The Impact of Economic Quality and Geographical Features on Renewable Energy Generation in Florida

Siddanth Devanathan
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Abstract

This paper aims to analyze the impacts of economic status and geographical conditions on renewable energy production in the state of Florida. This will be done using the consideration of the per-capita real GDP of the state and average solar production, both on a yearly basis. The end goal of this analysis is to estimate the viability, in terms of GDP increase, of solar energy as a renewable resource to push in the state of Florida and to compare it to other sources such as wind energy. This analysis will be conducted through linear regression and significance testing for slopes that aim to estimate the relationship between these parameters using collected data. The expected relationship is some statistically significant nonzero correlation between the independent and dependent variables of note, predicting a relationship using GDP as the independent variable. Endogeneity in data will be assumed as a nonfactor for the purpose of this analysis.

Methods & Data

This paper aims to estimate the relationship between per-capita real GDP and yearly average solar production for the years 2000–2019 and estimate changes in wind speed and potential wind energy production based on geographical area. To assess this relationship, we'll employ linear regression techniques and Student T-testing to determine the significance of the slope. In addition, we will compare regression graphs between several different wind reading zones to determine the effect of geographical location on wind speed and potential production.

The data for this analysis was obtained from Floridian sources such as Florida Solar, TECO, and global energy sources such as the Energy Information Administration (EIA, n.d.) and the International Energy Agency (IEA, n.d.). Information was acquired from several recent publications describing Florida's energy state and analyses of this state in comparison to the others. Data collected included, but was not limited to, monthly solar production in Florida over 2000–2019, yearly per-capita GDP from 2000–2019, and wind speeds in plateau regions, swamp regions, and highland regions over one month.

Python was used to generate accurate statistical models and regression test results for the models and regressions. Packages used were pandas, statsmodels.api, plotlyexpress, and numpy. Following the compiling of data into an Excel '.csv' file, the program was used to run a linear regression of per-capita real GDP against yearly average solar production, as well as comparisons of wind speed vs geographical location.

The primary analysis will be conducted using a T-test for the slope of a linear regression alongside a confidence interval for the slope of the linear regression. We will use a significance level of α=0.10 to test this hypothesis. Data will be measured by relating the values to one another unaltered and by log-transforming GDP Per Capita.

Figure 1

Trends of GDP (Thousands of dollars, Right-hand axis) and Solar Production over Time (MwH, Left-hand axis)

