Exploring the Relationship between Carbon Emissions and Economic Development: A Non-Parametric Analysis using Kaya's Identity

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Introduction

Over the past 30 years, political activities aimed at addressing climate change have increased, leading to the creation of the United Nations Framework Convention on Climate Change (UNFCCC) in 1992. While the Kyoto Protocol of 1997 helped reduce greenhouse gas emissions in some affluent nations between

2008 and 2012, it had limitations. In 2015, the Sustainable Development Goals (SDGs) were set, with targets aimed at economic-related environmental degradation. However, despite these initiatives, global warming persists, and more significant action is required. COP26, which encompasses 90% of the world's economy, has set new global paths towards net-zero carbon emissions. The 2015 Paris Agreement and COP26 greenhouse gas emission reduction pledges are late, with the COP27 expected to vow and act to increase global climate change adaptation investment.

India has made progress in addressing climate change, with a 21% drop in greenhouse gas emissions between 2005 and 2014. However, due to its ambitious industrial growth plans, 25% of its greenhouse gas emissions come from industrial power use and emission intensity. India's energy security may be threatened by the shift to renewable energy, which requires an adequate mineral supply, quick technological advancement, and new energy sources.

The industrial sector is crucial to meeting the COP26 decarbonization goal as it drives the economies of many industrialized and developing nations, including India. However, the industrial sector also contributes significantly to CO2 emissions, ecological damage, and health issues. To reduce environmental damage and promote sustainable growth, industries are seeking energy transition and energy-intensive production technologies. India's industrial and electricity usage over the past 20 years have worsened its environmental issues, with the energy sector emitting almost half of the country's CO2 and the industrial sector generating one-fourth. India needs to address its industrial sector's energy consumption to reduce its greenhouse gas emissions and mitigate the adverse effects of climate change.

Literature Review

Zhang (2009) divides China's carbon emissions into four categories using Kaya's identity: CO2 emission intensity, energy intensity, structural changes, and economic activities. The relationship between carbonization and industrialization is analysed by Narasingha Das (2023) utilizing the identification of Kaya. This study investigates the effect of industrial value-added (IGVA), population, energy intensity, and carbon intensity on India's CO2 emissions.

On the basis of the environmental Kuznets curve (EKC) hypothesis, several studies have investigated the relationship between environmental quality and GDPPC. When the economy grows and reaches a particular level of per capita income, it is anticipated that a U-shaped connection would emerge between GDPPC and CO_2 emissions. With further gains in economic growth, carbon emissions will begin to decline (Grossman and Krueger 1995; Dinda 2004; Stern 2004).

The findings of Zarco-Soto et al. (2021) demonstrated that Spain's CO_2 emissions are greatest in the most populous and densely populated cities. based on Liu et al. (2021), a 1% increase in China's urban population would result in a 0.3% decrease in CO_2 emissions per capita and an increase of approximately 1% in total CO_2 emissions.

Akram et al. (2020) supported the Environmental Kuznets Curve hypothesis by examining the effects of energy intensity on environmental degradation in 66 developing countries between 1990 and 2014. According to Hossain et al. (2022), India's pace of decarbonization is growing due to its rising energy intensity.

Objectives:

The objectives of our study are:

- Estimate Kaya’s identity based on the non-parametric regression approach.
- Try to use energy intensity and carbon intensity which were undiscovered controllable factors in the formation of Kaya's identity in India.
- To help the policymakers to understand the impacts of the different variables used for the study.

Methodology

To examine the nexus between the carbonization and industrialization under Kaya's identity I will be using Kernel Regression Using Nadarya Watson Estimator. We will be using the non parametric approach for estimation of the data. I will be using biannual data from 1995 to 2020 to examine Kaya's identity's carbonization-industrialization link. The study's datasets include notations, measurements, and sources.

Dependent Variables:Co2 emission

Independent Variables: Population, Per capita GDP, Energy Intensity, Carbon intensity, Industrialization

Econometric Methodology

We use Kernel Regression for non-parametric analysis using a data on India's variables. We will be using one of the kernel regression methods called Nadaraya-Watson Estimator.
The Kernel Density Function K(z) used is Gaussian.

$K(z)= \exp(-z^2/2)$

Y is the

dependent Variable

$m(x):=E[Y|X=x]=\int y f_{Y|X=x}(y)dy$

$=\int yf(x,y)dy/f_X(x)$

X is a

vector of explanatory variables

$f(x,y;h)=1n\ i=1nK_{h1}(x-X_i)K_{h2}(y-Y_i),\ \ h=(\ h_1,\ h_2)^T$

$f_X(x,h1)=1ni=1nK_{h1}(x-X_i),$

Where $K_H(z):=|H|^{-1/2}K(H^{-1/2}z)$

therefore ,

$m(x)=\int yf(x,y;h)dyf(x,h1)= \int y1n\ i=1nK_{h1}(x-X_i)K(y-Y_i)dy1ni=1nK_{h1}(x-X_i)$

$=$

$1n\ i=1nK_{h1}(x-X_i)\int yK(y-Y_i)dy1ni=1nK_{h1}(x-X_i)$

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$1n\ i=1nK_{h1}(x-X_i)Yi1ni=1nK_{h1}(x-X_i)$

$=i=1nK_{h1}(x-X_i)i=1nK_{h1}(x-X_i)Y_i = i=1nW_i Y_i$

Where $W_i= K_{h1}(x-X_i)i=1nK_{h1}(x-X_i)$, is the weights for the weighted average.

