  (290 observations deleted due to missingness)
Multiple R-squared:  0.101,     Adjusted R-squared:  0.069
F-statistic: 3.25 on 10 and 279 DF,  p-value: 0.000551
```

This model includes years as binary variables, based in 2015, which were added to control for year-over-year changes. We would interpret the results as on average, holding all else constant, a 1 percentage point increase in the Δunemployment rate will decrease ΔReal GDP by 4.89e-4 percentage points. We fail to reject the null hypothesis and the results are also not statistically significant.

The Robust SE interpretation is that on average, holding all else constant, when the Δunemployment rate increases by 1%, the ΔReal GDP falls by 4.89e-4 percentage points. However, these results are still not statistically significant.

Getting non-statistically significant results leads us to reassess our control variables, specifically, our education variables. These variables were an attempt to control for some amount in the change in education, as they would be thought to have both an effect on our dependent variable, **Δ**RGDP, and some correlation with our variable of interest, **Δ**UNEMP_RATE.

However, these variables are not all-encompassing of all the changes in education, and they may be influenced by the particular economic sector or industry. As the data on education was also limited to the years 2015-2019, this limits our observations to half of the total collected, and this may cause omitted variable bias. Our next step would be to remove our education variables, as their reliability is currently questionable.

Model 2

Model Fit Measures

				Overall Model Test			
Model	R^2	Adjusted R^2	RMSE	F	df1	df2	p
1	0.14727	0.12922	4.12744	8.16028	12	567	<.001

Model Coefficients - Delta_RGDP

			95% Confidence Interval			
Predictor	Estimate	SE	Lower	Upper	t	p
Intercept [a]	0.83055	0.76969	−0.68125	2.34235	1.07907	0.281
Delta_UNEMP_RATE	0.00238	0.00297	−0.00345	0.00821	0.80236	0.423
POPESTIMATE	9.19514e−8	1.20350e−7	−1.44435e−7	3.28338e−7	0.76403	0.445
year:						
2011 – 2010	0.30551	0.78464	−1.23565	1.84668	0.38936	0.697
2012 – 2010	−1.61695	0.77996	−3.14891	−0.08499	−2.07312	0.039
2013 – 2010	1.66736	0.78606	0.12341	3.21131	2.12116	0.034
2014 – 2010	2.51605	0.78018	0.98366	4.04844	3.22498	0.001
2015 – 2010	3.22473	0.78727	1.67841	4.77105	4.09610	<.001
2016 – 2010	2.87921	0.78031	1.34656	4.41186	3.68984	<.001
2017 – 2010	2.13285	0.78907	0.58300	3.68270	2.70301	0.007
2018 – 2010	1.66667	0.78111	0.13245	3.20089	2.13372	0.033
2019 – 2010	4.53747	0.78902	2.98771	6.08722	5.75079	<.001
Real_PCPI	−5.04095e−7	1.03010e−5	−2.07368e−5	1.97286e−5	−0.04894	0.961

[a] Represents reference level

```
Call:
lm(formula = Delta_RGDP ~ Delta_UNEMP_RATE + POPESTIMATE + year +
    Real_PCPI, data = data)

Residuals:
    Min      1Q  Median      3Q     Max
-19.382  -2.065  -0.185   1.810  22.480

