HOW DOES ECONOMIC GROWTH AFFECT ENVIRONMENTAL DAMAGES?

EVIDENCE FROM COUNTRY-LEVEL PANEL LEVEL DATA

Tatem Cheney

Department of Economics and Finance
School of Business and Economics
SUNY Plattsburgh
tchen009@plattsburgh.edu

May 2023

Abstract

The environmental effects of economic growth are a new topic of discussion in economics. Social media has been a large part of the rapidly increasing concern for our environment. How do us as consumers play a role in the long-term effect environmental damage could have on our planet? We have seen a large increase in average temperature and carbon dioxide emissions in the past 50 years. This is largely due to the increase in consumption of goods by consumers, increase in population and increase in international trade. Having an economy that is continuously growing, how much are we damaging our environment? Is there a possibility that this increase in our economy could eventually save our environment as technology continues to increase? Continuous economic growth can create long term environmental damage that is irreversible. Using regression analysis the following study will determine the relationship between environmental damage, using CO2 emissions and economic growth, using gross domestic product, GDP. The findings of this study include a negative relationship when the model is linear and an inverted U shape relationship when the model is quadradic. Therefore, dismissing the hypothesized positive linear relationship of the Daly Curve and affirming the inverted U shape of the Kuznets Curve.

Keywords: *economic growth, environmental damage, CO2, Kuznets Curve*

1. Introduction

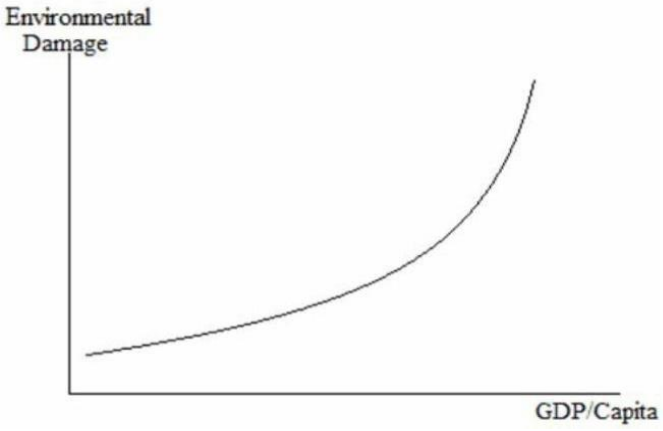
Our environment is an important resource that individuals tend to overlook. As a society, we have a problem considering long-term environmental damage. Societal consumption leading to economic growth is a major cause of environmental damage. There are studies stating that overall economic growth will lead to a continuous increase in environmental damage. On the other hand, there is research (Chow and Li, 2014; Dinda, 2004) that indicates as our economy grows, environmental damage will increase to a certain extent and eventually start to decrease. This difference of opinions formulates the research question, "How does economic growth affect environmental damage?" The stated question will be analyzed through country-level panel data, through the years 1966-2016 and includes the following countries: Canada, United States, Australia, Sweden, Switzerland, France, Germany, United Kingdom, Norway, and Finland. The dependent variable analyzed to measure environmental damage is CO2. The independent variables included will be GDP per capita in USD, population growth and exports.

Since the relationship between environmental damage and economic growth is a new interest in economics, the effect is unclear because new studies are continuously being released. The relationship between the two can be used to demonstrate how economic growth is affecting our environment. The damage we are creating could be detrimental to our earth and this research is being done to minimize long-term effects. After consulting with the research, I hypothesize that environmental damage and economic growth will have a positive linear relationship. As the economy continues to grow, environmental damage will also continue to increase. Due to contradicting theories, the following study will be conducted to prove the Daly Curve Hypothesis and disprove the Environmental Kuznets Curve.

