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The Effect of Environmental Change on GDP

Jackson V. Barliant

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Climate change is one of the most debated topics of the 21st century. Not only has it been detrimental to our eco-system, but it is beginning to redefine and reshape society. Can the U.S. economy continue to flourish while acknowledging the necessary steps that need to be taken in regard to combatting climate change? Yes, the inherent change within our environment due to climate change can not only be withstood by our economy, but it presents an opportunity to revolutionize and expand through innovation.

The first suspected effects of climate change began in the early 19th century and ever since have been intensely researched and debated both regarding possible causes, as well as the magnitude with which it is occurring. Aside from the immediate environmental impact, climate change has also sent shockwaves through the global economy. Specifically, from a quantitative standpoint, how does the movement towards a more sustainable environment affect Gross Domestic Product? As social awareness towards climate change and humankind's ecological footprint continues to grow, businesses, governments, and society continues to ensure the preservation of the planet while also striving to maintain the health of the economy. The question then becomes, is it possible to not only maintain the stability of the economy but rather accelerate GDP growth and economic expansion through an increased eco-consciousness? With this goal in mind it becomes a very comprehensive valuation as to how GDP is ultimately affected by movements towards becoming a more ecofriendly and sustainable environment.

Dating back to the very beginnings of the United States, agriculture has played an instrumental role in shaping and cultivating both foreign and domestic trade. Along with agriculture, natural energy has also been a staple to the development and advancement of global markets. Currently the U.S. energy and agricultural markets show no signs of deviating from their past. Through a Forecast performed by the U.S. Energy Information Administration, the U.S. is projected to continue to increase net exports and become a true net exporter by 2020.[1] With both sectors being so deeply rooted in the history and the development of the U.S. market space, it becomes a genuine concern as to how to meet

[1] https://www.eia.gov/todayinenergy/detail.php?id=34912

agricultural and energy exports forecasts while embracing the shift towards going green, and subsequently what overall effect this will have on the economy.

Through the World Bank open data source, I was able to compile multiple energy and agricultural-based variables that I hypothesized to be statistically significant in explaining U.S. GDP from 1990-2017.[2] With my dependent variable being U.S. GDP on an annualized basis, I looked to find independent variables that covered various components of the U.S. agriculture and energy sectors that were also highly correlated with environmental trends and climate change. In search of fulfilling this criteria I was able to collect data from 1990-2017 on *CO_2 Emissions*, *Fossil Fuel Energy Consumption*, *Renewable Energy Consumption*, *Agricultural Land*, *Net Energy Imports*, *Fuel Exports*, and *Total Natural Resources Rents*. Collectively these various datasets depict the U.S.'s overall shift towards a more sustainable environment, while also displaying this eco-friendly movement's overall impact on United States Gross Domestic Product.

My initial expectations were that the two most likely variables to show statistical significance in relation to GDP were *Energy Imports* and *Fuel Exports.*[3] The *Energy Imports* dataset is expressed as a net percentage of energy use less production, both being measured in oil equivalents.[4] A country with negative net energy imports, represents a net exporter, or a country whose value of exports outweighs its value of imports. From 1990-2017 the time series representation of *Energy Imports* reveals a 20-year peak in 2005 and has been decreasing ever since.[5] As the U.S.'s net energy imports move closer to

[2] https://data.worldbank.org/indicator

[3] See Chart 1

[4] Energy use refers to use of primary energy before transformation to other end-use fuels, which is equal to indigenous production plus imports and stock changes, minus exports and fuels supplied to ships and aircraft engaged in international transport.

[5] See Graph 1

negative, the data signals the U.S.'s shift towards becoming a true net exporter. Subsequently, as a net exporter this will put upward pressure on U.S. GDP and accelerate economic expansion. In regard to *Fuel Exports*, this data is measured as a percentage of merchandise exports. Specifically, the fuels accounted for in this dataset include mineral fuels, lubricants, and related materials. Conversely to the *Energy Imports* data, in 2005 fuel exports began to increase drastically through 2014 where it reached nearly 12%, then experiencing a relative deceleration, and later experiencing a lower high in 2017.[6] The *Fuel Exports* data further supports the same conclusion drawn previously from the net imports data revealing that the U.S. is in fact moving closer to becoming a true net exporter.