Coefficients:
                  Estimate Std. Error t value Pr(>|t|)
(Intercept)       8.31e-01   9.27e-01    0.90  0.37056
Delta_UNEMP_RATE  2.38e-03   2.80e-03    0.85  0.39583
POPESTIMATE       9.20e-08   6.65e-08    1.38  0.16743
year2011          3.06e-01   9.25e-01    0.33  0.74119
year2012         -1.62e+00   9.84e-01   -1.64  0.10098
year2013          1.67e+00   7.73e-01    2.16  0.03152 *
year2014          2.52e+00   8.90e-01    2.83  0.00485 **
year2015          3.22e+00   8.36e-01    3.86  0.00013 ***
year2016          2.88e+00   7.66e-01    3.76  0.00019 ***
year2017          2.13e+00   8.44e-01    2.53  0.01177 *
year2018          1.67e+00   8.62e-01    1.93  0.05356 .
year2019          4.54e+00   8.18e-01    5.55  4.4e-08 ***
Real_PCPI        -5.04e-07   1.18e-05   -0.04  0.96603
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 4.17 on 567 degrees of freedom
Multiple R-squared:  0.147,     Adjusted R-squared:  0.129
F-statistic: 7.48 on 12 and 567 DF,  p-value: 6.9e-13
```

This model omits the year 2010 and it compares it to other years from 2011 to 2019. In addition, this regression includes our control variables while excluding our education variables. We would interpret this as on average, holding all else constant, a 1 percentage point increase in the Δunemployment rate will increase ΔReal GDP by 0.00238 percentage points. The Robust SE interpretation is exactly the same as the linear regression interpretation. We can speculate that we are dealing with some amount of omitted variable bias and will test our questionable variables to gauge if they will adjust our estimator. The results are not statistically significant, and we fail to reject the null hypothesis.

Model 3

Model Fit Measures

				Overall Model Test			
Model	R^2	Adjusted R^2	RMSE	F	df1	df2	p
1	0.14839	0.12883	4.12472	7.58656	13	566	<.001

Model Coefficients - Delta_RGDP

			95% Confidence Interval			
Predictor	Estimate	SE	Lower	Upper	t	p
Intercept [a]	0.67718	0.79009	−0.87468	2.22904	0.85710	0.392
Delta_UNEMP_RATE	0.00238	0.00297	−0.00345	0.00821	0.80098	0.423
POPESTIMATE	−5.51135e−8	2.08543e−7	−4.64726e−7	3.54499e−7	−0.26428	0.792
year:						
2011 – 2010	0.36191	0.78753	−1.18493	1.90876	0.45955	0.646
2012 – 2010	−1.51626	0.78880	−3.06559	0.03307	−1.92224	0.055
2013 – 2010	1.80577	0.80241	0.22971	3.38183	2.25044	0.025
2014 – 2010	2.70651	0.81092	1.11374	4.29928	3.33759	<.001
2015 – 2010	3.42376	0.82048	1.81220	5.03531	4.17288	<.001
2016 – 2010	3.08027	0.81447	1.48052	4.68001	3.78195	<.001
2017 – 2010	2.33427	0.82298	0.71780	3.95074	2.83635	0.005
2018 – 2010	1.87347	0.81716	0.26844	3.47851	2.29266	0.022
2019 – 2010	4.74485	0.82492	3.12457	6.36513	5.75189	<.001
Real_PCPI	−6.59515e−7	1.03049e−5	−2.08999e−5	1.95809e−5	−0.06400	0.949
Real_Benefits_paid	6.81343e−10	7.88956e−10	−8.68295e−10	2.23098e−9	0.86360	0.388

[a] Represents reference level

```
Call:
lm(formula = Delta_RGDP ~ Delta_UNEMP_RATE + POPESTIMATE + year +
    Real_PCPI + Real_Benefits_paid, data = data)

Residuals:
    Min      1Q  Median      3Q     Max
-19.418  -2.008  -0.182   1.790  22.513

