The Impact of Trade on the Environment

Cody Cheatham

Department of Economics, California State University, Chico

Econ 495W: Capstone in Economics

May 17, 2023

Abstract

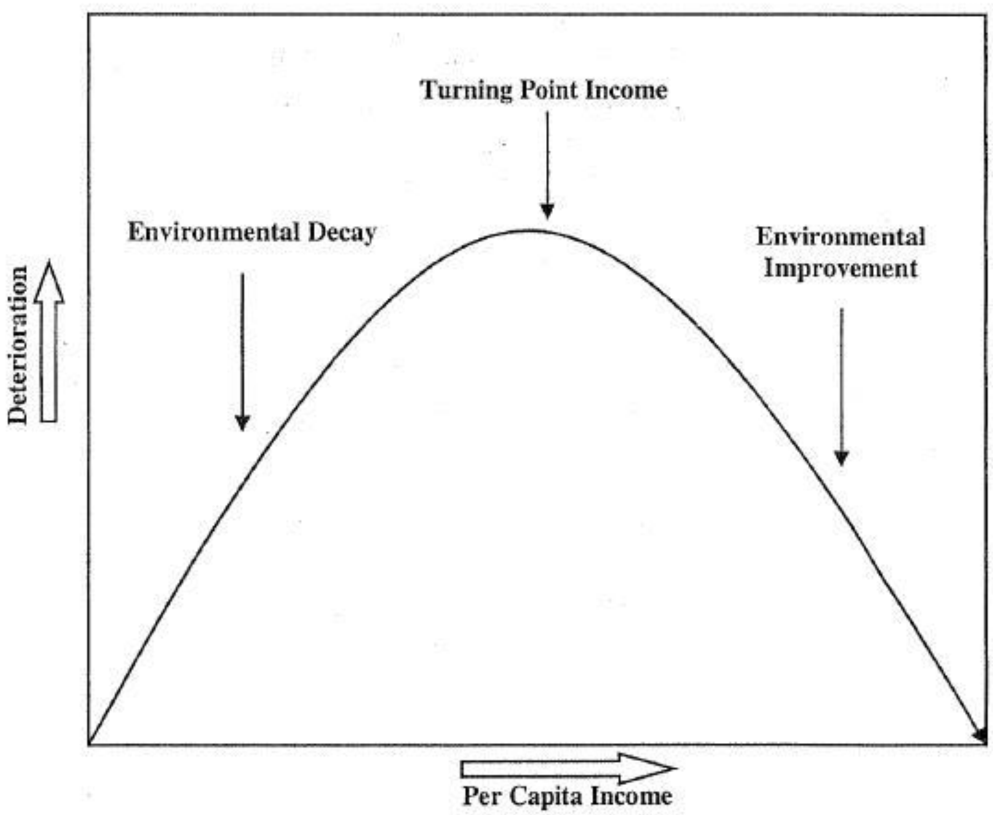
This paper explores the possible effect international trade can have on environmental degradation. This is done empirically through an OLS regression. The three pollutants tested in this analysis are carbon dioxide, nitrous oxide, and sulfur dioxide due to them being essential in the processes in the production of goods. The results for the regressions of carbon dioxide per capita, and sulfur dioxide per capita show that the EKC hypothesis does hold for these types of emissions, however, the ratio of imports and exports to GDP was shown to have a negative effect on the level of pollutants. The regression for nitrous oxide did not comply with the EKC hypothesis, and in fact, had the opposite effect. An attempt was made to explain a possible cause into why this result could possibly happen. While the EKC hypothesis did hold for two of the three pollutants tested, not all expectations were upheld in the results for each regression.

Introduction

Trade is an essential component of the global economy, providing countries with access to goods, services, and resources that they may not have otherwise been able to obtain. Trade can increase economic growth, create jobs, and raise living standards, among other benefits. However, it is important to recognize that trade can also have negative impacts on the environment. As global trade has increased over the past few decades, concerns about its impact on the environment have grown. Trade can lead to increased deforestation, pollution, and other forms of environmental degradation. These negative impacts can have far-reaching consequences for the health and well-being of people and ecosystems around the world.

This analysis is based off the Environmental Kuznets Curve hypothesis. This is an economic theory that is used to suggest a specific pattern between environmental degradation and economic development. Figure 1 shows an example of the EKC. It shows an inverted U shape curve. As the level of per capita income increases, the level of environmental degradation will also increase. This is until the turning point. At this point, it is assumed that the country will introduce more environmental regulations, leading to environmental improvement as the level of per capita income increases.