Similar to both *Fuel Exports* and *Energy Imports* the *Fossil Fuel Energy Consumption* data provided a summation of the energy sector as a whole.[7] The *Fossil Fuel Energy Consumption* data is measured as a percent of total energy consumption, specifically covering coal, oil, petroleum, and natural gas products. Through the fossil fuel time-series it is made evident that fossil fuel consumption is also progressively decreasing over the 17-year period, revealing a shift away from fossil fuels.[8] As this shift occurs, the U.S. population seeks a substitute energy source in renewable energy. The *Renewable Energy Consumption* dataset is quantified as a percentage of total final energy consumption. Despite renewable energy consumption amassing a much smaller portion of overall energy consumption, it is made apparent through a time-series analysis that in-fact as predicted, renewable energy consumption has been increasing since 2002.[9] Together the *Fossil Fuel Energy Consumption* and *Renewable Energy Consumption* datasets sufficiently support and depict the societal shift towards renewable resources and away from fossil fuels.

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[6] See Graph 2
[7] See Chart 2
[8] See Graph 3
[9] See Graph 4

In an attempt to analyze the current state of the U.S.'s agricultural wealth, the *Agricultural Land* dataset displays total agricultural land as a percent of the U.S.'s total land area. Specifically, it refers to the share of land area that is arable, under permanent crops, and under permanent pastures. Arable land includes land defined by the FAO as land under temporary crops (double-cropped areas are counted once), temporary meadows for mowing or for pasture, land under market or kitchen gardens, and land temporarily fallow. Land abandoned as a result of shifting cultivation is excluded. Land under permanent crops is land cultivated with crops that occupy the land for long periods and need not be replanted after each harvest, such as cocoa, coffee, and rubber. This category includes land under flowering shrubs, fruit trees, nut trees, and vines, but excludes land under trees grown for wood or timber. Permanent pasture is land used for five or more years for forage, including natural and cultivated crops.[10] Due to the fact that agricultural land is partially renewable and partially non-renewable, it is to be expected that the percent of agricultural land in the U.S. decreases on a relatively constant basis. This trend reveals the importance of increased preservation of agricultural land in hopes of supporting increased exports for years to come.

The final two independent variables help to add perspective in regard to the way in which the climate is changing, and the primary factors affecting this change. The CO_2 variable is measure with respect to metric tons per capita. Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring.[11] The final variable measures *Total Natural Resources Rents.* This variable is measured as a percent of GDP. Total natural resources rents are the sum of oil rents, natural gas rents, coal rents (hard and soft), mineral rents, and forest rents.[12] A rent in regard to

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[10] Food and Agriculture Organization

[11] Carbon Dioxide Information Analysis Center, Environmental Sciences Division, Oak Ridge National Laboratory, Tennessee, United States.

[12] World Bank staff estimates based on sources and methods described in "The Changing Wealth of Nations 2018: Building a Sustainable Future" (Lange et al 2018).

oil is essentially the difference between the selling price and the production cost. These two variables help to solidify two of the primary contributors to climate change.