The resulting estimator is the Nadaraya-Watson Estimator.

The resulting estimates plot the relation between Co2 and different factors affecting it.

Hypothesis:

- Population is not a significant factor for co2 emission
- GDP percapita does not cause co2 emission
- Carbon intensity doesnot cause Co2 emission
- Industrialization doesnot cause co2 emission
- Energy intensity doesnot cause co2 emission

Variable Definition and sources

Series	Notation	source
Carbon emission	CO2	World development indicators
population	POP	
GDP-per capita	GDPPC	

Energy intensity	EI	
Carbon intensity	CI	
Industrial gross value added	IGVA	

Data Collection:

The data you have gathered for India contains a number of indicators that are essential to comprehending the country's economic and environmental performance.

CO2 emissions: This indicator represents the entire quantity of carbon dioxide emitted by all economic activities in India. Carbon dioxide is a greenhouse gas that contributes to global warming and climate change, and it is essential to monitor emissions in order to comprehend India's environmental impact.

Energy intensity: This indicator gauges the quantity of energy consumed by the Indian economy per unit of GDP. It provides insight into India's energy efficiency in producing economic output. A decrease in energy intensity indicates that India is utilising energy more efficiently.

Population: This indicator represents the total number of people living in India, and it is an important factor to consider when analyzing the country's economic and environmental performance.

Carbon intensity: This indicator measures the quantity of CO2 emitted by the Indian economy per unit of GDP. It indicates the amount of carbon dioxide emitted per unit of economic output. A decrease in carbon intensity indicates that India is emitting less CO2 per unit of economic output, as its carbon intensity is decreasing.

Industrial goods value: This indicator evaluates the overall value of India's industrial production, which includes manufacturing, mining, and construction. It provides a sense of the magnitude and significance of India's industrial sector.

GDP per capita: This indicator represents India's total economic output divided by the country's population. It provides a sense of how prosperous the average Indian is and how the country's economic development is affecting the populace.

The data on the above indicators was collected from the website of world bank data.https://data.worldbank.org/

The collected data is compiled in a spreadsheet inked below
Eco342_TermPaper_data

Summary Statistics

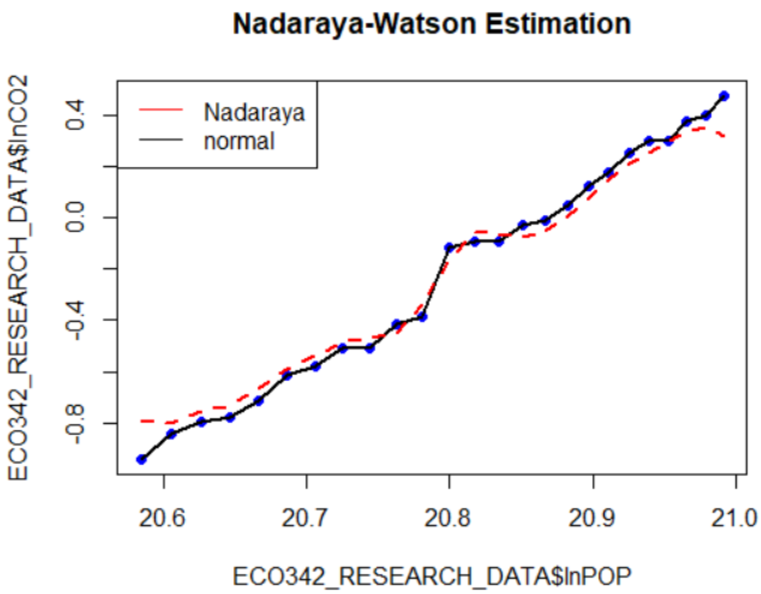
Variable	Obs	Mean	Std. Dev.	Min	Max
lnco2	25	-.1994082	.4456937	-.9416085	.4762342
lnpop	25	20.80596	.1254842	20.58452	20.99119
lnei	25	1.18008	.5651562	.255524	1.888622
lnci	25	.7753302	.0968208	.609708	.952026
lnigva	25	25.96947	.729688	24.99185	27.05823
lngdppc	25	6.421816	.5687038	5.708774	7.352354