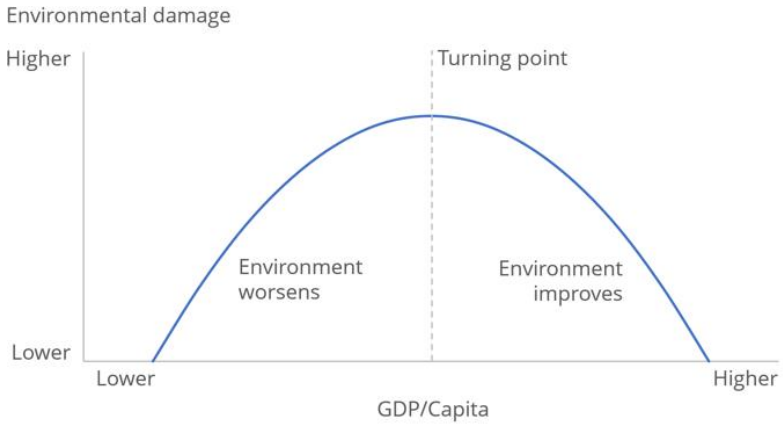
I will determine the relationship that exists between environmental damage and economic growth. Following the research, I will be attempting to prove a positive linear relationship and

disprove an inverted U shape relationship. The theory including a positive linear relationship is the Daly Curve Hypothesis, which can be seen in Graph 1. The Daly Curve Hypothesis has environmental damage as the dependent variable on the Y-axis and economic growth (GDP) as the independent variable on the X-axis. It shows a positive relationship between the two, meaning as economic growth increases environmental damages will also increase. The theory used to explain the quadratic relationship in the shape of an inverted U is the Environmental Kuznets Curve, which can be seen in Graph 2. The Environmental Kuznets Curve has environmental damage on the Y-axis and economic growth (GDP) on the X-axis. The Environmental Kuznets Curve explains that when economic growth first increases environmental damage will increase to a certain level, then as the economy continues to grow the state of the environment will start to improve, decreasing environmental damages.

Although my study hypothesizes the positive linear relationship of the Daly Curve Hypothesis, my results deny this hypothesis. They show a negative relationship between economic growth and environmental damages when the model is linear. After analyzing a quadratic model using my variables, the Environmental Kuznets Curve is present. There is a turning point where economic damage stops increasing and starts decreasing as GDP continually increases.



Graph 1 (ons.gov.uk)



Graph 2 (researchgate.net)

2. Literature Review

The literature has concluded mixed results in relation to economic growth and environmental damage. There are some studies that prove the presence of a positive linear relationship between environmental damage and economic growth, whereas other studies conclude the inverted U shape of the Environmental Kuznets curve. I will analyze multiple studies showing that the relationship between economic growth and environmental damage is either positive linear, shaped as a U or an inverted U shape.

The first study demonstrating a relationship between economic growth and environmental damage is "Economic development and CO2 emissions: A nonparametric panel approach." (Azomahou et al., 2006). This study analyzes 100 countries from 1960-1996. They use CO2 as the dependent variable and GDP as the independent variable, consistent with my study. An upward-sloping positive linear relationship between CO2 and GDP was determined, rejecting the polynomial inverted U shape of the Environmental Kuznets curve. Demonstrating that the positive linear relationship shown in the Daly curve hypothesis is correct.

The second study is called "Are the Economy and the Environment Decoupling? A Comparative International Study, 1960–2005." (Jorgenson and Clark, 2012), is a panel-level analysis done on 88 countries over 45 years. Jorgenson and Clark use different forms of CO2 as

the dependent variables, total CO2, CO2 per capita, and CO2 per GDP per capita. They study how their independent variables, GDP per capita, trade, population, and urban population, effect the dependent variables. There were discrepancies when using CO2 per capita and CO2 per GDP, as a statistical insignificance was present. When the authors used total CO2 emissions as the dependent variable, they demonstrated a statistically significant positive linear relationship between CO2 and GDP. They also found the increase in CO2 levels to be more significant in wealthier countries. Therefore, this study demonstrates my hypothesized positive linear relationship between GDP and CO2 emissions.

The third study called "The Relationship Between Economic Growth and CO2 Emissions in EU Countries: A Cointegration Analysis" (Onofrei et al., 2022), uses a cointegration analysis to analyze the relationship between economic growth and CO2 emissions in European countries from 2000 to 2017. Cointegration means that both variables move together in the long run. They found a linear relationship between CO2 and economic growth, a 1% change in GDP leads to a 0.072 change in CO2. The issue with this study is that it analyzes the cointegration of the GDP and CO2 therefore, it determined that the two moved together. Relating this study to my hypothesis, since they move together, as GDP increases, CO2 will also increase.