Figure 1: Environmental Kuznets Curve



Note: A visual representation of the environmental Kuznets curve. Reprinted from Property and Environmental Research Center, by J. Wood. Retrieved on May 12th, 2023. https://www.perc.org/2011/02/10/mexico-and-the-environmental-kuznets-curve/. Copyright 2018 by Property and Environmental Research Center.

Literature Review

There are many previous studies with empirical data showing a relationship between trade, economic growth, and environmental degradation. These studies are done across different regions, each having different values for GDP, and emissions.

Kleemann and Abdulai explore the inter-relations between economic growth, international trade, and environmental degradation. This is done empirically through panel data. Kleemann and Abdulai state that previous studies focusing on the impact economic growth has on environmental degradation were criticized for several reasons. One reason being that these earlier empirical studies concentrated on a few pollutants, which lead to false interpretation that any other pollutant has the same relationship to income. A major point that Kleemann and Abdulai make within their literature review, is that there is some conflict in previous studies that examine the trade-environment relationship. They list previous studies that all come to different conclusions about the relationship between a country's trade and environmental degradation. One study concluded that trade liberalization reduces pollution, while another study was skeptical about any positive effects trade liberalization has on the environment (Kleenmann and Abduali, 2013).

The variables used in this empirical study include trade intensity, income, income squared, and the log of the population density. The model used by Kleemann and Abdulai in this study is given as

$$ED_{it} = \beta_1 TRADE_{it} + \beta_2 GDP_{it} + \beta_3 GDPSQ_{it} + \beta_4 LNPOPD_{it} + \delta_t + \mu_i + \epsilon_{it}$$

δt is the time-specific intercept, μi represents country- specific effects that summarize the influence of unobserved variables such as infrastructure, period average climate, history and culture and that are assumed to be distributed independently across countries, with variance σ2 μ, and εit is the stochastic error term for each country i and year t (Kleenmann and Abduali, 2013). The results of this study state that there is an Environmental Kuznets Curve for most of the pollutants tested, but there were some reservations, and that environmental liberalization is beneficial to richer countries but harmful to poorer countries (Kleenmann and Abduali, 2013).

Azam empirically investigates the impact of environmental degradation by CO2 emissions on the economic growth of 11 Asian countries between 1990 and 2011. Azam states that the predominant causes of air and water pollution and global warming are objectively understood as the consequence of enhanced and unrestrained human activities at distinctive stages of economic growth and development, such as agriculture, industries, transportation, and energy production (Azam, 2016). Azam states Previous studies reveal that investigations on the direct impact of CO2 emissions on economic growth are insufficient. Most studies either overlook or ignore the impact of environmental degradation on economic growth. Therefore, this study aims to empirically explore the impact of environmental degradation by CO2 emissions on economic growth (Azam, 2016).

The equations used for Azam's empirical analysis is as follows:

$$(1)\ G_{it} = B_i + B_1 EN_{it} + B_2 EC_{it} + B_3 IN_{it} + B_4 GS_{it} + B_5 HK_{it} + E_{it}$$

$$(2)\ G_{it} = B_i + B_1 EN_{it} + B_2 EC_{it} + B_3 IN_{it} + B_4 GS_{it} + B_5 HK_{it} + l_i + m_{it}$$

The difference between these two equations is that equation 1 indicates that there is a constant parameter that varies across countries but not overtime, and equation 2 uses the variable l_i which represents country specific random effects. Empirical results exhibit that environmental degradation has a significantly negative impact on economic growth. Empirical findings also suggest that environmental degradation should be regulated (Azam, 2016).

Gorus and Aslan conducted an empirical study using the the Environmental Kuznets Curve (EKC) hypothesis and the Pollution Haven Hypothesis (PHH) for for MENA (Middle East and North Africa). By using balanced panel data methodology, this study aims to investigate the links and direction of causality between per capita income, foreign direct investment, energy use and carbon dioxide emission for MENA countries for the period of 1980–2013. This study finds partial support for both the EKC and the PHH for MENA countries (Gorus and Aslan, 2019). Gorus and Aslan state One source of the EKC hypothesis stems from the fact that changes in production structure in developed economies are not accompanied by equivalent changes in consumption pattern structure of these countries. The PHH is a possible channel for this mechanism offered in the literature (Gorus and Aslan, 2019).