It was made quite evident through simple time-series analysis, *Net Energy Imports* and *Fuel Exports* adequately displayed the current and future forecasted expansion of U.S. exports, a primary factor in applying upward pressure to GDP. Likewise, the relationship between *Fossil Fuel Energy Consumption* and *Renewable Energy Consumption* provided graphical evidence that in-fact within the United States there is currently a heightened sense of eco-conscious energy consumption. As for the other variables it was not nearly as easy to assess the correlation amongst each other and our dependent variable, GDP. With the need for more clarity in regard to the overall statistical significance of each independent variable relative to GDP, a regression analysis of each independent variable was performed.[13] The regression output revealed the overall statistical significance of each variable as well as the equation; **GDPA = 19560.13 + 150.35*ENERGY_IMPORTS + 527.22*FUEL_EXPORTS - 1557.63*AGRICULTURE + 517.40*FOSSIL_FUEL + 1256.87*RENEWABLE_ENERGY + 245.73*CO2 + 668.37*NATURAL_RESOURCES.** As predicted both *Energy Imports* and *Fuel Exports* are in fact statistically significant in explaining the dependent variable GDP. Based on a P-Stat test at 10% significance level, the initial regression revealed that Energy Imports is statistically significant with a P-Value of 8%, and Fuel Exports is statistically significant with a P-Value of 6%. With this being the case we can now assess based on the aforementioned output equation, for every single unit increase in Energy Imports GDP increases by 150.35 units. Similarly, for every single unit increase in Fuel Exports GDP increases by 527.22 units. These results support the initial hypothesis that in fact Fuel Exports and Energy Imports would be statistically significant in contributing to the overall U.S. GDP.

[13] See Regression 1

The first regression also returned statistically significant P-Values for both *Agriculture* and *Renewable Energy*. With respect to *Agriculture*, this variable is statistically significant as it displays a P-Value of 1%. *Renewable Energy* was also revealed to be statistically significant as it returned a P-Value of 8%. In relation to the original output equation, for every single unit increase in *Agriculture*, GDP is negatively affected by 1557.63 units, and for every single unit increase in *Renewable Energy* GDP increases by 1256.87 units. As far as the other variables, *Fossil Fuel,* CO_2, and *Natural Resources* these variables were proved to be statistically insignificant in explaining their effect on GDP. After running a second regression by omitting each statistically insignificant variable one by one I was able to narrow the variables down to strictly the statistically significant contributors.[14] Through these results it is made apparent that our initial assumptions surrounding the overall affect that both energy and agriculture have on GDP are correct. *Energy Imports*, *Agriculture*, and *Renewable Energy* are the most statistically significant variables when explaining the dependent variable of GDP.

Through my quantitative analysis it has been made apparent that as society adapts to environmental changes taking place today and continues to combat climate change it is feasible to embrace GDP growth and economic expansion. As GDP continues to increase fossil fuel consumption is experiencing a relative decrease while renewable energy consumption continues to rise. These variables reveal that in-fact the health of the economy not only can remain stable during this environmental shift towards reducing humankind's ecological footprint, but rather the economy can phase through an expansion and continue to flourish. This is specifically made evident as the U.S. economy moves closer and closer to becoming a true net exporter. As the overall value of exports