The fourth study called "Stoking the fires? CO2 emissions and economic growth" (Holtz-Eakin and Selden, 2005) this study analyzes 130 countries from 1951-1986 the authors use the current relationship between economic growth and environmental damages to forecast their future relationship. Using CO2 to demonstrate environmental damage and GDP to demonstrate economic growth, they concluded that as GDP increased by 1 percent, CO2 emissions increase by 1.8%, showing the Daly Curve Hypothesis. Holtz-Eakin and Selden's current results showing a linear-positive relationship helped them forecast a similar trend for the future. Concluding that people

should not put their faith into the inverted U shape model. Therefore, we should start finding ways to the environment because it will not fix itself.

The fifth study called "Three Totally Different Environmental/GDP Curves" (Bratt, 2012). This study analyzes the three different environmental economic curves. The Daly Curve showing a positive linear relationship, the Kuznets curve showing an inverted U shape and the Environmental Brundtland Curve, Bratt's invention, showing a U shape relationship. Bratt looks at different studies inspecting different relationships between the environment and the economy. Bratt states that "the EKC is time limited" (Bratt, 2012) and "is not environmentally conscious but economic conscious" (Bratt, 2012) He said that the EKC is an economic theory to help ease politicians' thoughts. Bratt concluded that there is a positive monotonic relationship between economic growth and environmental damage. Therefore, agreeing with the Daly curve hypothesis.

The sixth study called "The Relationship of Energy and CO2 Emissions with GDP per Capita in Colombia" (Patino et. al, 2020). This study uses time series data from 1971-2017 to analyze the relationship between CO2 emissions and socioeconomic variables such as GDP. When comparing CO2 per capita and GDP per capita in a quadradic regression, the authors found that GDP decreased CO2 emissions and $\boldsymbol{GDP^2}$ increased CO2 emissions, creating a U shape, verifying Bratt's prediction of the Brundtland curve. The results also demonstrate a positive linear relationship between CO2 and GDP. Therefore, this study cannot confirm the existence of the Environmental Kuznets Curve.

The first six studies all came to the same conclusion that there is an absence of the Environmental Kuznets Curve concerning economic growth and environmental damages. They concluded that there is either a positive linear relationship between GDP and CO2, as GDP increases CO2 emissions will also increase, or a U shape relationship that occurs. On the other

hand, some studies demonstrate an inverted U shape relationship between economic growth and environmental damage.

The seventh study will focus on the Environmental Kuznets Curve. It is called "Environmental Kuznets Curve: Conclusive Econometric Evidence for CO2" (Chow and Li, 2014). This study conducts a statistical hypothesis using panel data analysis on 132 countries from 1992 to 2004 trying to prove the Environmental Kuznets Curve. Chow and Li have pushed aside the theoretical aspect of the relationship between economic growth and environmental damages, analyzing solely the statistics. They examine the relationship between CO2 emissions, dependent variable, and GDP per capita, independent variable. Chow and Li address the rejection of the Environmental Kuznets Curve by many other economists. The findings of their study demonstrate the existence of the Environmental Kuznets Curve. Although Chow and Li's study disagrees with my hypothesis, it is important to have knowledge on the indifferences related to environmental economics.

The eighth study, "Environmental Kuznets Curve Hypothesis: A Survey" (Dinda, 2004) Dinda's study demonstrates an overview and analysis of many studies relating to the relationship between economic growth and environmental damage. Dinda discusses that there is a paradox that exists in relation to economic growth and environmental damage. But notes that the Environmental Kuznets Curve is relevant in certain scenarios, for example, when air pollutants such as, CO2 are present. The literature cannot demonstrate a turning point for economic growth where emissions start decreasing. Although Dinda found mixed results in relation to the Environmental Kuznets Curve, they did find it exists in the presence of air pollutants which my study is analyzing.

Overall, the relationship between economic growth and environmental damage is a very controversial topic in economics. The first six studies demonstrate a lack of proof for the Environmental Kuznets Curve, whereas the last two prove its existence. Using my data, I will try

to show a positive linear relationship between economic growth and environmental damage, creating proof for The Daly Curve Hypothesis and proof against The Environmental Kuznets Curve.