Correlation Map

	lnco2	lnpop	lnei	lnci	lnigva	lngdppc
lnco2	1.0000					
lnpop	0.9945	1.0000				
lnei	-0.9480	-0.9473	1.0000			
lnci	0.9785	0.9833	-0.9663	1.0000		
lnigva	0.9608	0.9616	-0.9972	0.9701	1.0000	
lngdppc	0.9485	0.9478	-1.0000	0.9667	0.9973	1.0000

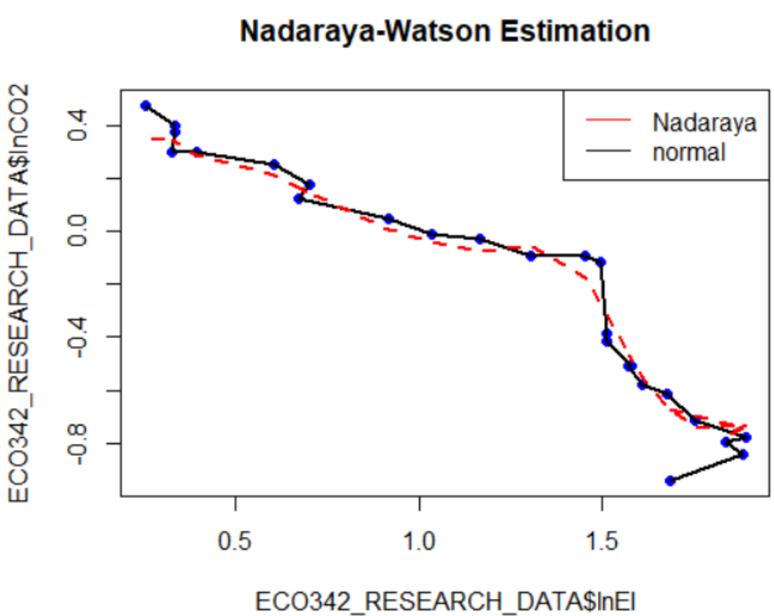
- CO2 emissions (lnco2) are strongly correlated with population (lnpop), energy intensity (lnei), carbon intensity (lnci), industrial goods value (lnigva), and GDP per capita (lngdppc).
- Population (lnpop) is highly correlated with all other variables, which is not surprising since it is a fundamental driver of economic and environmental change.
- Energy intensity (lnei) and carbon intensity (lnci) are strongly negatively correlated (-0.9480), meaning that as one of them decreases, the other tends to increase. This is logical, as reducing energy intensity typically involves shifting towards lower-carbon energy sources and reducing carbon intensity.
- Industrial goods value (lnigva) is strongly correlated with CO2 emissions, population, and GDP per capita, which suggests that industrial production is a major contributor to economic growth and environmental impact in India.
- GDP per capita (lngdppc) is strongly correlated with all other variables, which indicates that economic growth is intertwined with changes in population, energy use, carbon emissions, and industrial production in India.

Relation between CO2 emission and Population



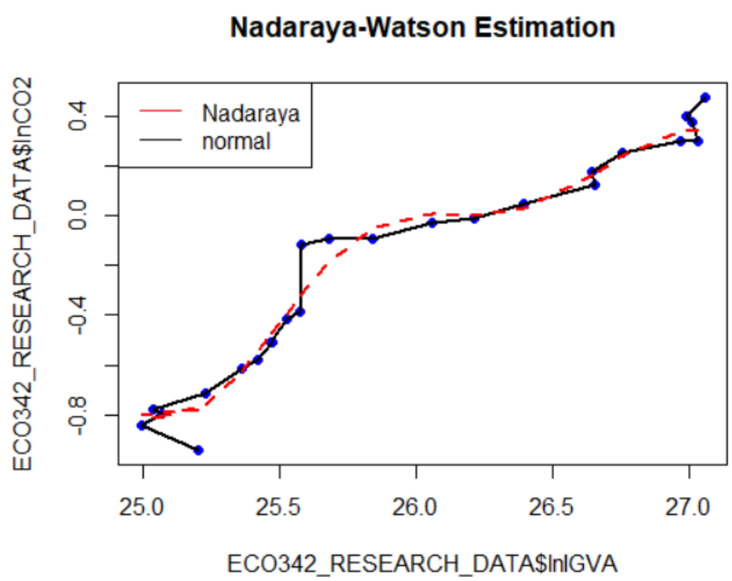
From 1990 to 2014, fossil fuel usage and CO2 emissions increased as the population demanded more energy, transportation, and infrastructure. As India's population grew, urbanisation and industrialization boosted energy and resource consumption. Population growth also leads to more farming, which emits greenhouse gases. Thus, population growth has driven CO2 emissions in India.