Coefficients:
                    Estimate Std. Error t value Pr(>|t|)
(Intercept)         6.77e-01   9.45e-01    0.72  0.47386
Delta_UNEMP_RATE    2.38e-03   2.80e-03    0.85  0.39553
POPESTIMATE        -5.51e-08   1.18e-07   -0.47  0.63928
year2011            3.62e-01   9.30e-01    0.39  0.69740
year2012           -1.52e+00   9.93e-01   -1.53  0.12719
year2013            1.81e+00   8.00e-01    2.26  0.02443 *
year2014            2.71e+00   9.37e-01    2.89  0.00401 **
year2015            3.42e+00   8.84e-01    3.87  0.00012 ***
year2016            3.08e+00   8.12e-01    3.79  0.00017 ***
year2017            2.33e+00   8.92e-01    2.62  0.00912 **
year2018            1.87e+00   9.16e-01    2.05  0.04124 *
year2019            4.74e+00   8.61e-01    5.51  5.5e-08 ***
Real_PCPI          -6.60e-07   1.18e-05   -0.06  0.95563
Real_Benefits_paid  6.81e-10   4.79e-10    1.42  0.15552
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 4.18 on 566 degrees of freedom
Multiple R-squared:  0.148,     Adjusted R-squared:  0.129
F-statistic: 7.16 on 13 and 566 DF,  p-value: 5.24e-13
```

This regression includes the Real_Benefits_paid, but, unfortunately, there is no change to the estimator, thus it should not be included. The interpretation would be that on average, holding all else constant, a 1 percentage point increase in the ∆unemployment rate will increase ∆Real GDP by 0.00238 percentage points. The results are not statistically significant, and we fail to reject the null hypothesis. Once again, the Robust SE interpretation is the same as the linear regression interpretation, with the p-value and t-test only slightly changing.

Model 4

Model Fit Measures

				Overall Model Test			
Model	R^2	Adjusted R^2	RMSE	F	df1	df2	p
1	0.15015	0.13063	4.12046	7.69238	13	566	<.001

Model Coefficients - Delta_RGDP

			95% Confidence Interval			
Predictor	Estimate	SE	Lower	Upper	t	p
Intercept [a]	6.51082	4.17200	−1.68367	14.70532	1.56060	0.119
Delta_UNEMP_RATE	0.00232	0.00297	−0.00350	0.00815	0.78392	0.433
POPESTIMATE	6.22801e−8	1.22145e−7	−1.77633e−7	3.02193e−7	0.50989	0.610
year:						
2011 – 2010	0.29908	0.78402	−1.24087	1.83903	0.38147	0.703
2012 – 2010	−1.61945	0.77933	−3.15018	−0.08872	−2.07801	0.038
2013 – 2010	1.65050	0.78552	0.10761	3.19339	2.10116	0.036
2014 – 2010	2.49797	0.77965	0.96660	4.02934	3.20395	0.001
2015 – 2010	3.20281	0.78679	1.65742	4.74820	4.07072	<.001
2016 – 2010	2.85899	0.77981	1.32731	4.39067	3.66625	<.001
2017 – 2010	2.11143	0.78858	0.56253	3.66033	2.67751	0.008
2018 – 2010	1.64683	0.78061	0.11359	3.18008	2.10967	0.035
2019 – 2010	4.51588	0.78853	2.96708	6.06469	5.72696	<.001
Real_PCPI	−1.48859e−6	1.03171e−5	−2.17532e−5	1.87760e−5	−0.14428	0.885
male_per	−11.08298	8.00064	−26.79754	4.63159	−1.38526	0.167

[a] Represents reference level

```
Call:
lm(formula = Delta_RGDP ~ Delta_UNEMP_RATE + POPESTIMATE + year +
    Real_PCPI + male_per, data = data)

Residuals:
    Min      1Q  Median      3Q     Max
-19.336  -2.022  -0.216   1.744  22.312