3. Empirical model and Estimation

The final equation used to analyze the linear relationship between economic growth and environmental damage is as follow:

$$CO_2it = \beta_0 + \beta_1 lnGDP_{it} + \beta_2 POPGR_{it} + \beta_3 lnEXP_{it} + \varepsilon_{it}$$

This equation is a semi-log regression where there are logarithms present in the independent variables GDP and EXP. I made the decision to put GDP and EXP in logarithmic form to reduce the gap between the minimum and maximum values.

The dependent variable used in my regression is CO2 emissions to explain environmental damages. CO2 emissions are widely used to measure the state of our environment. Therefore, the greater the CO2 emissions, the more damaged our environment becomes, and vice versa. To demonstrate economic growth, my independent variables are gross domestic product, population growth, and exports. I predict that all my independent variables would be positively related to my dependent variable, making CO2 levels increase as they increase. The expected signs for my independent variables are shown in Table 1.

Table 1 Variables and Expected Signs

Variable	Expected sign
GDP	+
POPGR	+
EXP	+

The most important independent variable in my model is GDP, as GDP is a measure of economic growth when GDP increases, it means the economy is growing. I hypothesize that the sign of GDP will be positive to demonstrate a positive linear relationship between economic growth and environmental damage. The Daly Curve Hypothesis states that as our economy grows, environmental damages continue to worsen therefore, CO2 emissions will increase. The Daly Curve Hypothesis does not include a turning point like the Environmental Kuznets Curve. To choose the type of regression I will be using for my country-level panel data I will be conducting two separate regression tests. For the random-effect model and the fixed-effect model, I will then perform the Hausman test to determine which is best suitable for my regression. I will be conducting some more tests to make sure there are no issues with my final regression. The first test I will be conducting is the variance inflation factor which analyzes multicollinearity between my variables. Multicollinearity is when independent variables are too highly correlated with each other, this can affect the estimation of the coefficients. The next test I will be conducting is the modified Wald test to look for heteroskedasticity. Heteroskedasticity is when the standard deviation is inconstant over time. The final test I will be conducting is the Wooldridge test which tests for serial correlation. Serial correlation is when the error terms in different time periods are correlated. If either heteroskedasticity or serial correlation is present, then the vce robustness check will need to be done to fix these issues.

4. Data

At the start of my project, I had collected data for 6 independent variables but after I had learned more on my topic and did more tests, I decided to narrow it down to 3 main independent variables. In this description I will still include where I had found all my variables and their explanations. Refer to Table 2.

Table 2. Variables Description, Sources, and Signs

Variable	Description	Source	Estimated sign	Omitted (Y/N)
CO2	The amount of CO2 emitted in metric tons	Worldbank	----------	**N**
GDP	The gross domestic product per capita in USD	Worldbank	+	**N**
POPGR	The growth of population	Worldbank	+	**N**
EXP	Exports of goods and services in USD	Worldbank	+	**N**
INC	The average per capita income in USD	Worldbank	+	**Y**
AVTEMP	Average temperature in degrees Celsius.	Worldbank	+	**Y**
PRECIP	Precipitation in centimetres	Worldbank	+	**Y**

I chose CO2 as my dependent variable as it is one of the most known measures of environmental damage, more CO2 emitted into the environment, the greater the environmental damage. I chose three independent variables for my final regression, GDP, POPGR, and EXP. I decided to omit INC because it is too highly correlated with GDP, found when conducting the pairwise correlation matrix (refer to Table 3), the relationship between the two was 0.9975. After seeing how highly correlated GDP and INC were, I tested for multicollinearity using the variance inflation factor. The mean VIF that included both INC and GDP was 100.00, whereas the mean VIF omitting INC was 1.26. This demonstrates a relationship between GDP and INC which means the model had multicollinearity that will skew the results of my coefficients. Therefore, INC and GDP could not simultaneously be in my regression, and I omitted INC.