Relation between CO2 emission and Energy Intensity

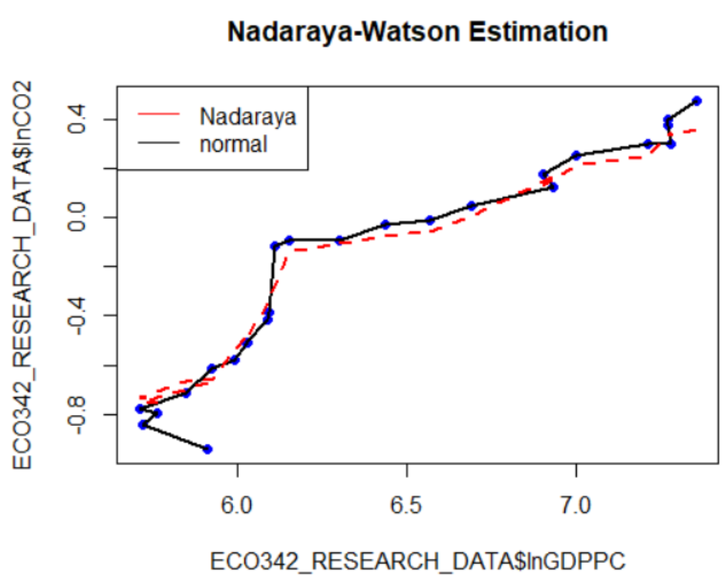


The reason for this negative relation between the variables as shown in the graph may be due to these reasons. Indian government launched several energy efficiency policies aimed at reducing energy consumption and promoting energy-efficient technologies in different sectors. For instance, the Bureau of Energy Efficiency (BEE) was established in 2002 to promote energy efficiency, reduce energy consumption and greenhouse gas emissions in different sectors. India implemented various carbon pricing policies, such as a carbon tax on fossil fuels, which incentivized the transition to cleaner energy sources and energy-efficient technologies.Indian economy has also seen a major shift towards service based sectors. All these are the major reasons for this shift.

Relation between industrialization and co2 emission

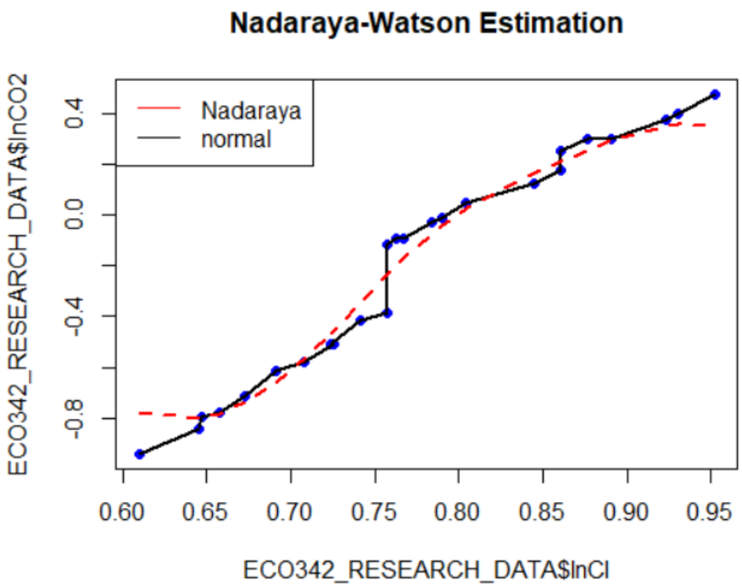


India is continuously expanding it’s industrial sector to fuel the countries economy and the growth of these industries has been fueled by the increased use of fossil fuels such as coal, oil, and natural gas for energy.



CO2 emissions and GDP per capita in India over the years shows a positive correlation, indicating that as the country's economy has grown, so too has its carbon footprint. However, the rate at which CO2 emissions increase with GDP per capita has been reducing over the years, indicating that India is gradually decoupling economic growth from carbon emissions.

Relation between Carbon intensity and CO2 emission



Carbon Intensity is directly proportional to the carbon emission. However, in recent years, the country has made efforts to reduce its carbon intensity and shift towards a more sustainable energy mix. There is a slight downward trend in carbon Intensity over recent years