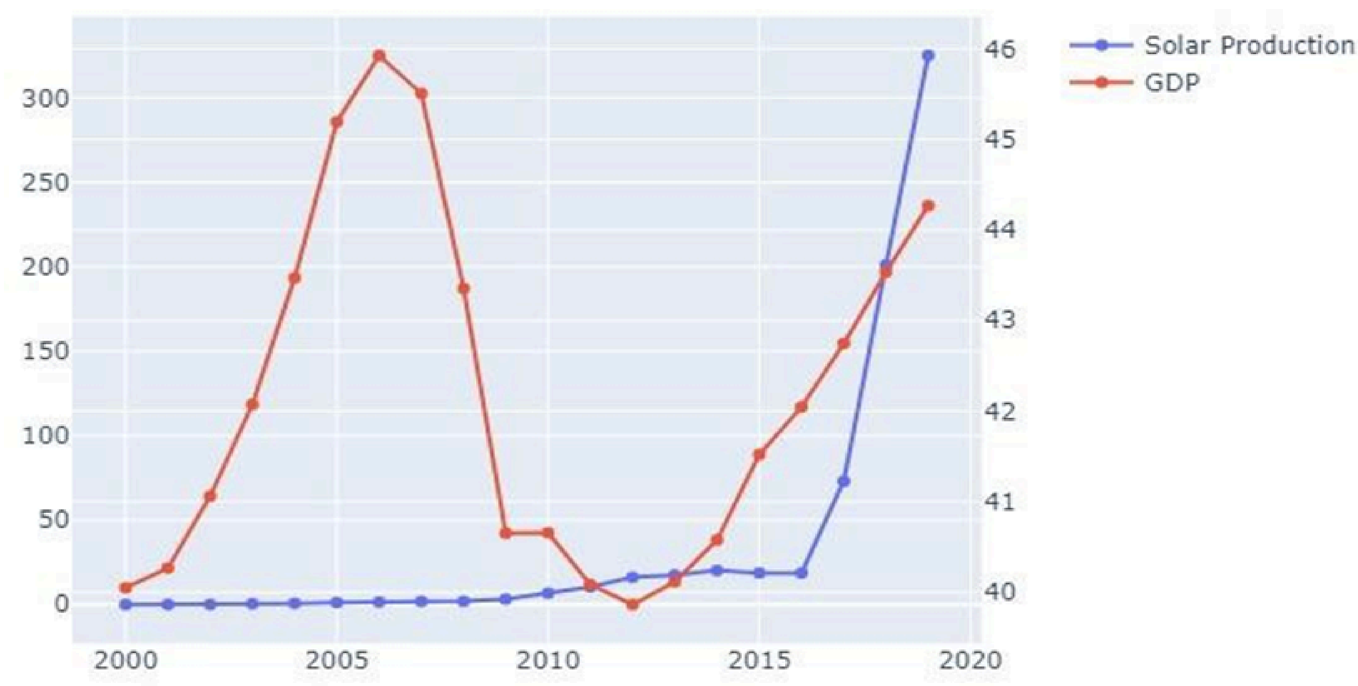
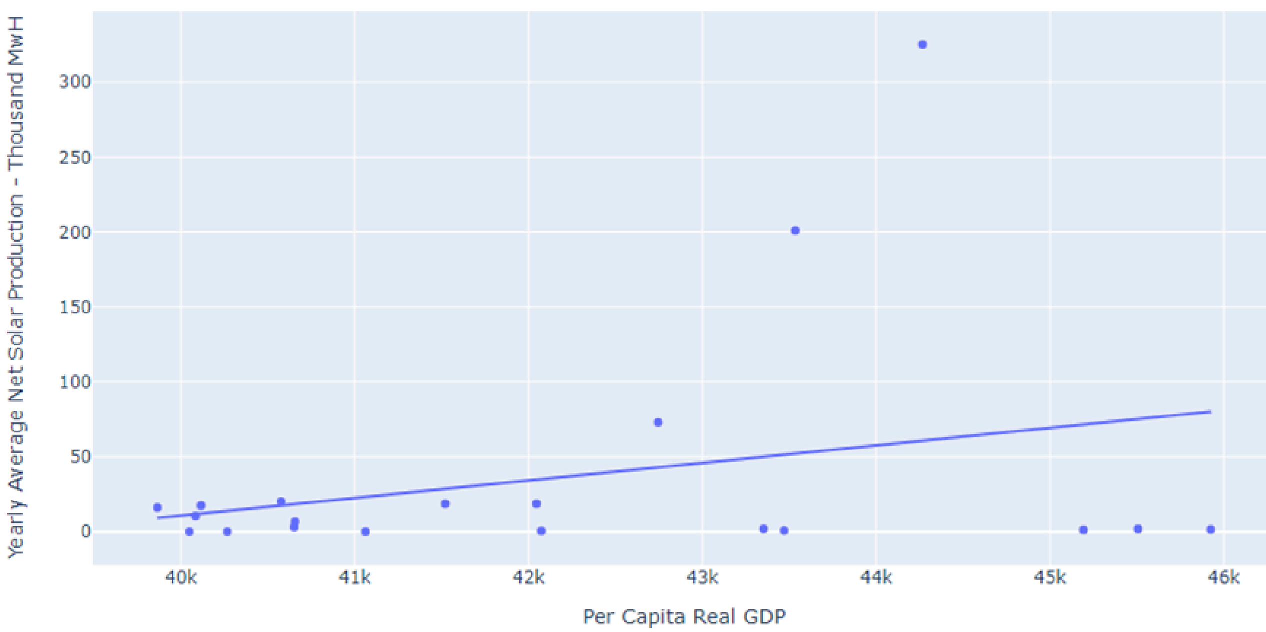


