Economic Growth and Climate Change in G7 Countries

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Motivation

- World faces economic and policy uncertainties worsened by political polarizations
  - Democratic vs autocratic governments, industrialized vs developing economies, liberal vs conservative political philosophies
- Global uncertainty has adverse consequences for investment and economic growth
- World faces environmental policy uncertainty to curb anthropogenic CO_2 emissions in face of severe impacts of climate change
  - Rising temperatures, severe and changing weather patterns, warming and rising sea levels, increased droughts, loss of species, food insecurity, health risks, and poverty and displacement

Kuznets Curve

- Simon Kuznets proposed income inequality first rises and then falls as economic development proceeds
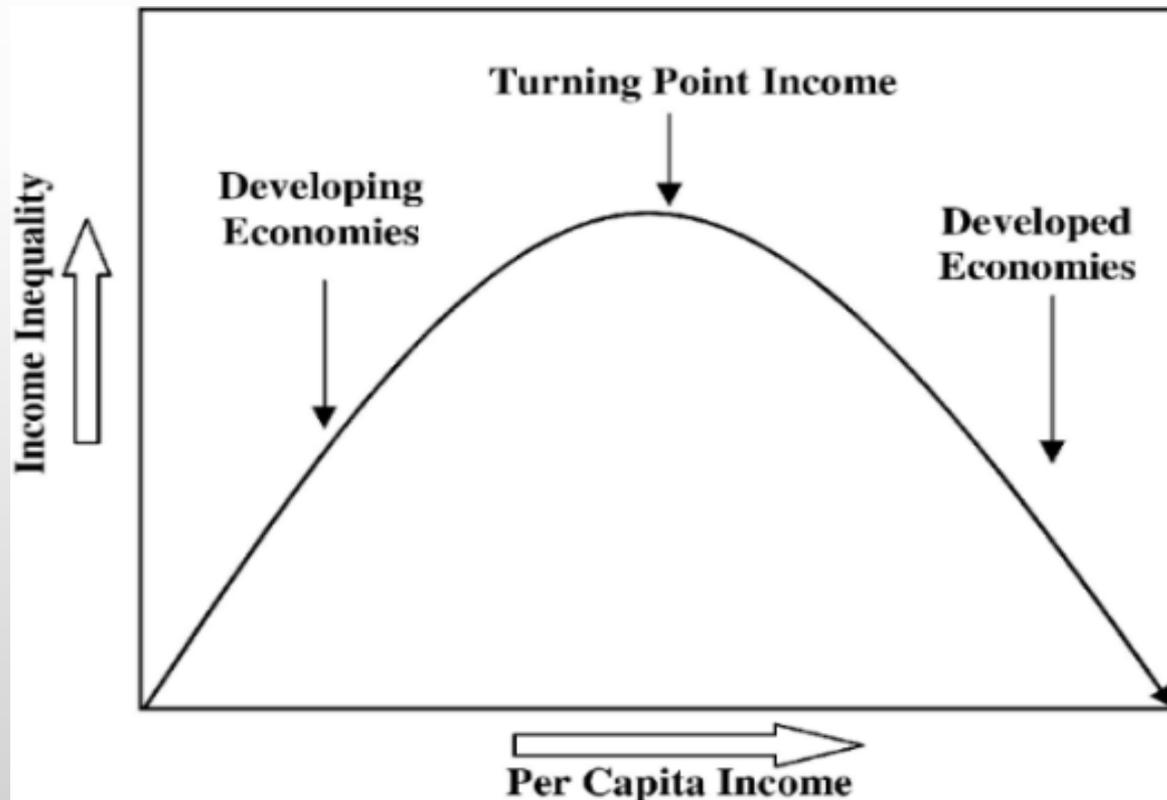
Environmental Kuznets Curve

- Environmental degradation (emissions per capita) is inverted U-shaped function of per capita income

- In early stages of economic growth, pollution emissions increase and environmental quality declines

Trend reverses beyond some level of per capita income

- At high income levels, economic growth leads to improvement in environmental quality