This study examined the following 9 countries: Algeria, Egypt, Iran, Jordan, Morocco, Pakistan, Sudan, Tunisia, and Turkey. The model used to investigate the possible relationship between environmental degradation and economic indicators is as follows:

$$CO2_{it} = \alpha_i + \beta_1 GDP_{it} + \beta_2 GDP_{it}^2 + \beta_3 FDI_{it} + \beta_4 EU_{it} + \varepsilon_{it}$$

Where the data employed in this study includes four variables: CO2 emissions per capita, real GDP per capita, FDI inflows, and energy use per capita. This study finds partial support for both the EKC and the PHH for MENA countries. Furthermore, the empirical results show that foreign direct investment inflows and energy use have exacerbated pollution in the majority of MENA countries (Gorus and Aslan, 2019).

Tachie et al explores the effect of trade openness in developed countries using EU-18 economies where they employed an econometric approach that accounts for cross-section dependence among study variables. Tachie et al states that one of the shortcomings of previous earlier studies centering on a cross section of 18 EU member states is that Previous studies in most EU to out familiarity, specifically on emission and trade openness, mainly center only on the aforementioned variable in a univariate framework thus leading to the issue of omission of variable biasness (Tachie et al, 2020). They state that another issue with previous studies is that despite the large number of research investigating the effect of trade openness on CO2 emissions, those centering on panel studies often use panel approaches that assume cross-sectional independence. Thus, relying on only the assumption of cross-sectional independence is most likely to cause erroneous in the case where the panel data suffers from the issues of cross-sectional connectedness (Tachie et al, 2020). This study employed the Dumitrescu and Hurlin (2012) Granger causality test (henceforth D-H test) to assess the direction of causalities among study variables (Tachie et al, 2020).

The final model that was proposed for this study is as follows:

$$lnCO2_{it} = \alpha_0 + \beta_1 lnTO_{it} + \beta_2 lnEC_{it} + \beta_3 lnGDP_{it} + \beta_4 lnGPD_{it}^2 + \beta_5 lnUR_{it} + \varepsilon_{it}$$

where CO2 represents carbon dioxide emissions, GDP represents the gross domestic product which serves as a proxy of economic growth, EC denotes energy consumption, TO

which is the variable of interest representing trade openness, GDP and GDP^2 are economic growth of its square whose respective parameter estimates are required to validate the ECK conjuncture and UR represents urbanization (Tachie et al, 2019). The results of this study confirmed the environmental Kuznets curve and pollution halo and pollution haven hypothesis were confirmed at both estimation methods. The Dumetriscu-Hurlin Granger causality test results confirmed bidirectional causality between trade openness and energy consumption and between trade openness and economic growth. Again, unidirectional Granger causality is running from trade openness and CO2 emissions. Policy recommendations are further proposed (Tachie et al, 2020).

Both Kleemann and Abdulai, as well as Gorus and Aslan mention that previous earlier studies used a similar reduced model when testing with the Environmental Kuznets Curve. This reduced model used by previous earlier studies can be seen below:

$$E_{it} = \beta_o + \beta_1 Y_{it} + \beta_2 Y_{it}^2 + \lambda_t + \alpha_i + \varepsilon_{it}$$

Frankle and Rose examine the relationship between international trade and environmental concerns. They found that and increase in trade can lead to greater economic growth and development, which can in turn lead to improved environmental conditions. However, they also point out that increased trade can lead to greater environmental degradation if countries engage in a "race to the bottom" by lowering environmental standards to attract investment and trade. Their analysis was done by using the following model:

$$EnvDam_i = \varphi_0 + \varphi_1 ln(y/pop)_{90,i} + \varphi_2 ln[\,(y/pop)_{90,i}^2] + \beta\,([X + M]/Y)_{90,i} + \varphi_3 Polity_{90,i} + \varphi_4\, ln(LandArea/pop)_{90,i} + e_{i,}$$

Frankle and Rose state “The estimated effect of the polity variable on pollution is always negative, suggesting that improved governance has a beneficial effect. It is generally significant statistically. The same is true of land area per capita, evidence that population density has an adverse effect on concentration of pollutants” (Frankle & Rose, 2005).