Coefficients:
                  Estimate Std. Error t value Pr(>|t|)
(Intercept)       6.51e+00   4.86e+00    1.34  0.18051
Delta_UNEMP_RATE  2.32e-03   2.79e-03    0.83  0.40575
POPESTIMATE       6.23e-08   6.65e-08    0.94  0.34939
year2011          2.99e-01   9.33e-01    0.32  0.74873
year2012         -1.62e+00   9.87e-01   -1.64  0.10147
year2013          1.65e+00   7.76e-01    2.13  0.03389 *
year2014          2.50e+00   8.92e-01    2.80  0.00526 **
year2015          3.20e+00   8.40e-01    3.81  0.00015 ***
year2016          2.86e+00   7.69e-01    3.72  0.00022 ***
year2017          2.11e+00   8.45e-01    2.50  0.01275 *
year2018          1.65e+00   8.64e-01    1.91  0.05729 .
year2019          4.52e+00   8.25e-01    5.47  6.7e-08 ***
Real_PCPI        -1.49e-06   1.17e-05   -0.13  0.89921
male_per         -1.11e+01   9.46e+00   -1.17  0.24174
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 4.17 on 566 degrees of freedom
Multiple R-squared:  0.15,      Adjusted R-squared:  0.131
F-statistic: 6.88 on 13 and 566 DF,  p-value: 2.08e-12
```

In this model, we included male_per (the percentage of males), and it does not change the estimator significantly, thus it can be excluded from the regression. The interpretation is that on average, holding all else constant, a 1 percentage point increase in the Δunemployment rate will increase ΔReal GDP by 0.00232 percentage points. The results are not statistically significant, and we fail to reject the null hypothesis. Similar to our previous models, the Robust SE interpretation has not changed.

V. Conclusion

A notable weakness of our study is that it focuses on California counties, rather than on countries. Okun's law looks at GDP and unemployment rates on a national scale, not on a county-based scale. The challenge of our analysis is that we are focused on counties within the state of California, which when compared to countries, have a smaller population and fewer changes in the unemployment rate. Countries can experience much more fluctuation in other macroeconomic indicators than a county in California can. For example, if we analyze other countries, macroeconomic fluctuations are going to affect them differently. The one thing that is happening in our model is when we add the nominal year variable to the regression, we get a portion of Okun's law, and the reason we get that is that in a given year, our dataset consists of both macro and microeconomic variables. We are using macroeconomic variables at the county level, but the issue is that the actual macroeconomic variables are the same for all of the counties we are studying. There are no differences in fixed interest rates from the Federal Reserve, no change in GDP throughout the state of California, no difference in the exports and imports of the U.S., among other factors. One solution was to include years as a binary variable for every year to control for these macroeconomic factors that stay constant, however, as shown in our results, the effect is still not statistically significant.

Furthermore, it is important to evaluate the usefulness of our research with the help of internal and external validity. Internal validity says that if we take a random sample from the population and make some conclusions in our sample, we should be able to apply those conclusions to the population where the sample was taken from. If we cannot apply the conclusions to the population being studied, then the study is not internally valid. On the other hand, if there is internal validity, external validity asks if we can apply the study's results to different settings or different populations. If the answer is no, then the study is not externally valid. If a study is not internally valid, then it cannot be externally valid. Our study, being conducted throughout California counties for the years 2010-2019, would be internally valid, but not externally valid. As our previous literature review has stated, Okun's coefficient can and most likely does differ from state to state within the U.S., thus our conclusion would solely be limited to the state of California.

The years we are examining are from 2010-2019, however, during 2007-2009 the U.S. experienced a dramatic recession that took nearly 6 years to recover. During that financial crisis, real GDP fell by 4.3% and the unemployment rate in 2010 was reported to be 10.6% (Rich, 2013; Kochhar, 2021). Unfortunately, our collected data is for the years during the recovery period. As one could theorize, there is a high possibility that the recession's recovery period affected our results. Future research and studies should attempt to correct this error by studying other years prior to the financial crisis to see if the effect is different.

As we have previously mentioned, another flaw that we can observe in our study is that data on education variables could not be collected from the period of 2015-2019. If data are missing from education, which is an independent variable, there is no problem of bias, however, the education sample size became smaller which would have an effect on the results.

