iJournals: International Journal of Social Relevance & Concern (IJSRC)
ISSN:2347-9698, ijournals.in/ijsrc
Volume 12 Issue 9, September 2024

The Externalities of Infrastructure Investment

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DOI: 10.26821/IJSRC.12.9.2024.120903

ABSTRACT

In this paper, I analyze the relationship between infrastructure investment, environmental degradation and. I first present their theoretical link through the lens of the theory of externalities; in particular, investment in infrastructure is associated with a positive externality since infrastructure is a public good, but both the usage and the construction of infrastructure pose negative environmental externalities. I synthesize the relatively disparate literature on this topic, before jointly estimating these externalities using cross-country data. I find that a 1% increase in infrastructure investments is associated with a 1.04% increase in average GDP, and a 0.77% increase in greenhouse gas (GHGs) emissions. I find that a 1% higher tax rate on energy dampens the association of such investments on GHGs.

Keywords: Infrastructure Investment, Public Goods, Environmental Externality, Economic Growth

1. INTRODUCTION

Infrastructural development is critical for catalysing economic growth. Infrastructural development projects such as transport, communication, and electricity networks support the expansion of the economy, and in doing so they provide the essential foundation for its functioning, productivity and increased efficiency. This is evident in the amount governments spend on infrastructure -- the U.S. spends 2.3 percent of GDP on infrastructure, European countries spend 5 percent on average and China spends about 8 percent [1].

Investing in infrastructural developmental programs not only leads to economic growth but also helps in improving the quality of life and the standard of living of the people. For instance, rural electrification projects in countries like India have been linked to improved education outcomes and better health, as they allow for better access to information and healthcare services. This helps increase the literacy rate, while also reducing social issues such as crime and child marriage. The advancement of infrastructure allows countries to gain more domestic and foreign investors. Countries like Singapore and the United Arab Emirates have successfully attracted global businesses by developing their infrastructure and positioning themselves as global trade hubs.

However, in addition to the economic and social benefits that infrastructural projects provide, they also give rise to two types of externalities -- negative production externalities and positive production externality. During the development (and usage) of infrastructural projects, the release of harmful pollutants like carbon monoxide, carbon dioxide, and sulphur oxide into the atmosphere is common, which leads to air pollution. The air pollution is the cause of the aforementioned negative production externality, which can be interpreted as the external cost that spills over onto third-parties who are uninvolved with the construction of said infrastructure. On the other hand, infrastructural development projects fall under the category of public goods, due to their significant social benefits. As a result, private firms do not tend to invest in infrastructure and the market fails to allocate resources to the production of such goods. This ambiguity and dual nature of investment in infrastructures that create a negative production externality as well as a positive production externality makes it hard to meet at a point where no stakeholders have to pay the cost. Effective policy measures, such as regulations, taxes on negative externalities, and subsidies for positive externalities, are essential to balance these effects and ensure that the overall impact of construction projects is positive for society.

To investigate the relationship between infrastructural investments, and the two types of externalities it creates, this paper uses publicly available data from OECD to perform cross-country regression analyses. I find that a 1% increase in infrastructure investment is associated with a 1.037% increase in GDP. I argue that this suggests a positive multiplier effect, generated by the positive externalities of infrastructural investment. Secondly, I find that a 1% increase in average infrastructure investment is associated with a 0.774% increase in average GHG, which is suggestive of the negative externalities arising from infrastructure projects, at least in the form of environmental air pollution. Finally, I that this positive association between infrastructural investments and air pollution is dampened in countries with higher tax rates on energy usage, which is an input in constructing infrastructure, as well as necessary for usage of said infrastructure.

Previous research has been conducted to understand the relationship between infrastructure development and the environmental, economic, and social impact it has. The literature considered in this paper examines how infrastructure investments cause negative production externality, and then separately how investments in infrastructural projects generate a negative production externality. Relative to those papers, this paper jointly examines both these externalities on a common dataset, and increases the external validity of its findings by using a cross-country dataset. Moreover, this paper investigates how taxation, a canonical solution to negative externalities, shifts the balance between these two externalities.

Section 2 presents the background theory, helping to establish the key theoretical framework of this paper. Section 3 reviews the literature on economic growth and the environment, externalities of investing in infrastructure and the role of taxation in mitigating the negative third-party impacts of infrastructure construction. Section 4 conducts the empirical analysis of the paper, followed by a conclusion of findings.

2. THEORETICAL BACKGROUND

An externality occurs when the actions of an economic agent gives rise to a negative or positive effect on a third party. A third party is an entity who is not part of the relevant transaction or whose interests are not taken into consideration. In this section, I discuss the two types of externalities which arise from the public (or private) sector decision to invest in infrastructure.

2.1 Environmental Externalities

The production of infrastructure, for example the construction of roads or bridges, creates environmental externalities. That is, they impose external costs on third parties who are not involved in the production (or consumption) of infrastructure. These are called negative production (consumption) externalities. These costs extend to the future selves of individuals or firms who produce and/or consume the infrastructure. There are many examples of environmental externalities created by infrastructure. The most direct is the clearing of forests and natural habitats to create space for such projects leading to a loss of biodiversity. During the construction of infrastructure such as roads and bridges, harmful pollutants like carbon monoxide, carbon dioxide and sulphur dioxide are released which leads to air pollution, which is another externality.