Data and Model

Below is the cross-country equation used for further analysis:

$$Pollution_{it} = \beta_0 + \beta_1 (y/pop)_{it} + \beta_2\,(y/pop)_{it}^2 + \beta_3\,(X + M)/Y_{it} + \beta_4 (LandArea/pop)_i + \beta_5 Polity_{it} + \beta_6 Ocean_i + e$$

Where:

- Pollution represents one of the three harmful pollutants being tested (CO2, N2O, SO2) per capita by country i and year t,
- β_0 is the intercept of the equation,
- (y/pop) is the value of GDP per capita in country i and year t,
- (X + M)/Y is the ratio of nominal imports and exports to GDP per country i and year t,
- (LandArea/pop) is the land area per capita per country i,

- Polity is a measure of how democratic or autocratic the structure of country i during year t,
- Ocean is a dummy variable that describes if country i is bordering 2 or more oceans, and
- *e* is a residual term that represents other types of harmful pollutants.

The three different pollutants tested in this analysis contain carbon dioxide (CO_2), nitrous oxide (N_2O), and sulfur dioxide (SO_2) emissions. These pollutants were chosen because each is produced in an essential process in the production of goods. The primary source of Carbon Dioxide emissions is the burning of fossil fuels such as coal, oil, and gas, which also includes emissions from power plants, transportation, and other industrial processes. Carbon Dioxide emissions are also produced through land use changes such as deforestation and land degradation, which can cause a loss or carbon stored in vegetation and soil. Nitrous Oxide emissions are primarily produced through agricultural practices such as the use of nitrogen fertilizers, livestock manure management, and the cultivation of crops. Sulfur Dioxide emissions are primarily produced through industrial processes such as the burning of fossil fuels in places such as power plants and oil refineries. It is also important to note that carbon dioxide and nitrous oxide emissions can also be produced through waste management practices such as landfilling and wastewater treatment. The levels of these pollutants were measured in metric tons (tonnes).

Data collected for the model contains values from the year range of 2011-2021 for 99 countries. The data collected for each emission type was obtained from Our World in Data. The International Monetary Fund (IMF) contained data on the values of imports and exports for each country tested in United States Dollars. The world bank contained data for GDP (adjusted for ppp to allow for a more meaningful comparison of economic output in different countries), land area of each country (sq. kilometers), and population data. Values for polity were obtained from the Polity IV Project. Polity is a measure of how democratic or autocratic a country will be, it ranges from -10 to 10. The more positive the polity value is for a country, the more democratic that country will be, and the more negative the polity value is for a country, the more autocratic that country will be. For the variable Ocean, the world atlas was consulted to obtain a list of countries and the oceans that they border.

Based off this model, three regressions will be run, one for carbon dioxide, nitrous oxide, and sulfur dioxide. All pollutants will be per capita, to keep consistency with the rest of the model. The regressions will be labeled as follows; Regression 1: carbon dioxide per capita, Regression 2: nitrous oxide per capita, and Regression 3: sulfur dioxide per capita. With these three regressions, there are expectations of the coefficients of each variable in this model. To comply with the EKC hypothesis, GDP per capita is expected to be positive, and GDP per capita squared is expected to be negative. The value of these coefficients are essential when complying to the EKC hypothesis, as the squared value being negative creates the inverted parabola shape of the Kuznets curve. The nominal ratio of imports and exports to GDP is expected to be positive. This variable is the main explanatory variable of this model, it is also expected to be statistically significant. This is because it is expected that this variable will have the biggest impact on the increase in the level of each pollutant per capita. Land area per capita is also expected to be positive. Polity is expected to be negative, because if the value of polity is positive, meaning that the country is more democratic, there is an expectation that there would be improved regulations on environmental degradation in the country, leading to a decrease in the level of each pollutant per capita. Ocean is expected to be positive, because it is expected that the more oceans a country borders, the more ports that will be open, leading to an increase in trade.