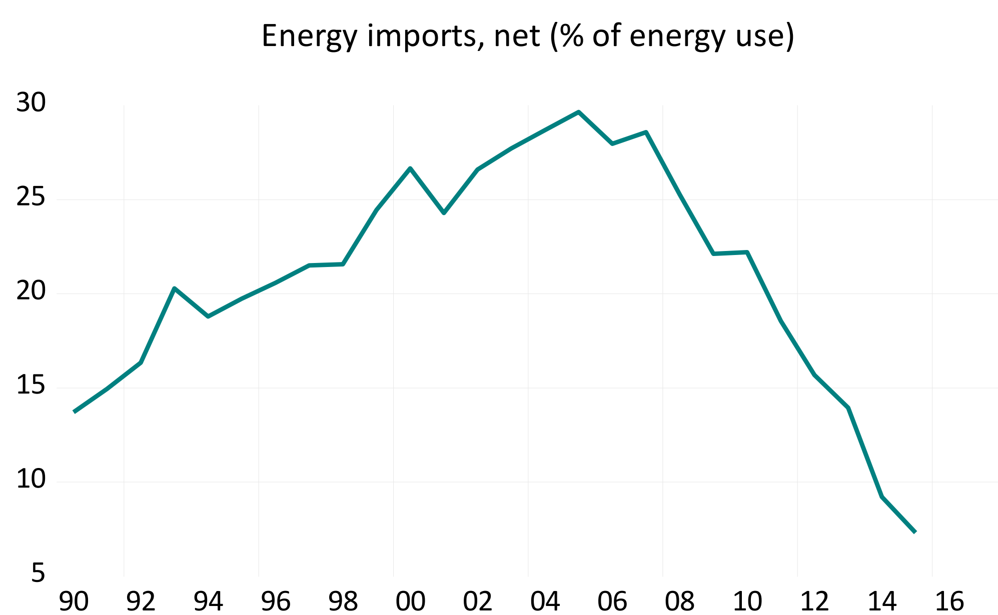
[14] See Regression 2

surpasses that of imports this is one of the most noteworthy factors in inflicting upward pressures on Gross Domestic Product.

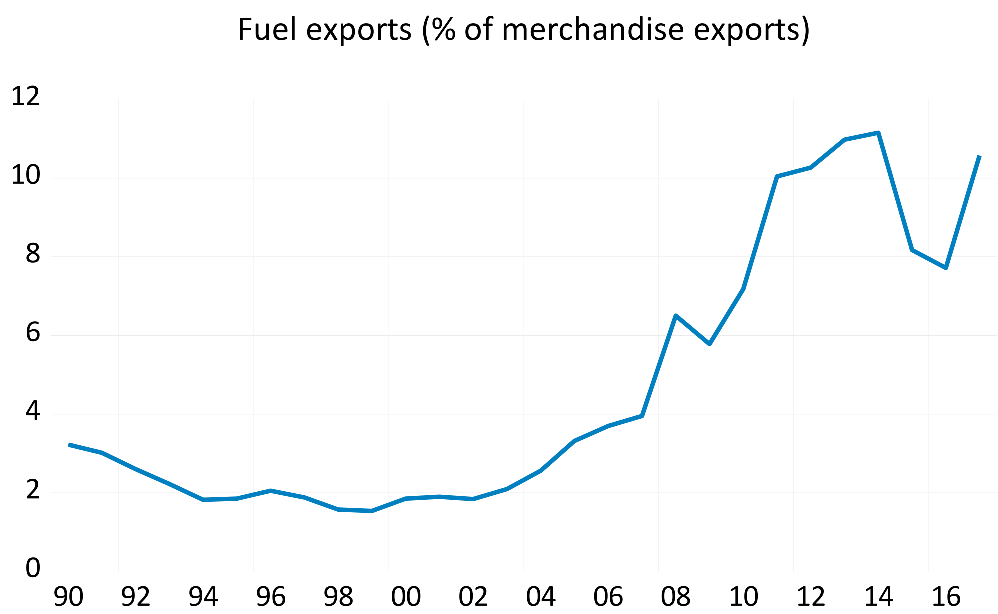
- **Chart 1**

	Variable 1		Variable 2	
	Net_energy_imports		Fuel_exports	
Summary Stats	Functions	Manual Calculation	Functions	Manual Calculation
Mean	21.02	21.02	4.69	4.69
Median	21.54		3.12	
Mode	#N/A		#N/A	
5th Percentile	10.34		1.66	
95th Percentile	28.67		10.84	
Q1	16.89		1.89	
Q3	26.27		7.31	
Inter Quartile Range		9.38		5.42
SD Sample	6.07	6.07	3.40	
SD Population	5.96	5.96	3.34	
Min	7.3		1.54	
Max	29.66		11.16	
Range		22.35		9.62
Coef. Of Var		28.90%		72.53%