Table 3 Correlation Matrix

Pairwise correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) CO2	1.000						
(2) GDP	-0.165***	1.000					
(3) AVTEMP	0.148***	-0.016	1.000				
(4) INC	-0.225***	0.997***	-0.029	1.000			
(5) POPGR	0.446***	0.136***	0.224***	0.185***	1.000		
(6) EXP	0.163***	0.403***	0.113**	0.425***	-0.048	1.000	
(7) PERCIP	-0.528***	0.243***	-0.065	0.285***	-0.271***	0.047	1.000

*** p<0.01, ** p<0.05, * p<0.1

There are no statistical discrepancies between AVTEMP and PRECIP, but they do not theoretically affect CO2. AVTEMP and PRECIP are also measures of economic damage therefore, it did not make sense to include them in my final regression. All the independent variables are statistically significant concerning the regression model at the 1% significance level, that is a good thing for the model. As mentioned in the empirical model and estimations, GDP and EXP are logged due to the wide gap between the minimum and maximum values. Therefore, as GDP increases by 1%, CO2 will increase or decrease by $\beta_1/100$ and, as EXP increases by 1%, CO2 will increase or decrease by $\beta_2/100$. Another notable aspect of the correlation matrix (Table 3) is that GDP is negatively correlated with CO2, going against my hypothesis. The summary statistics can be seen in Table 4.

Table 4. Descriptive Statistics

Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
GDP	496	26378.39	20290.905	1907.077	102913.45
AVTEMP	510	6.727	6.791	-6.85	22.72
CO2	510	11.427	4.721	4.362	23.081
INC	445	23157.118	16252.996	2137.893	80411.524
POPGR	510	.703	.491	-.59	3.19
EXP	486	2.786e+11	4.134e+11	1.714e+09	2.377e+12
PERCIP	510	804.021	268.44	343	1557.44

5. Empirical results

When doing regression analysis with panel data, there are two different regressions that can be used, the random effect model and the fixed effect model. To decide between the fixed effect model (**Table 5**) and the random effect model (**Table 6**), the Hausman test was conducted. After conducting the Hausman test the P-value is shown as 0.00 and the chi^2 was 233.19. Therefore, I reject the null hypothesis (being the random effect), determining that the fixed effect model (Table 5) is best suited for my regression.

Table 5. Regression results I

Regression results

CO2	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
ln_GDP	-5.22	.729	-7.16	0	-6.653	-3.788	***
POPGR	6.629	.381	17.40	0	5.88	7.377	***
lnEXP	1.381	.156	8.84	0	1.074	1.688	***
Constant	23.484	8.301	2.83	.005	7.168	39.8	***

Mean dependent var	11.589	SD dependent var	4.696
R-squared	0.452	Number of obs	476
F-test	115.964	Prob > F	0.000
Akaike crit. (AIC)	2528.409	Bayesian crit. (BIC)	2545.071

*** $p<.01$, ** $p<.05$, * $p<.1$

The fixed effect model demonstrated that all my independent variables are statistically significant with my regression. Determined by looking at the P-Values, which are all at 0, meaning that my independent variables are statistically significant at the 1% level. This regression also shows that the R^2 is 45.2 percent, which is decent. Another thing to consider is GDP's negative coefficient sign. As mentioned previously, in the correlation matrix (Table 3), this was unexpected and is against my hypothesis. This means that as GDP increases by 1% CO2 will decrease by 5.22/100 (0.0522).

Table 6. Regression Results II

Regression results

CO2	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
ln_GDP	-2.484	.275	-9.04	0	-3.022	-1.945	***
POPGR	5.26	.37	14.22	0	4.534	5.985	***
lnEXP	1.429	.157	9.12	0	1.122	1.736	***
Constant	-3.851	2.952	-1.30	.192	-9.636	1.934	

Mean dependent var	11.589	SD dependent var	4.696
Overall r-squared	0.342	Number of obs	476
Chi-square	245.627	Prob > chi2	0.000
R-squared within	0.433	R-squared between	0.048

*** $p<.01$, ** $p<.05$, * $p<.1$

Compared to the fixed effect model, the random effect model shows all the independent variables have P-values of 0 therefore, they are statistically significant at the 1% level. Again, GDP is negatively correlated with CO2, which is against my hypothesis. In the random effect model,

the R^2 is 34.2% which is not as good as in the fixed effect model. Another thing to note is that the coefficients, except for EXP, went up slightly. After analyzing both models and the Hausman test, I can conclude that the fixed effect model is best suited for my regression.