R Codes:

```
>library(readxl)
> ECO342_RESEARCH_DATA <-
read_excel("C:/Users/jayla/OneDrive/Desktop/ECO342_RESEARCH_DATA.xlsx"
)
> View(ECO342_RESEARCH_DATA)
> library(kernlab)
> install.packages("kernlab")
> library(kernlab)
> nw_model <-
ksvm(ECO342_RESEARCH_DATA$lnPOP,ECO342_RESEARCH_DATA$lnCO2,
type = "eps-bsvr", kernel = "rbfdot", kpar = "automatic")
> nw_model
> y_hat<- predict(nw_model, data.frame(x =
ECO342_RESEARCH_DATA$lnPOP))
>
plot(ECO342_RESEARCH_DATA$lnPOP,ECO342_RESEARCH_DATA$lnCO2,
pch = 16, col = "blue", main = "Nadaraya-Watson Estimation")
```

```
>
>
lines(ECO342_RESEARCH_DATA$lnPOP,ECO342_RESEARCH_DATA$lnCO2,
col = "black", lwd = 2)
> lines(ECO342_RESEARCH_DATA$lnPOP, y_hat, col = "red", lwd=2,lty=2)
> legend("topleft", legend = c("Line 1", "Line 2"), col = c("red", "black"), lty = 1)
> nw_model <-
ksvm(ECO342_RESEARCH_DATA$lnEI,ECO342_RESEARCH_DATA$lnCO2,
type = "eps-bsvr", kernel = "rbfdot", kpar = "automatic")
> y_hat<- predict(nw_model, data.frame(x = ECO342_RESEARCH_DATA$lnEI))
> plot(ECO342_RESEARCH_DATA$lnEI,ECO342_RESEARCH_DATA$lnCO2,
pch = 16, col = "blue", main = "Nadaraya-Watson Estimation")
> lines(ECO342_RESEARCH_DATA$lnEI,ECO342_RESEARCH_DATA$lnCO2,
col = "black", lwd = 2)
> lines(ECO342_RESEARCH_DATA$lnEI, y_hat, col = "red", lwd=2,lty=2)
> legend("topright", legend = c("Nadaraya", "normal"), col = c("red", "black"), lty =
1)
> nw_model <-
ksvm(ECO342_RESEARCH_DATA$lnCI,ECO342_RESEARCH_DATA$lnCO2,
type = "eps-bsvr", kernel = "rbfdot", kpar = "automatic")
> nw_model
y_hat<- predict(nw_model, data.frame(x = ECO342_RESEARCH_DATA$lnCI))
> plot(ECO342_RESEARCH_DATA$lnCI,ECO342_RESEARCH_DATA$lnCO2,
pch = 16, col = "blue", main = "Nadaraya-Watson Estimation")
> lines(ECO342_RESEARCH_DATA$lnCI,ECO342_RESEARCH_DATA$lnCO2,
col = "black", lwd = 2)
> lines(ECO342_RESEARCH_DATA$lnCI, y_hat, col = "red", lwd=2,lty=2)
> nw_model <-
ksvm(ECO342_RESEARCH_DATA$lnIGVA,ECO342_RESEARCH_DATA$lnCO
2, type = "eps-bsvr", kernel = "rbfdot", kpar = "automatic")
> y_hat<- predict(nw_model, data.frame(x =
ECO342_RESEARCH_DATA$lnIGVA))
>
plot(ECO342_RESEARCH_DATA$lnIGVA,ECO342_RESEARCH_DATA$lnCO2,
pch = 16, col = "blue", main = "Nadaraya-Watson Estimation")
```

```
>
lines(ECO342_RESEARCH_DATA$lnIGVA,ECO342_RESEARCH_DATA$lnCO2
, col = "black", lwd = 2)
> lines(ECO342_RESEARCH_DATA$lnIGVA, y_hat, col = "red", lwd=2,lty=2)
> nw_model <-
ksvm(ECO342_RESEARCH_DATA$lnGDPPC,ECO342_RESEARCH_DATA$lnC
O2, type = "eps-bsvr", kernel = "rbfdot", kpar = "automatic")
> y_hat<- predict(nw_model, data.frame(x =
ECO342_RESEARCH_DATA$lnGDPPC))
>
plot(ECO342_RESEARCH_DATA$lnGDPPC,ECO342_RESEARCH_DATA$lnCO
2, pch = 16, col = "blue", main = "Nadaraya-Watson Estimation")
>
lines(ECO342_RESEARCH_DATA$lnGDPPC,ECO342_RESEARCH_DATA$lnC
O2, col = "black", lwd = 2)
> lines(ECO342_RESEARCH_DATA$lnGDPPC, y_hat, col = "red", lwd=2,lty=2)
```

Base paper:

Investigating the nexus between carbonization and industrialization under Kaya's identity: fndings from novel multivariate quantile on quantile regression approach Narasingha Das1 · Partha Gangopadhyay2 · Pinki Bera3 · Md. Emran Hossain4 https://pubmed.ncbi.nlm.nih.gov/36708470/

Reference papers:

Zhang J (2009) Energy flows in complex ecological systems: a review. J Syst Sci Complex 22:345–359. https://doi.org/10.1007/ s11424-009-9169-3

Grossman GM, Krueger AB (1995) Economic growth and the environment. Q J Econ 110:353–377. https://doi.org/10.2307/2118443

Zarco-Soto IM, Zarco-Periñán PJ, Sánchez-Durán R (2021) Infuence of cities population size on their energy consumption and CO2 emissions: the case of Spain. Environ Sci Pollut Res 28(22):28146–28167