- **Graph 1**



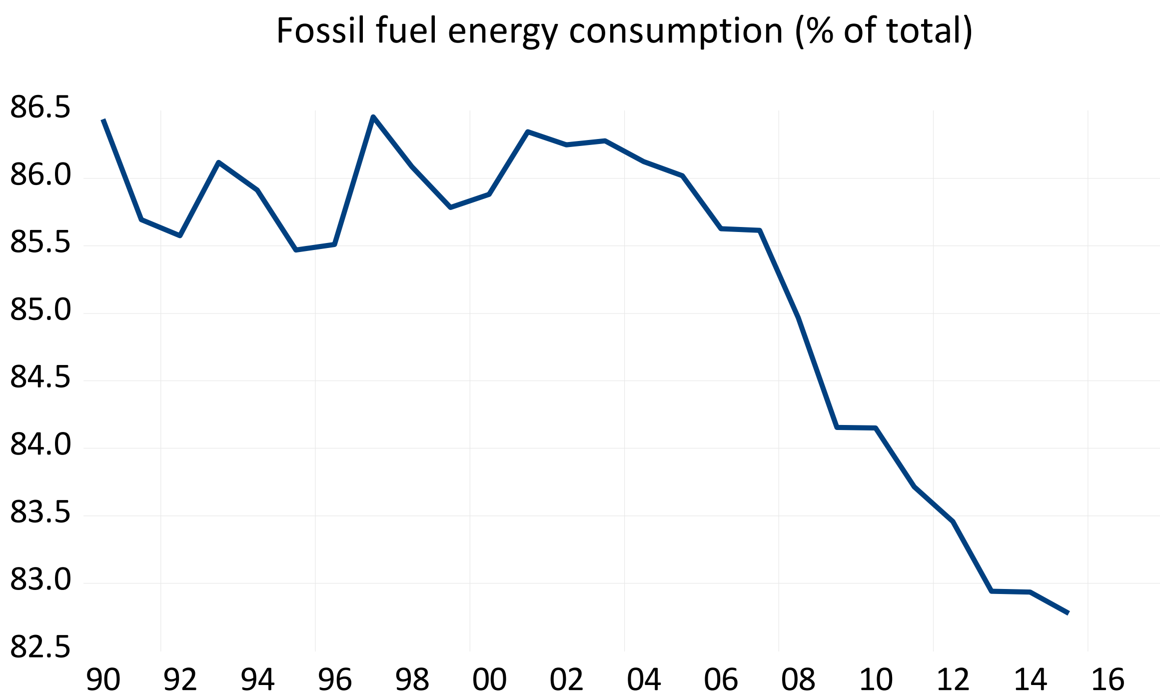
- **Graph 2**



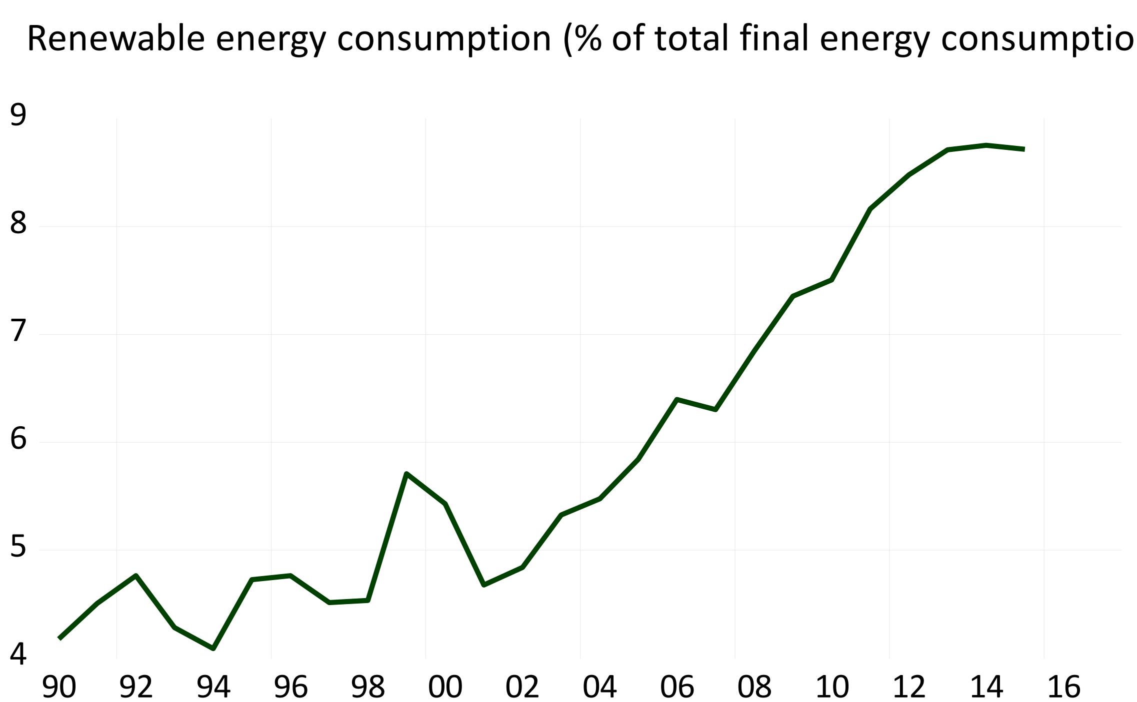
- **Chart 2**

	Variable 1		Variable 2	
	Fossil_fuel_energy_consumption		Renewable_energy_consumption	
Summary Stats	Functions	Manual Calculation	Functions	Manual Calculation
Mean	85.24	85.24	5.96	5.96
Median	85.66		5.45	
Mode	#N/A		#N/A	
5th Percentile	82.94		4.20	
95th Percentile	86.41		8.72	
Q1	84.36		4.69	
Q3	86.11		7.23	
Inter Quartile Range		1.75		2.54
SD Sample	1.19	1.19	1.60	
SD Population	1.17	1.17	1.56	
Min	82.8		4.09	
Max	86.46		8.75	
Range		3.68		4.67
Coef. Of Var		1.40%		26.78%

➢ **Graph 3**



➢ **Graph 4**



- **Regression 1**
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Dependent Variable: GDPA
Method: Least Squares
Date: 12/07/18 Time: 02:01
Sample (adjusted): 1990 2014
Included observations: 25 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	19560.14	71345.96	0.274159	0.7873
ENERGY_IMPORTS	150.3567	82.08794	1.831654	0.0846
FUEL_EXPORTS	527.2249	263.7918	1.998640	0.0619
AGRICULTURE	-1557.638	587.0931	-2.653136	0.0167
FOSSIL_FUEL	517.4017	812.7079	0.636639	0.5328
RENEWABLE_ENERGY	1256.874	684.7527	1.835515	0.0840