It is important to keep in mind that the actual level of the workforce, unemployment, and employment levels are limited to the data gathered from registered workers. As such, unregistered residents do not form part of our regression analysis. This includes unregistered documented citizens not accounted under the employment development department (EDD) as well as undocumented residents of California who form part of the workforce. Effectively, this ties down other variables, such as population and benefits paid. The estimated percentage of undocumented citizens in the state of California is about 5.6% (Pew Research Center, 2020).

As an overall consideration, contributing author and former employee of the Federal Reserve Bank of Cleveland, Brent Meyer, along with senior research economist, Murat Tasci, suggest that Okun’s law may not be the best indicator and statistic for unemployment rates. Okun’s rule of thumb states that a 2% rise in GDP will result in a 1% decline in the unemployment rate, however, this is not always the case. Mr. Meyer and Mr. Tasci cite U.S. 2011 data that shows the unemployment rate falling from 9.1% to 8.3%, however, during that time, real GDP rose by 1.6%. Based on our data, the results show that this relationship is not statistically significant. As one can see, this change does not follow Okun’s simplistic rule of thumb and cannot be relied on for years to come and is not ideal to study for counties. Another interesting observation that the authors make is that Okun’s law is normally tested using quarterly data, rather than annual data, and this will provide more stable results. Previous research, such as the study conducted in the United Kingdom by Dr. Stober, verifies this statement. As noted previously in our report, Dr. Stober found that the unemployment rate will fall by 0.074 points if GDP rises by 1 point. Unfortunately, quarterly data could not be obtained for individual California counties. However, this would be an interesting topic for future research to see if quarterly data for different counties does indeed provide better results.

VI. References

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VII. Data Description Table

Variable	Description	Source
county_name	County Name	
year	2010 - 2019	
RGDP	Real GDP (thousands of chained 2012 dollars)	BEA.gov CAGDP1_CA_2001_2019
CUR_GDP	Current-dollar GDP (thousands of current dollars)	BEA.gov CAGDP1_CA_2001_2019
GDP_Deflator	YOY GDP Deflator over previous year	Calculated in excel
Delta_RGDP	RGDP growth rate over previous year	Calculated in excel

POPESTIMATE	**Total Population**	**Census.gov** **CC-EST2019-AGESEX-[ST-FIPS]: Annual County and Puerto Rico Municipio Resident Population Estimates by Selected Age Groups and Sex: April 1, 2010 to July 1, 2019**

POPEST_MALE	**Male population**	**Census.gov** **CC-EST2019-AGESEX-[ST-FIPS]: Annual County and Puerto Rico Municipio Resident Population Estimates by Selected Age Groups and Sex: April 1, 2010 to July 1, 2019**
POPEST_FEM	**Female Population**	**Census.gov** **CC-EST2019-AGESEX-[ST-FIPS]: Annual County and Puerto Rico Municipio Resident Population Estimates by Selected Age Groups and Sex: April 1, 2010 to July 1, 2019**

LF	**Labor Force**	**BLS.gov** **Local_Area_Unemployment_Statistics__LAUS___Annual_Average.xlsx**
EMP	**Employed Workers**	**BLS.gov** **Local_Area_Unemployment_Statistics__LAUS___Annual_Average.xlsx**
UNEMP	**Unemployed Workers**	**BLS.gov** **Local_Area_Unemployment_Statistics__LAUS___Annual_Average.xlsx**

UNEMP_RATE	**Unemployment Rate**	**BLS.gov** **Local_Area_Unemployment_Statistics__LAUS___Annual_Average.xlsx**
Delta_UNEMP_RATE	**YOY unemployment rate from previous year**	**Calculated in excel**
Benefits_paid	**Total Unemployment Benefits Paid (Current dollars)**	**Data.CA.gov** **Benefits_Paid_By_County__All_Programs_ADDED_YEARLY_TOTALS.xlsx**

Real_Benefits_paid	**Benefits_paid adjusted for inflation employing GDP_Deflator**	**Calculated in excel**
Initial_claims	**Initial claims for all programs**	**Data.CA.gov** **Initial_Claims_By_County__All_Programs_TOTALS.xlsx**
Ex_claims	**Exhausted claims for all programs**	**Data.CA.gov** **Exhausted_Claims_By_County__All_Programs_TOTALS.xlsx**
PCPI	**Per Capita Personal Income, Dollars, Annual, Not Seasonally Adjusted**	**FRED.StLouisFed.org** **PCPI06001.xls-PCPI06115.xls**
Real_PCPI	**PCPI adjusted for inflation employing GDP_Deflator**	**Computed in Excel**

EDU_DIP_GED	**Total (Estimate) Population 25 years and over with a High School Diploma or GED equivalent, 2015-2019**	**census.gov** **via edu.ipynb**

GED_per	**EDU_DIP_GED divided by total estimate population, giving percentage of population with a High School Diploma or GED equivalent, 2015-2019**	**Computed in Jamovi**
EDU_AA	**Total (Estimate) Population 25 years and over with an Associate's degree, 2015-2019**	**census.gov via edu.ipynb**
AA_per	**EDU_AA divided by total estimate population, giving a percentage of population 25 years and over with an Associate's degree, 2015-2019**	**Computed in Jamovi**
EDU_BA	**Total (Estimate) Population 25 years and over with a Bachelor's degree, 2015-2019**	**census.gov via edu.ipynb**

BA_per	**EDU_AA divided by total estimate population, giving a percentage of population 25 years and over with a Bachelor's degree, 2015-2019**	**Computed in Jamovi**
EDU_MA	**Total (Estimate) Population 25 years and over with a Master's degree, 2015-2019**	**census.gov via edu.ipynb**
MA_per	**EDU_MA divided by total estimate population, giving a percentage of population 25 years and over with a Master's degree, 2015-2019**	**Computed in Jamovi**