Plagarism report

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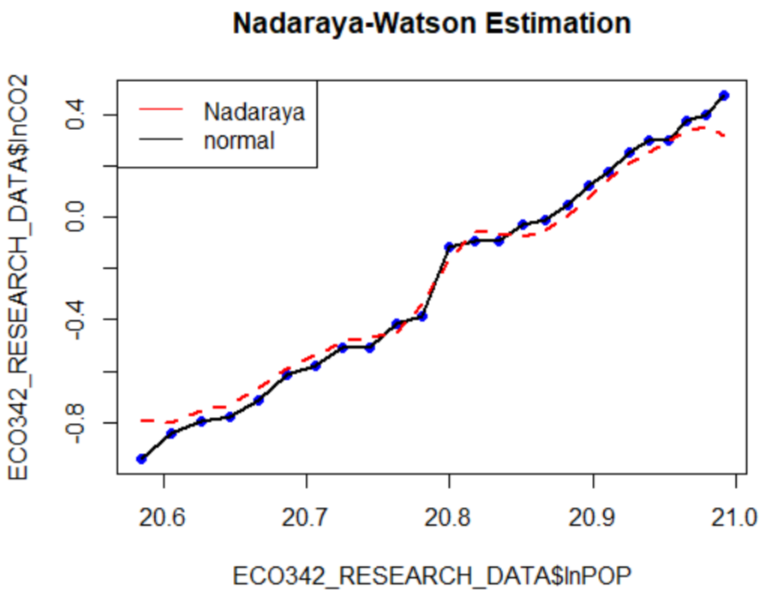
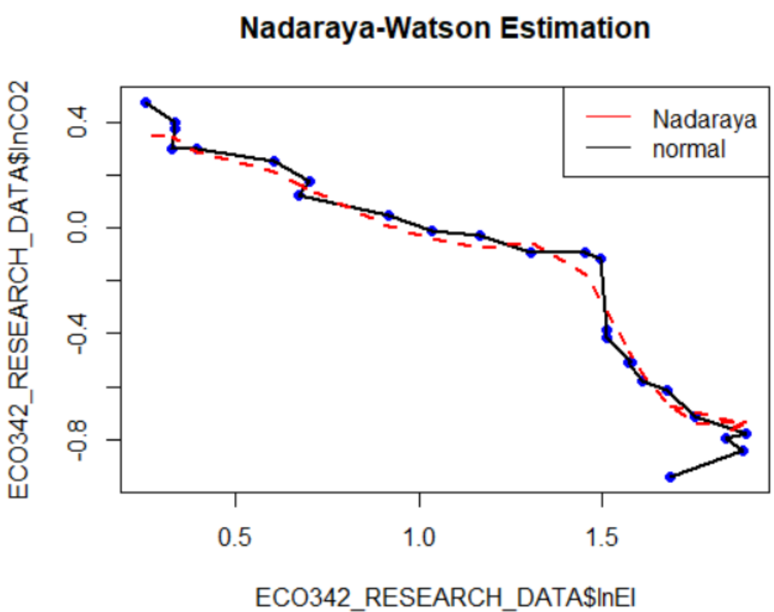
Relation between CO2 emission and Population



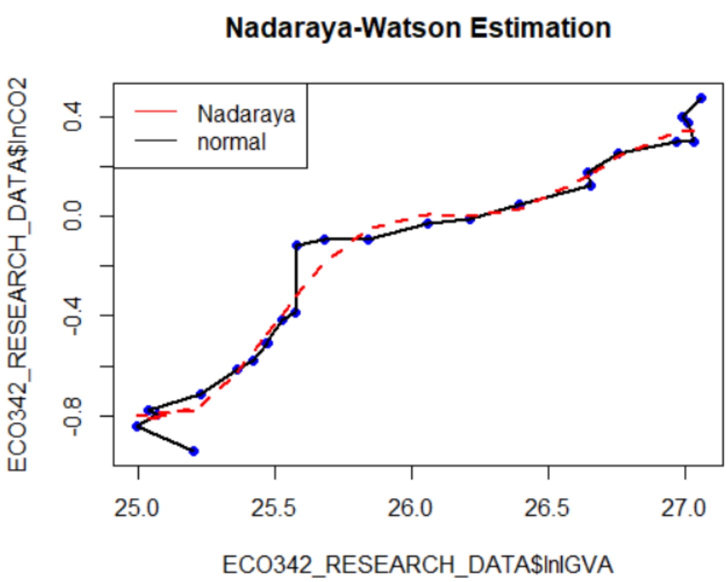
From 1990 to 2014, fossil fuel usage and CO2 emissions increased as the population demanded more energy, transportation, and infrastructure. As India's population grew, urbanisation and industrialization boosted energy and resource consumption. Population growth also leads to more farming, which emits greenhouse gases. Thus, population growth has driven CO2 emissions in India.