Following the model selection, I ran tests for heteroskedasticity and serial correlation. The modified Wald test for heteroskedasticity shows the chi2 (51) as 128.55 and the Prob>chi2 as 0.00. Rejecting the null hypothesis and concluding that my model has heteroskedasticity. The Wooldridge test for serial correlation shows that the F (1,50) is 321.496 and the Prob>F as 0, determining that there is also serial correlation. To fix this problem, I did the fixed effect vce robustness regression (Table 7).

Table 7. Regression Results III

Regression results

CO2	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
ln_GDP	-5.22	.703	-7.43	0	-6.633	-3.808	***
lnEXP	1.381	.107	12.92	0	1.166	1.595	***
POPGR	6.629	.574	11.55	0	5.476	7.782	***
Constant	23.484	8.982	2.61	.012	5.442	41.526	**

Mean dependent var	11.589	SD dependent var	4.696
R-squared	0.452	Number of obs	476
F-test	302.659	Prob > F	0.000
Akaike crit. (AIC)	2526.409	Bayesian crit. (BIC)	2538.906

*** $p<.01$, ** $p<.05$, * $p<.1$

This robust model has eliminated heteroskedasticity and serial correlation in my regression. As GDP increases by 1%, CO2 emissions will decrease by 5.22/100 or 0.0522. As EXP increases by 1%, CO2 will increase by 1.381/100 or 0.01381. As POPGR increases by 1, CO2 will increase by 6.629. The P-values remain at 0 therefore, all the independent variables remain statistically significant. The standard error has slightly decreased in all the variables except EXP. The coefficients have all remained the same. Although GDP was the only coefficient whose estimation was incorrect, it is the most important factor when looking at economic growth. Therefore, disproving my hypothesis of a positive linear relationship.

6. Robustness check

When I first started researching the relationship between economic growth and environmental damages, I found many studies that showed a simultaneous relationship between the two. Therefore, I started out with two dependent variables GDP and CO2. I would then attempt to prove that a simultaneous relationship exists. After doing more research, I determined that there were more credible studies that showed how economic growth affected environmental damage. Therefore, I decided to make CO2 my sole dependent variable.

My initial empirical linear model is as follows:

$$CO_2it = \beta_0 + \beta_1 GDP_{it} + \beta_2 AVTEMP_{it} + \beta_3 POPGR_{it} + \beta_3 EXP_{it} + \beta_4 PRECIP_{it} + \beta_5 INC_{it} + \varepsilon_{it}$$

As mentioned previously, the summary statistics (Table 4), demonstrated a difference between the minimum and maximum values for income, exports, and GDP. Therefore, I decided to log them. Again, after running the pairwise correlation matrix (Table 3) I found that GDP and INC are highly correlated. Therefore, eliminating INC from my regression and getting a new regression:

$$CO_2it = \beta_0 + \beta_1 lnGDP_{it} + \beta_2 AVTEMP_{it} + \beta_3 POPGR_{it} + \beta_4 lnEXP_{it} + \beta_5 PRECIP_{it} + \varepsilon_{it}$$

Then after doing more research and reading studies about the effect of Economic growth on environmental damage, I determined that average temperature and precipitation did not make sense in my regression. They were initially part of my regression when I attempted to prove a simultaneous relationship between economic growth and environmental damage. Now that CO2 was the sole dependent variable, they are not theoretically significant. Creating my third and final regression:

$$CO_2it = \beta_0 + \beta_1 lnGDP_{it} + \beta_2 POPGR_{it} + \beta_3 lnEXP_{it} + \varepsilon_{it}$$

As seen in my results, my hypothesis was incorrect. Therefore, I decided to see if the contradicting theory, the Environmental Kuznets Curve that shows an inverted U shape, was the correct model.

Creating another regression model to demonstrate a quadratic relationship between economic growth and environmental damage:

$$CO_2it = \beta_0 + \beta_1 lnGDP_{it} + \beta_2 lnGDP^2 + \beta_3 POPGR_{it} + \beta_4 lnEXP_{it} + \varepsilon_{it}$$

The fixed effect model for the above regression can be seen in Table 8.