Results

Table 1: Results for Regression 1

Source	SS	df	MS
Model	15585.8905	6	2597.64842
Residual	10214.3864	983	10.391034
Total	25800.2769	989	26.0872365

Number of obs	=	990
F(6, 983)	=	249.99
Prob > F	=	0.0000
R-squared	=	0.6041
Adj R-squared	=	0.6017
Root MSE	=	3.2235

co2_per_cap	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
gdp_per_cap	.0003382	.0000152	22.22	0.000	.0003083	.0003681
gdp_per_cap_sq	-2.14e-09	1.89e-10	-11.34	0.000	-2.51e-09	-1.77e-09
nx_gdp	-1.415226	.4687577	-3.02	0.003	-2.335107	-.4953451
polity	-.0579711	.0085594	-6.77	0.000	-.0747679	-.0411743
lndarea_per_cap	15.13064	1.297941	11.66	0.000	12.58358	17.67769
ocean	.3400339	.2631341	1.29	0.197	-.1763353	.8564032
_cons	-.6486147	.226446	-2.86	0.004	-1.092988	-.2042415

Regression Results for Carbon Dioxide per capita across the explanatory variables GDP per capita, GDP per capita squared, the ratio of nominal imports and exports to GDP, polity, land area per capita, and ocean.

Table 1 shows the results for Regression 1. This regression focuses on carbon dioxide per capita over the model. The coefficients for GDP per capita and GDP per capita squared were accurate to the expectations presented, meaning that this model when tested for carbon dioxide per capita does comply with the EKC hypothesis. The coefficient for nx_gdp (this is the ratio of nominal imports and exports to GDP) is negative. This differs from the expectations where it was expected to have a positive effect on the amount of carbon dioxide per capita. This means that for every 1% increase in nx_gdp, the level of carbon dioxide per capita will decrease by 1.415226 tonnes. The coefficient for polity was negative, this falls in line with the expectations set for the model. Both Land Area per capita and Ocean were positive, also falling in line with expectations. The p-values for GDP per capita, GDP per capita squared, nx_gdp, polity, and land area per capita were very low, with all variables except for nx_gdp being 0.000, meaning that these variables are very statistically significant. The p-value for nx_gdp, while not 0.000, was still very statistically significant at 0.003, again falling in line with expectations. The p-value for ocean was 0.197, meaning that this variable was not statistically significant at a 95% confidence level.

Table 2: Results for Regression 2

Source	SS	df	MS			
Model	247.71821	6	41.2863683	Number of obs	=	990
Residual	190.847458	983	.194147973	F(6, 983)	=	212.65
				Prob > F	=	0.0000
				R-squared	=	0.5648
				Adj R-squared	=	0.5622
Total	438.565668	989	.443443547	Root MSE	=	.44062

n2o_per_cap	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
gdp_per_cap	-5.36e-06	2.08e-06	-2.57	0.010	-9.44e-06	-1.27e-06
gdp_per_cap_sq	1.44e-10	2.58e-11	5.58	0.000	9.35e-11	1.95e-10
nx_gdp	.0890097	.0640745	1.39	0.165	-.0367289	.2147483
lndarea_per_cap	5.990128	.1774157	33.76	0.000	5.641971	6.338285
polity	.0143977	.00117	12.31	0.000	.0121018	.0166937
ocean	-.1094495	.0359678	-3.04	0.002	-.1800321	-.038867
_cons	.2671966	.0309529	8.63	0.000	.2064552	.327938

Regression Results for Nitrous Oxide per capita across the explanatory variables GDP per capita, GDP per capita squared, the ratio of nominal imports and exports to GDP, polity, land area per capita, and ocean.

Table 2 shows the results for Regression 2. This regression focuses on nitrous oxide per capita over the model. However, the results for Regression 2 when compared to Regression 1 are very interesting. This can first be seen through the coefficients of GDP per capita and GDP per capita squared. Unlike the results for Regression 1, the results for Regression 2 show that the EKC hypothesis does not hold for this model when nitrous oxide is the dependent variable. The coefficient for GDP per capita was negative, and the coefficient for GDP per capita squared was positive, not falling within expectations and creating a normal U shape curve. The coefficient for nx_gdp was positive, falling within expectations, however the p-value for this variable was 0.165, making nx_gdp not statistically significant at a 95% confidence level. The coefficient for land area per capita was positive. The coefficient for polity was positive for this regression, not falling in line with what the expectations were. The coefficient for ocean also did not fall in line with expectations.

The cause of these results is unclear, however, looking at the data used for this analysis, an interesting result can be inferred. The top 10 countries with the highest levels of nitrous oxide in the year 2021 can be seen in Table 3.

Table 3: Highest Levels of N2O in the Year 2021

Country	Year	N2O
China	2021	552280000.00
United States	2021	265740000.00
India	2021	261740000.00
Brazil	2021	187290000.00
Indonesia	2021	99400000.00
Australia	2021	71460000.00
Pakistan	2021	66670000.00
Russia	2021	65120000.00
Argentina	2021	48610000.00
Ethiopia	2021	48080000.00

The top 10 countries in the year 2021 that had the highest levels of N2O. This table is used to help further the analysis of Regression 2.