Figure 1 represents the individual trends of Per Capita Real GDP (Right-hand Y axis) and Yearly Average Solar Production (Left-hand Y axis) over time by year, over the years (2000-2019). From these trends, it can be observed first that the drop in Per Capita Real GDP occurred significantly over the years 2006-2008, likely caused by the economic crash around this time period. While this caused the GDP to drop significantly, it does not appear to have majorly affected solar production due to a preexisting lack of change in the dependent variable. Prior to the time period beginning approximately around the year 2012, solar energy was likely not a primary focus of the Floridian renewable energy agency and thus did not vary much, regardless of the economic downturn. It is likely that had there not been such a downturn; the trend would still look similar to the one above. A likely explanation for the above is an already-low production of solar energy, such that this drop in GDP did not reduce it significantly. Another key feature of the above is the combined increase in both GDP and Yearly Average Solar Production over the years 2015–2019, representing a combined growth (regrowth in the case of GDP). In 2016, the advent of new solar technology likely spurred the significant increase, potentially caused by the increase in GDP. In addition, the return of tax credits for solar energy likely contributed to a significant rise in solar production in the same year, encouraging both firms and individuals to increase and support solar renewables (Solar Energy Industries Association [SEIA], n.d., p. 5).

Figure 2

Least squares Regression GDP vs. Solar Production MwH. (Solar Data from the Energy Information Administration (2023).



Following the regression of yearly per-capita GDP against average solar production in Florida, the preceding display was produced. Figure 2, a least-squares regression line of GDP on Solar production, shows a generally inconsistent positive relationship between the two variables, with several outliers present. The general trend appears to arise, which is that changes in GDP values affect solar energy production, but this remains to be verified. The data also appears to possess a large degree of variability, containing several influential and high-leverage points that flatten the regression line. The reason for the notably low coefficient of regression stems from the large difference in the magnitude of units between the two variables, a cosmetic feature caused by the use of unconverted data. The model does not include a constant due to the impractical nature of predicting for a 0 Per Capita GDP, a scenario that is unlikely to ever occur. From the graph alone, there is little evidence for a significant relationship between these two variables due to inconsistent outliers and a slope attributable to chance alone.

However, the following statistics provide additional evidence. Figure 2, shown below, demonstrates test statistics and indicators of spread to provide a more in-depth analysis. The key objects of note are the Hypothesis t-test statistic, the Probability value of rejection, and the confidence interval for the true slope, in addition to the equation of the line itself.

Figure 3

Numerical Regression Results

Dep. Variable:	Yearly Average Net Solar Production - Thousand MwH	R-squared (uncentered):	0.178
Model:	OLS	Adj. R-squared (uncentered):	0.135
Method:	Least Squares	F-statistic:	4.109
Date:	Sun, 17 Sep 2023	Prob (F-statistic):	0.0569
Time:	19:19:03	Log-Likelihood:	-115.86
No. Observations:	20	AIC:	233.7
Df Residuals:	19	BIC:	234.7
Df Model:	1		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
Per Capita Real GDP	0.0009	0.000	2.027	0.057	-2.85e-05	0.002

Omnibus:	32.097	Durbin-Watson:	0.273
Prob(Omnibus):	0.000	Jarque-Bera (JB):	60.938
Skew:	2.767	Prob(JB):	5.85e-14
Kurtosis:	9.520	Cond. No.	1.00