Relation between CO2 emission and Energy Intensity



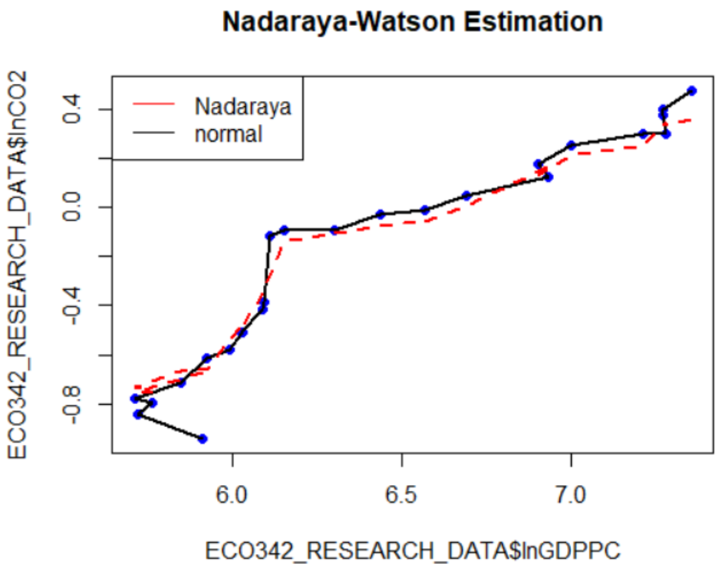
The reason for this negative relation between the variables as shown in the graph may be due to these reasons. Indian government launched several energy efficiency policies aimed at reducing energy consumption and promoting energy-efficient technologies in different sectors. For instance, the Bureau of Energy Efficiency (BEE) was established in 2002 to promote energy efficiency, reduce energy consumption and greenhouse gas emissions in different sectors. India implemented various carbon pricing policies, such as a carbon tax on fossil fuels, which incentivized the transition to cleaner energy sources and energy-efficient technologies.Indian economy has also seen a major shift towards service based sectors. All these are the major reasons for this shift.

Relation between industrialization and co2 emission



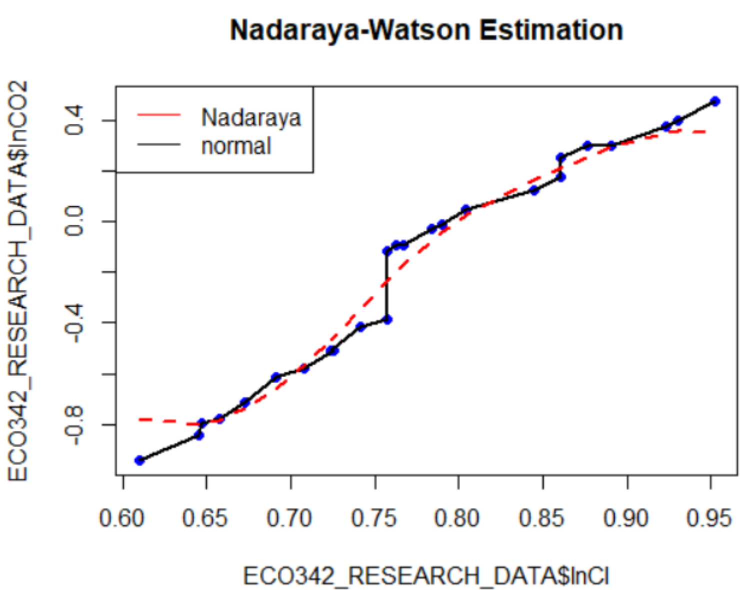
India is continuously expanding it’s industrial sector to fuel the countries economy and the growth of these industries has been fueled by the increased use of fossil fuels such as coal, oil, and natural gas for energy.

Relation between CO2 emission and GDP per capita



CO2 emissions and GDP per capita in India over the years shows a positive correlation, indicating that as the country's economy has grown, so too has its carbon footprint. However, the rate at which CO2 emissions increase with GDP per capita has been reducing over the years, indicating that India is gradually decoupling economic growth from carbon emissions.

Relation between Carbon intensity and CO2 emission



Carbon Intensity is directly proportional to the carbon emission. However, in recent years, the country has made efforts to reduce its carbon intensity and shift towards a more sustainable energy mix. There is a slight downward trend in carbon Intensity over recent years