As we can see from Table 3, the top 10 countries with the highest values of N2O in the year 2021 include China, the United States, India, Brazil, Indonesia, Australia, Pakistan, Russia, Argentina, and Ethiopia. While taking this information at face value, there is not much evidence that an issue with the values of nitrous oxide for these countries would indicate a problem for the regression results. However, when looking back to what the main causes in the production of nitrous oxide are, we can see that they are all agriculturally related. According to Sean Ross, the world's top four food-producing countries—China, India, the U.S., and Brazil—share the advantages of large populations, ample land area, and climate zones suitable for growing a variety of crops, though there are also major differences in the role that food production plays in their economies (Ross, 2023). Looking back to Table 3, we can see that the top 4 countries with the highest amounts of nitrous oxide based off the data used in this analysis were consistent with Ross' findings. This can possibly suggest that while the EKC hypothesis may be consistent with carbon dioxide and other emissions caused by the production of goods, the EKC hypothesis may not fit for goods created in the agricultural sector (i.e. Food). However, this is only speculation, as more testing on this specific topic would have to be done to come to a more concrete conclusion.

Table 4: Results for Regression 3

Source	SS	df	MS			
Model	2879.14626	6	479.857709	Number of obs	=	990
Residual	2182.40189	983	2.22014434	F(6, 983)	=	216.14
				Prob > F	=	0.0000
				R-squared	=	0.5688
				Adj R-squared	=	0.5662
Total	5061.54815	989	5.11784444	Root MSE	=	1.49

so2_per_cap	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
gdp_per_cap	.0001522	7.04e-06	21.63	0.000	.0001384	.000166
gdp_per_cap_sq	-8.65e-10	8.73e-11	-9.90	0.000	-1.04e-09	-6.93e-10
nx_gdp	-1.405109	.2166754	-6.48	0.000	-1.830308	-.9799093
lndarea_per_cap	3.004978	.5999515	5.01	0.000	1.827645	4.182311
polity	-.0337684	.0039564	-8.54	0.000	-.0415324	-.0260044
ocean	.0312367	.1216294	0.26	0.797	-.2074463	.2699198
_cons	-.083435	.1046709	-0.80	0.426	-.2888391	.121969

Regression Results for Sulfur Dioxide per capita across the explanatory variables GDP per capita, GDP per capita squared, the ratio of nominal imports and exports to GDP, polity, land area per capita, and ocean.

Table 4 shows the results for Regression 3. This regression focuses on sulfur dioxide per capita over the model. The results for Regression 3 are very similar to the results to Regression 1, returning to some form of normalcy between the results. The coefficients for GDP per capita were positive, and the coefficient for GDP per capita squared was negative, both complying with the EKC hypothesis. Much like Regression 1, the coefficient for nx_gdp was negative, not falling in line with expectations. While the actual value of the coefficient slightly differs from that of Regression 1, the conclusion of both coefficients remains the same. A 1% increase in nx_gdp will cause a decrease in the level of sulfur dioxide to decrease by 1.405109 tonnes. The coefficient for land area per capita was positive, keeping with expectations. The coefficient for polity was negative, much like Regression 1, and keeping with expectations. The coefficient for ocean was positive, keeping with expectations. Besides the actual values of the coefficients differing from Regression 1, the p-values also differed. Much like Regression 1, all variables were statistically significant except for ocean, however, all statistically significant variables have a p-value of 0.000, and the p-value for ocean being 0.797. This means that when sulfur dioxide per capita is the dependent variable of the model, the variable ocean is very statistically insignificant.

Conclusion

Trade has been a highly debated topic over the years. In this study, the Environmental Kuznets Curve hypothesis was used to structure the analysis of three different pollutants and examine the possible effects trade could have on them. The EKC is an economic theory, that in simple terms, describes the potential pattern between environmental degradation and the level of economic development of a country. Through the three regressions run for this analysis, it can be concluded that trade can have a variety of effects on the level of a pollutant based off the model used. While not all regressions showed favorable results to the expectations posed in this study, it was shown that for two of the three types of emissions tested in this analysis, the trade had a negative effect on any environmental degradation. The results for the regression of nitrous oxide per capita over the model showed that a possible cause for the rejection of the EKC hypothesis could be due to the agricultural nature of nitrous oxide.