The predicted coefficient of the relationship shown above in Figure 3 is 0.0009, showing a small variation in solar production for a change of 1 in the per-capita GDP. The small value is likely caused by significantly larger units of Per Capita Real GDP; however, the real effect is rather consistent. While this number is small, the t-test statistic of **t = 2.027** with 19 degrees of freedom shows a significant value at **α = 0.10**. The probability of obtaining a regression slope coefficient of 0.0009 or further in both directions of significance is **0.057**, demonstrating a significant hypothesis test. With this information and the currently assumed independence of the data confirmable through the 10% condition, there is enough evidence to reject the null hypothesis in the test of:

$$H_0: \beta = 0$$
$$H_A: \beta \neq 0$$

We may conclude that there is a significant nonzero association between the yearly per-capita GDP and the yearly average solar production in Florida.

Discussion

Considering the newly tested association of these two variables, it can be reasonably concluded that the economic wellness of Florida relates to the yearly average solar production in a nonzero, relatively linear relationship. This information may prove useful to solar plants as they analyze potential factors causing their influxes of energy and rates and also provide a bright outlook for future renewables in Florida.

An Important factor of note in this relationship is a potential circular effect. While the increase in real GDP Per Capita may impact the Yearly Average Solar production, the same increase in solar production may impact GDP in return. This may cause an endogenous change in both variables, though this model assumes the return impact of solar energy prediction on the GDP is negligible (Stephanie, n.d., p. 5). In addition, other tertiary/omitted variables may cause bias in the coefficient of Per Capita GDP on Yearly Average Solar Production. One such omitted variable may include political changes, a categorical modifier of these increases. As different leaders take over these projects, emphases may change, and there may be greater or lesser changes in Solar Production and in GDP based on economic reform. In addition, the environment may have a significant impact on these changes. Recent changes in atmospheric ozone levels may result in a greater solar intensity due to global warming, potentially increasing the effects of the Yearly Average Solar Production. This would cause bias in favor of yearly Solar Production in the positive direction, likely reducing the reliability of results. A final potential change of the variables would be a decrease in the costs of producing solar energy. As briefly touched on previously, new technologies, in addition to budget and political changes, have resulted in the ability to farm solar energy more efficiently. In addition, this increase in infrastructure was likely made possible by the changes in Per Capita GDP, another piece of evidence for the endogenous relationship between the variables.

Another key factor of consideration is that it cannot be concluded reliably that the Per Capita Real GDP causes changes in the Yearly Average Solar Production. This particular test shows a correlation between the variables, but there are likely several extra variables, such as those discussed above, that change the dependent variable as well. Thus, a reasonable conclusion would be that changes in the Per Capita GDP impact the Yearly Average solar production but are not the only influencing factor. Though not the only influencing factor, the macroeconomic state of Florida does appear to affect the yearly average solar production, and thus, in times of economic prosperity, we should expect corresponding increases in solar production.

Comparison

In the search for a sustainable source of energy in Florida, several potential competitors have been considered, one of them being wind. Several reasons exist as to why wind energy is not a sustainable solution to Florida's energy concern and why solar energy would be more effective, a notable one being the lack of viable wind speeds throughout the state. According to the Wind Exchange's pilot study of offshore wind speeds, for example, data have returned low wind speeds that are unviable for efficiently producing energy that would outweigh the costs. On land, in addition, wind speeds are typically found to be under six mph, which is not nearly enough to generate wind energy cost-effectively (WINDExchange, n.d., pp. 3-8). In contrast, solar energy is uniformly powerful and viable across the state and is far easier to produce cost-efficiently in Florida. The prior analysis determines a correlation between Yearly Average Solar production and Per Capita Real GDP, providing a likely predictor for solar energy's growth as well, making it a more future-proof investment tied to the economy.

Conclusion

In final conclusion, the most effective forward path for Floridian renewable energy generation would be the push for greater solar production and economic stimulation. The benefits of an easily predictable agent of renewable growth and a uniform and reliable source cause the projects to hinge primarily on the growth of technology and labor, which would be stimulated by a spike in GDP. These factors, when combined, paint a promising picture of future Florida solar renewables.

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