R Codes

```
>library(readxl)
> ECO342_RESEARCH_DATA <- read_excel("C:/Users/jayla/OneDrive/Desktop/ECO342_RESEARCH_DATA.xlsx")
> View(ECO342_RESEARCH_DATA)
> library(kernlab)
> install.packages("kernlab")
> library(kernlab)
> nw_model <- ksvm(ECO342_RESEARCH_DATA$lnPOP,ECO342_RESEARCH_DATA$lnCO2, type = "eps-bsvr", kernel = "rbfdot", kpar = "automatic")
> nw_model
> y_hat<- predict(nw_model, data.frame(x = ECO342_RESEARCH_DATA$lnPOP))
> plot(ECO342_RESEARCH_DATA$lnPOP,ECO342_RESEARCH_DATA$lnCO2, pch = 16, col = "blue", main = "Nadaraya-Watson Estimation")
>
> lines(ECO342_RESEARCH_DATA$lnPOP,ECO342_RESEARCH_DATA$lnCO2, col = "black", lwd = 2)
> lines(ECO342_RESEARCH_DATA$lnPOP, y_hat, col = "red", lwd=2,lty=2)
> legend("topleft", legend = c("Line 1", "Line 2"), col = c("red", "black"), lty = 1)
> nw_model <- ksvm(ECO342_RESEARCH_DATA$lnEI,ECO342_RESEARCH_DATA$lnCO2, type = "eps-bsvr", kernel = "rbfdot", kpar = "automatic")
> y_hat<- predict(nw_model, data.frame(x = ECO342_RESEARCH_DATA$lnEI))
> plot(ECO342_RESEARCH_DATA$lnEI,ECO342_RESEARCH_DATA$lnCO2, pch = 16, col = "blue", main = "Nadaraya-Watson Estimation")
> lines(ECO342_RESEARCH_DATA$lnEI,ECO342_RESEARCH_DATA$lnCO2, col = "black", lwd = 2)
> lines(ECO342_RESEARCH_DATA$lnEI, y_hat, col = "red", lwd=2,lty=2)
> legend("topright", legend = c("Nadaraya", "normal"), col = c("red", "black"), lty = 1)
> nw_model <- ksvm(ECO342_RESEARCH_DATA$lnCI,ECO342_RESEARCH_DATA$lnCO2, type = "eps-bsvr", kernel = "rbfdot", kpar = "automatic")
> nw_model
y_hat<- predict(nw_model, data.frame(x = ECO342_RESEARCH_DATA$lnCI))
> plot(ECO342_RESEARCH_DATA$lnCI,ECO342_RESEARCH_DATA$lnCO2, pch = 16, col = "blue", main = "Nadaraya-Watson Estimation")
> lines(ECO342_RESEARCH_DATA$lnCI,ECO342_RESEARCH_DATA$lnCO2, col = "black", lwd = 2)
> lines(ECO342_RESEARCH_DATA$lnCI, y_hat, col = "red", lwd=2,lty=2)
> nw_model <- ksvm(ECO342_RESEARCH_DATA$lnIGVA,ECO342_RESEARCH_DATA$lnCO2, type = "eps-bsvr", kernel = "rbfdot", kpar = "automatic")
> y_hat<- predict(nw_model, data.frame(x = ECO342_RESEARCH_DATA$lnIGVA))
> plot(ECO342_RESEARCH_DATA$lnIGVA,ECO342_RESEARCH_DATA$lnCO2, pch = 16, col = "blue", main = "Nadaraya-Watson Estimation")
> lines(ECO342_RESEARCH_DATA$lnIGVA,ECO342_RESEARCH_DATA$lnCO2, col = "black", lwd = 2)
> lines(ECO342_RESEARCH_DATA$lnIGVA, y_hat, col = "red", lwd=2,lty=2)
> nw_model <- ksvm(ECO342_RESEARCH_DATA$lnGDPPC,ECO342_RESEARCH_DATA$lnCO2, type = "eps-bsvr", kernel = "rbfdot", kpar = "automatic")
> y_hat<- predict(nw_model, data.frame(x = ECO342_RESEARCH_DATA$lnGDPPC))
> plot(ECO342_RESEARCH_DATA$lnGDPPC,ECO342_RESEARCH_DATA$lnCO2, pch = 16, col = "blue", main = "Nadaraya-Watson Estimation")
> lines(ECO342_RESEARCH_DATA$lnGDPPC,ECO342_RESEARCH_DATA$lnCO2, col = "black", lwd = 2)
> lines(ECO342_RESEARCH_DATA$lnGDPPC, y_hat, col = "red", lwd=2,lty=2)
```

Base paper:

Investigating the nexus between carbonization and industrialization under Kaya's identity: fndings from novel multivariate quantile on quantile regression approach Narasingha Das1 · Partha Gangopadhyay2 · Pinki Bera3 · Md. Emran Hossain4 https://pubmed.ncbi.nlm.nih.gov/36708470/

Reference papers:

Zhang J (2009) Energy flows in complex ecological systems: a review. J Syst Sci Complex 22:345–359. https://doi.org/10.1007/ s11424-009-9169-3

Grossman GM, Krueger AB (1995) Economic growth and the environment. Q J Econ 110:353–377. https://doi.org/10.2307/2118443

Zarco-Soto IM, Zarco-Periñán PJ, Sánchez-Durán R (2021) Infuence of cities population size on their energy consumption and CO2 emissions: the case of Spain. Environ Sci Pollut Res 28(22):28146–28167

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