Environmental Kuznets Curve
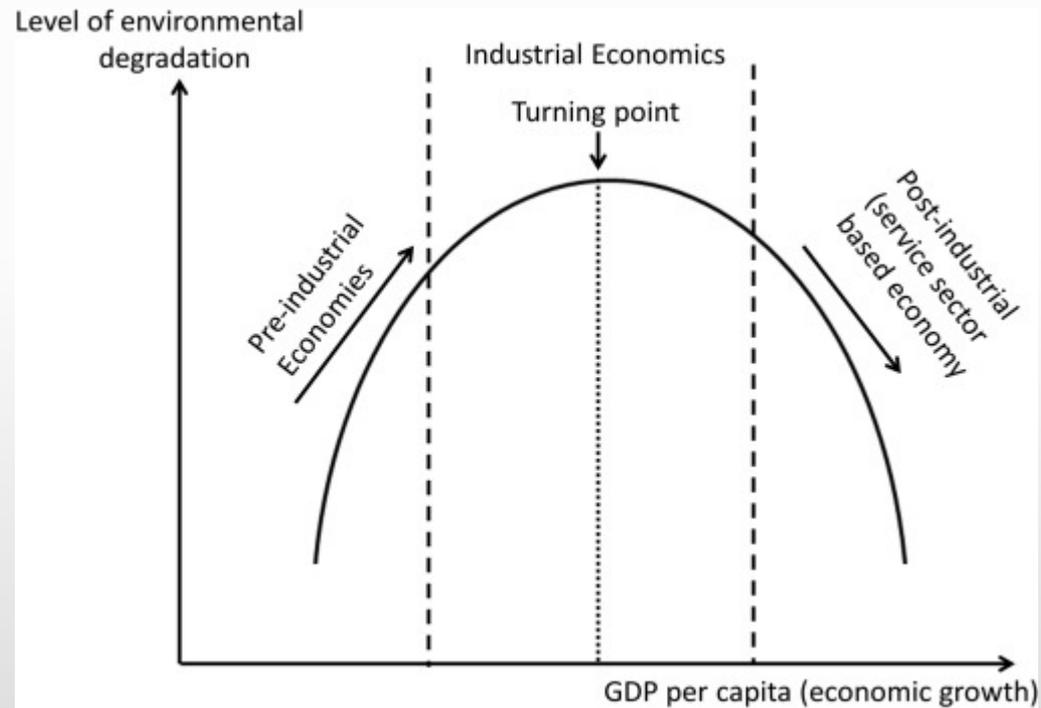
Literature Review

- Scientific research has affirmed CO_2 emissions are responsible for global warming but review of academic research relating to EKC hypothesis provides mixed results

- Saqib and Benhmad (2021) report only 57 percent of published articles find empirical evidence for EKC hypothesis and 43 percent point to mixed results (very weak or no discernible relationship)

- Stern (2004), Begum *et al*. (2015), Al-Mulali *et al*. (2016) and Liu *et al*. (2017) suggest EKC relationship cannot be considered for environmental policy implications

- Allard *et al*. (2018) report some complex results like an N-shaped EKC relationship for low-income and middle-income, but consistent inverted U-shaped relationship for CO_2 emissions

- Proponents of EKC suggest countries must institutionalize it as an environmental policy to curb burgeoning climate change effects (Grossman and Kruger, 1991)

Literature Review

- Stern (2004) insists EKC type relationship cannot be applied in developing relationship between pollutants and environment

- Nasir *et al*. (2019) and Pham *et al*. (2020) assert macroeconomic factors (e.g., financial development, foreign direct investment, population, international trade, and technological development) affect EKC type relationships and influenced by global uncertainty

- Several studies of EKC hypothesis in G7 countries in absence of policy uncertainty report mixed results
  - No EKC type relationship between CO_2 emissions and GDP per capita in Canada, Germany, Italy, Japan and U.S. (Wanger, 2015; Liu *et al*., 2022)
  - Relationship exists for France and U.K. but only for certain economic threshold points (Fosten *et al*., 2012, and Sephton and Mann, 2016)

About this Research

- We examine EKC relationship between per capita CO2 emissions and GDP per capita in G7 Countries in presence of uncertainty using panel data from 1960-2022

- Conduct series of diagnostic tests to determine most appropriate estimation technique

- Employ fixed-effects estimation method

- World Uncertainty Index (WUI) used as measure of uncertainty

- First study to use WUI to investigate EKC relationship, and consumption-based data on CO2 emissions in G7 countries

World Uncertainty Index

- Published since 1996 and includes quarterly data for 143 countries
- Based on frequency of word "uncertainty" in Economist Intelligence Unit country reports (based on major political and economic events)
- Fluctuates due to major incidents
  - E.g., September 11th attacks, SARS outbreak, second Gulf War, global financial crisis, Euro debt crisis, European border crisis, U.K. Brexit, 2016 U.S. elections, COVID-19 pandemic, and Russia-Ukraine conflict
- Political or economic uncertainty in large country like U.S. or in a group of countries such as G7 has significant spillover effects globally

Methodology

- Model uses quadratic income function transformed into natural logarithmic form:

$$\ln CO_{2it} = \beta_o + \beta_1 \ln GDPP_{it} + \beta_2 (\ln GDPP_{it})^2 + \beta_3 \ln WUI_{it} + \varepsilon_{it}$$

- Dependent variable (lnCO2): natural log of per capita CO2 emissions of country i in year t
- Explanatory variables: natural logs of GDP per capita, square of natural log of GDP per capita, and natural log of WUI of country i in year t
- Intercept (β_o): represents other factors that influence CO2 emissions
- β1, β2, β3: coefficient parameters of explanatory variables
- Ɛit: error term [ε ~ n (μ, σ2)]