Table 8. Regression Results IV

Regression results

CO2	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
ln_GDP	31.957	7.745	4.13	0	16.734	47.181	***
ln_GDP2	-1.859	.386	-4.82	0	-2.617	-1.101	***
POPGR	6.567	.371	17.68	0	5.837	7.298	***
lnEXP	1.302	.153	8.50	0	1.001	1.603	***
Constant	-158.928	38.695	-4.11	0	-234.987	-82.868	***

Mean dependent var	11.589	SD dependent var	4.696
R-squared	0.481	Number of obs	476
F-test	97.366	Prob > F	0.000
Akaike crit. (AIC)	2504.835	Bayesian crit. (BIC)	2525.662

*** $p<.01$, ** $p<.05$, * $p<.1$

In the fixed effect model, the R^2 is 48.1% that is better than the linear model. All the independent variables are statistically significant with a p-value of 0. Another thing to note is this demonstrates an inverted U shape because ln_GDP is positive and ln_GDP2 is negative. Therefore, this affirms the Environmental Kuznets Curve, disagreeing with my hypothesis that the relationship between environmental damage and economic growth is not quadratic. This relationship can also be represented with a graph.

Following the fixed effect model, I wanted to see if the random effect model produced similar results. The random effect model can be found in Table 9.

Table 9. Regression Results V

Regression results

CO2	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
ln_GDP	33.341	3.729	8.94	0	26.032	40.65	***
ln_GDP2	-1.856	.193	-9.63	0	-2.234	-1.478	***
POPGR	6.201	.352	17.60	0	5.51	6.891	***
lnEXP	1.411	.143	9.84	0	1.13	1.692	***
Constant	-175.373	18.018	-9.73	0	-210.687	-140.059	***

Mean dependent var	11.589	SD dependent var	4.696
Overall r-squared	0.450	Number of obs	476
Chi-square	386.056	Prob > chi2	0.000
R-squared within	0.475	R-squared between	0.079

****p<.01, **p<.05, *p<.1*

The random effect model shows similar results to the fixed effect model, with the R^2 being slightly smaller at 45% and all the p-values being significant at the 1% level. Again, it shows the inverted U shape because GDP is positive and GDP^2 is negative. Demonstrating that the shape of the Environmental Kuznets curve is present in my regression model. At first, as GDP increases, CO2 levels also increase, then there is a turning point as GDP continues to increase, CO2 will start to decrease. Demonstrating that economic growth will cause environmental damages to increase at first, but after a certain point an increase in economic growth will start to better the environment by decreasing environmental damages. After conducting the fixed effect and random effect models, I had to determine which model best fits my regression by running the Hausman test. The Hausman test can be seen in Figure 1.

Figure 1. Hausman test

Hausman (1978) specification test	
	Coef.
Chi-square test value	19.312
P-value	.001

The Hausman test concluded that the correct model for my regression is the fixed effect model as the chi^2 was 19.312 and the P-value was 0.001. Following the Hausman test, I did tests for heteroskedasticity and serial correlation. The modified Wald test for heteroskedasticity concluded

that the Chi2 (51) is 663.62 and the Prob>chi2 is 0.000. Showing that heteroskedasticity is present in my regression. The Wooldridge test for serial correlation demonstrated that serial correlation is present because the F (1,50) is 663.62 and the Prob>chi2 is 0.000. To fix this, I did the vce robust regression for a fixed effect model seen in Table 10.

Table 10. Regression Results VI

Regression results

CO2	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
ln_GDP	31.957	4.276	7.47	0	23.369	40.545	***
ln_GDP2	-1.859	.218	-8.52	0	-2.297	-1.421	***
POPGR	6.567	.641	10.24	0	5.28	7.855	***
lnEXP	1.302	.103	12.63	0	1.095	1.509	***
Constant	-158.928	21.731	-7.31	0	-202.576	-115.28	***

Mean dependent var	11.589	SD dependent var	4.696
R-squared	0.481	Number of obs	476
F-test	121.439	Prob > F	0.000
Akaike crit. (AIC)	2502.835	Bayesian crit. (BIC)	2519.496

*** $p<.01$, ** $p<.05$, * $p<.1$

After correcting for heteroskedasticity and serial correlation, the conclusion remains the same. An inverted U shape (quadratic) relationship between economic growth and environmental damage is present in my model. The p-values remain statistically significant at the 1% level and a pretty good R^2 at 48.1%. Another thing to note is that all the coefficients and standard errors went slightly down except for POPGR.