Current limitations with this analysis include the lack of significant evidence towards the conclusion that agriculturally based emissions can cause a rejection of the EKC hypothesis. Given more time and more extensive analysis based specifically on nitrous oxide, a concrete conclusion can be made on the true effect of nitrous oxide on the EKC hypothesis. Another possible limitation could be the lack of other significant emissions being tested by this model. Other emissions could possibly show varying results that trade could have on the level of environmental degradation.

Overall, not all results complied with the EKC hypothesis and other expectations put on the results of this model. However, with trade being statistically significant for two of the three types of emissions tested, it can be assumed that trade can have a possible negative effect on environmental degradation. Given that these results also comply with the EKC hypothesis, it can also be assumed that the level of emissions in countries with a larger amount of economic development will decrease due to the increase in trade.

References

Azam, M. (2016). Does environmental degradation shackle economic growth? A panel data investigation on 11 Asian countries. *Renewable and Sustainable Energy Reviews*, *65*, 175–182. https://doi.org/10.1016/j.rser.2016.06.087

Chepkemoi, J. (2017, April 25). *Which countries border more than one ocean?* WorldAtlas. Retrieved April 05, 2023, from https://www.worldatlas.com/articles/which-countries-border-more-than-one-ocean.html

Frankel, J. A., & Rose, A. K. (2005). Is Trade Good or Bad for the Environment? Sorting out the Causality. *The Review of Economics and Statistics*, *87*(1), 85–91. http://www.jstor.org/stable/40042924 \

GDP per capita, PPP (current international $). Data. (2023). Retrieved April 2, 2023, from https://data.worldbank.org/indicator/NY.GDP.PCAP.PP.CD?view=chart

Global Sulphur Dioxide (so_2) emissions by world region. Our World in Data. (2023). Retrieved March 19, 2023, from https://ourworldindata.org/grapher/so-emissions-by-world-region-in-million-tonnes

Goods, Value of Exports, Free on board (FOB), US Dollars. IMF data. (2023). Retrieved March 15, 2023, from https://data.imf.org/regular.aspx?key=63087885

Gorus, M. S., & Aslan, M. (2019). Impacts of economic indicators on environmental degradation: Evidence from MENA countries. *Renewable and Sustainable Energy Reviews*, *103*, 259–268. https://doi.org/10.1016/j.rser.2018.12.042

Gross Domestic Product . IMF data. (2023). Retrieved March 15, 2023, from https://data.imf.org/regular.aspx?key=63122827

Gene M. Grossman , Alan B. Krueger, Economic Growth and the Environment, The Quarterly Journal of Economics, Volume 110, Issue 2, May 1995, Pages 353–377, https://doi.org/10.2307/2118443

Kleemann, L., & Abdulai, A. (2011). The impact of trade and economic growth on the environment: Revisiting the cross-country evidence. *Journal of International Development*, *25*(2), 180–205. https://doi.org/10.1002/jid.1789

Land area (sq. km). The World Bank. (2023). Retrieved March 17, 2023, from https://data.worldbank.org/indicator/AG.LND.TOTL.K2

Population, total. The World Bank. (2023). Retrieved March 17, 2023, from https://data.worldbank.org/indicator/SP.POP.TOTL?end=2021&start=2011

Ritchie, H., Roser, M., & Rosado, P. (2020, May 11). *CO2 emissions*. Our World in Data. Retrieved March 19, 2023, from https://ourworldindata.org/co2-emissions

Ross, S. (2023, May 1). *4 countries that produce the most food*. Investopedia. https://www.investopedia.com/articles/investing/100615/4-countries-produce-most-food.asp

Tachie, A.K., Xingle, L., Dauda, L. *et al.* The influence of trade openness on environmental pollution in EU-18 countries. *Environ Sci Pollut Res* **27**, 35535–35555 (2020). https://doi.org/10.1007/s11356-020-09718-9

The Polity Project. PolityProject. (2018). Retrieved April 2, 2023, from https://www.systemicpeace.org/polityproject.html

Wood, J., Yablonski, B., Yablonski, M., & Sanchez, L. (2018). Mexico and the environmental kuznets curve. PERC. https://www.perc.org/2011/02/10/mexico-and-the-environmental-kuznets-curve/