Methodology

- $\beta 3$ indicates whether WUI is significant in predicting CO_2 emissions

- Sign of $\beta 3$ also significant
  - Negative sign indicates WUI reduces CO_2 emissions
  - Positive sign implies WUI contributes to CO_2 emissions

Income Turning Point

- Income turning point (ITP) can be estimated by

$$\tau = \exp\left(-\frac{\beta_1}{2\beta_2}\right)$$

- Estimated value of ITP provides required income threshold point
  - Economic growth beyond threshold essential to control CO2 emissions
  - Provides level of country's sustainable economic growth

Data

- World Development Indicators (World Bank)
- World Uncertainty Index
- Panel data
    - 1960-2022
    - 427 observations

Descriptive Statistics

Table 1. Variable Definitions and Descriptive Statistics

Variables	Description	Mean	Standard Deviation	Min.	Max.
$ln PP$CO2	Natural log of per capita carbon emissions (dependent variable)	2.425	0.404	1.162	3.146
lnGDPP	Natural log of GDP per capita measured (US dollars in 2015 prices)	10.192	0.397	8.761	10.923
$(ln$GDPP$)^2$	Square of natural log of GDP per capita (US dollar in 2015 prices)	104.025	8.001	76.763	119.321
lnWUI	Natural log of World Uncertainty Index	0.461	0.278	0.000	1.744

N = 427

Empirical Approach

- Prior to examining EKC type relationship, several diagnostic tests performed to find best-fitting estimation technique
- Test for unit root to accommodate for possible structural breaks in data
  - Test confirms all unit root processes rejected and longitudinal panel data are stationary
- Kao test suggests all variables are free of co-integration
- Hausman test suggests fixed-effects model is superior to random-effects model
- Results from fixed-effects model are presented in Table 2
  - Results from random-effects estimation included for comparison

Results

Table 2. Results of Fixed-Effects and Random-Effects Models

Variables	FE Model	RE Model
	Coefficients	Coefficients
lnGDPP	11.735***	11.697***
	(0.704)	(0.711)
$(ln\text{GDPP})^2$	-0.555***	-.535***
	(0.035)	(0.035)
lnWUI	-0.059**	-.060**
	(0.026)	(0.026)
INTERCEPT	-57.074***	-56.889***
	(3.536)	(3.571)
σ_u	0.387	0.249
σ_e	0.141	0.141
ρ (fraction of variance due to u_i)	0.881	0.755

Notes:
1. n = 427.
2. Values in parentheses are standard errors.
3. *, **, and *** represent significance at 10 percent, 5 percent, and 1 percent levels.

Interpretation

- Dependent variable (natural log of per capita CO_2 emissions) is explained by all explanatory variables
- Results confirm existence of EKC relationship for CO_2 emissions
  - Natural log of GDP per capita and its square term are significant
  - Positive coefficient of natural log of GDP per capita suggests one percent change in GDP per capita will increase CO_2 emissions per capita by 11.735 percent
  - Negative and significant square term of natural log of GDP per capita indicates rate of change in per capita CO_2 emissions is negatively related to rate of change in GDP per capita
  - Finding provides important insight about controlling CO_2 emissions in addressing issue of global warming and climate change
    - If EKC hypothesis exists for CO_2 emissions, economic growth can be an environmental policy tool in that increasing incomes would likely help to improve wide array of environmental indicators

Interpretation

- World Uncertainty Index variable is significant and negative
  - One percent increase in World Uncertainty Index will reduce CO2 emissions by 0.059 percent
- Increase in uncertainty leads to decrease in investment demand and economic growth, reducing CO2 emissions
  - Uncertainty may result in lower CO2 emissions in G7 countries
- Important to increase investment because it contributes to economic growth
- Growth must be environmentally sustainable and inclusive

Income Turning Point (ITP)

- ITP estimates threshold GDP per capita that starts decoupling of emissions of CO_2 as economic growth continues

- Estimated ITP is $47,843.73
  - Attainable for all G7 countries with the exception of Japan and Italy
  - Table 3

- First study to employ World Uncertainty Index to calculate slope of GDP per capita and square term

Income Turning Point for CO2 Emissions (2023 Prices)

G7 Countries	$47,844
Canada	$53,548
France	$47,001
Germany	$52,727
Italy	$38,326
Japan	$33,806
United Kingdom	$49,099
United States	$81,632

Summary and Conclusion

- Examine EKC relationship between CO_2 emissions and GDP per capita in G7 Countries in presence of uncertainty using panel data from 1960-2022

- Use quadratic income model and World Uncertainty Index

- Income turning point is estimated

- Results based on fixed-effects and random-effects models confirm existence of EKC relationship for CO_2 emissions in G7 countries

- Uncertainty may contribute to lower carbon emissions
  - Higher uncertainty associated with lower levels of investment and capital accumulation with negative implications for long-term growth, but favorable effects in terms of emissions
  - Tradeoff suggests investment is critical for economic growth but also imperative growth is environmentally sustainable and inclusive

- Income turning point is achievable for all countries with exception of Italy and Japan