CO2	245.7336	761.5814	0.322662	0.7509
NATURAL_RESOURCES	668.3778	675.1394	0.989985	0.3361

R-squared	0.970287	Mean dependent var	11319.76
Adjusted R-squared	0.958052	S.D. dependent var	3630.030
S.E. of regression	743.4754	Akaike info criterion	16.31489
Sum squared resid	9396847.	Schwarz criterion	16.70493
Log likelihood	-195.9361	Hannan-Quinn criter.	16.42307
F-statistic	79.30499	Durbin-Watson stat	1.592347
Prob(F-statistic)	0.000000		

- **Regression 2**

Dependent Variable: GDPA
Method: Least Squares
Date: 12/07/18 Time: 23:08
Sample (adjusted): 1990 2015
Included observations: 26 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	72265.34	28801.89	2.509049	0.0200
ENERGY_IMPORTS	87.39415	41.96237	2.082679	0.0491
AGRICULTURE	-1618.207	591.3297	-2.736556	0.0120
RENEWABLE_ENERGY	1793.264	267.9701	6.692031	0.0000

R-squared	0.952929	Mean dependent var	11581.33
Adjusted R-squared	0.946511	S.D. dependent var	3798.552
S.E. of regression	878.5191	Akaike info criterion	16.53499
Sum squared resid	16979509	Schwarz criterion	16.72854
Log likelihood	-210.9549	Hannan-Quinn criter.	16.59073
F-statistic	148.4613	Durbin-Watson stat	1.222859
Prob(F-statistic)	0.000000		