Overall, I conducted a robustness check for the quadratic model because my hypothesized positive linear model was incorrect. The new model including ln_ GDP^2 demonstrates an inverted U shape with the dependent variable, CO2, increasing then decreasing as the most important independent variable, GDP, increases.

7. Discussion

In conclusion, the paradox between studies involving environmental damage and economic growth demonstrate an uncertainty in environmental economics. But everyone agrees that consumers play

a critical role in damaging our environment. The regression I ran showed that GDP negatively affects CO2, which was the opposite of my hypothesis. I hypothesized that there would be a positive linear relationship between economic growth and environmental damage. The other two variables, population growth and exports, were the correct sign, but my focus was on the effect of GDP. Although my study could not prove a positive linear relationship between economic growth and environmental damage, there are many studies that did. After determining the falsity of my hypothesis through my regression analysis, I used a quadratic empirical model to demonstrate the presence of the Environmental Kuznets Curve. As economic growth increased, environmental damage would initially increase, but as economic growth continued to increase, there was a turning point where environmental damage would start to decrease. There are also studies that demonstrate proof of the Environmental Kuznets curve (Chow and Li, 2014; Dinda, 2004) Overall, we should not rely solely on the Environmental Kuznets Curve to resolve our environmental issues since it is a debateable theory. As consumers we need to be more ecologically conscious with our consumption. We must find more ways to diminish CO2 emissions in the environment to create a better environment for future generations.

References

Azomahou, T., Laisney, F., Van, P. N. (2006). Economic development and CO2 emissions: A nonparametric panel approach, *Journal of Public Economics*, 90(6–7),1347-1363.https://doi.org/10.1016/j.jpubeco.2005.09.005.

Bratt, L. (2012). Three Totally Different Environmental/GDP Curves, *InTech*. https://doi.org/10.5772/26616

Chow, C. G., Li, J. (2014). Environmental Kuznets Curve: Conclusive Econometric Evidence for CO2, *Pacific Economic Review*, 19(1), 1–7. https://doi.org/10.1111/1468-0106.12048

Dasgupta, S., Laplante, B, Wang, H., and Wheeler, D. (2002). Confronting the Environmental Kuznets Curve. *Journal of Economic Perspectives*, 16 (1): 147-168. https://doi.org/10.1257/0895330027157

Dell, M., Jones, B., and Olken, B. (2008). Climate Change and Economic Growth: Evidence from the Last Half Century. *American Economic Journal: Macroeconomics*,4. https://doi.org/10.3386/w14132.

Holtz-Eakin, D., Selden, T. (1995). Stoking the fires? CO2 emissions and economic growth, *Journal of Public Economics*, 57(1), 85-101. https://doi.org/10.1016/0047-2727(94)01449-X.

Dinda, S. (2004) Environmental Kuznets Curve Hypothesis: A Survey, *Ecological Economics*, 49, 432-455. https://doi.org/10.1016/j.ecolecon.2004.02.011

Jorgenson, A., and Clark, B. (2012). Are the Economy and the Environment Decoupling? A Comparative International Study, 1960–2005, *American Journal of Sociology 2012*, 118(1), 1-44. https://doi.org/10.1086/665990

Onofrei, M., Florentina, V. A., Elena, C. (2022). The Relationship Between Economic Growth and CO2 Emissions in EU Countries: A Cointegration Analysis, *Frontiers in Environmental Science*, 10 https://doi.org/10.3389/fenvs.2022.934885

Patiño, L. I., Padilla, E., Alcántara, V., and Raymond, J. L. (2020). *Atmosphere*, 11(8), 778. https://doi.org/10.3390/atmos11080778

Shafik, N. (1994). Economic Development and Environmental Quality: An Econometric Analysis. *Oxford Economic Papers*, *46*, 757–773. https://www.jstor.org/stable/2663498