There have been many cases where the production and/ or consumption of infrastructure investments have been directly linked to environmental damages. In 2020, Papa New Guinea announced the Connect PNG project, a road network construction project aiming to build 16,000 kilometres of road. [2] find that the proposed network critically endangers 54 bio-diversity habitats across the country, and the associated logging to destroy over 5% of its primary forests.

2.2 Public Goods

Infrastructure projects, especially transport investments such as roads and bridges, are widely-considered public goods. Public goods have two key characteristics. They are *non-rivalrous*, which consumption by one person does not reduce the good's availability for another individual, and *non-excludable*, which means it is not possible to exclude an individual from using the good. In some cases, infrastructure projects can be made excludable, such as if there are tolls on a road, or rivalrous, such as through limits on volume of traffic, but such cases are the exception as opposed to the rule. One indicator that infrastructure projects are public goods is that they are often government-funded. Due to the free-rider problem private firms do not invest in infrastructure, goods as they are unable to charge a price by making it excludable. Hence, markets fail to allocate resources to the production of such goods.

When governments produce infrastructure by investing in them, it gives rise to a positive production externality. The third party who benefits from this externality are the people who can access and use these investments. For example, an initiative to build a road to improve connectivity by the government, would lead to increases individuals being able to commute more efficiently, minimizing the time spend they spend on road and allowing them to travel safely through reducing the risk of accidents. The individuals who benefit from this can be distinct to those involved in the production process.

These positive externalities are evident through cases in which infrastructure projects lead to improvements in living standards, above and beyond the benefit to the producer. For example, [3] estimate that road improvements in Mexico between 1986 and 2014 resulted in increased market access for rural areas, which in turn led to a 2.9% - 6.5% increase in employment. Similarly, new roads built in Peru between 2003 and 2010 contributed to about 4% increase in jobs in export-leading firms [4].

LITERATURE REVIEW

3.1 Economic Growth and Environmental Degradation

There is a long-standing literature which maps the causal relationship between economic growth, investments and environmental sustainability. [5], [6] and [7], provide comprehensive descriptions of different perspectives on this relationship. The approach taken in this earlier literature is to match theoretical insights with limited empirics, to test how economic growth affects the environment and the key investment strategies to promote economic growth.

[5] differentiates between future threats of global warming, versus current urban air pollution in developing countries, citing the need to solve issues of resource constraints for the latter, as it poses a more pressing threat to the welfare of millions of people. He claims that there is a mismatch between those who currently suffer from a degrading environment, versus those who stand to suffer from projected losses of un-sustainable growth, and the need not discount present welfare as highly as environmental policies seem to.

[7] wrote one of the most well-cited review papers since the turn of the century on this topic. He reviews the various posited theories between how economic growth can spoil the environment, and where future investment should target to minimize this trade-off. He debates whether it is energy-use, waste by-products or polluting the biosphere which poses the greatest threat, as well as whether increased, decreased or sustained economic activity is the way forward. He concludes that the environmental Kuznets curve is consistent with much of the work so far in this area.

In another review paper entitled 'Economics growth and the Environment: A review of Theory and Empirics', [6] develops four simple growth models to identify key features of investment for sustainable growth, which include: technological progress in abatement, intensified abatement, shifts in national output composition, and induced innovation. On the empirical side, they conclude that a relationship between the environment and economic growth is not well understood due to limited data to answer such a wide-scope of question.

A seminal citation in this literature is "Economic Growth and the Environment" by Gene M. Grossman and Alan B. Krueger [8]. This paper focuses on analyzing how economic growth impacts the environment by looking at the relationship between economic growth and four types of environmental indicators: urban air pollution, and the state of river oxygen regime in river basins, as well as decal and heavy-metal contamination of river basins. The authors use country-level information data on per capita GDP and environmental indicators to examine this relationship. Their results show that economic growth does not lead to a long-term continuous degradation of the environmental quality. Instead, there is an initial decline in environmental quality, across all four indicators, followed up by improvement for most indicators with turning points occurring before a country reaches a per capita income equivalent of 8000 USD.

While this literature provides valuable insight into theoretical takes on the relationship between investment, economic growth and the environment, its level of generality makes it hard to discern specific hypotheses and ways in which to test them. In what is to follow, I focus in on previous work on the growth and environmental implications of infrastructure investments. This literature takes on a more case-study approach, allowing for more detailed empirical results.

3.2 Environmental Production Externalities of Infrastructure

It is widely acknowledged that negative environmental externalities are generated both by infrastructure-based investments, and the usage of said infrastructure.

The most prolific theory on investments and its effects on the environment is the Environmental Kuznets Curve. This is usually depicted as inverted U-relationship between economic output per capita and some measures of environmental quality. Initially, as incomes and investment increases, pollution rises too, hitting a peak at some mid-level of income, before falling again as economic development becomes more sustainable in its progress. Reference [9] explores this, and alternative, theoretical explanations for the observed inverted U-shaped relationship between environmental degradation and per-capita income. To do this, they calibrate a theoretical model to the United States using unrelated information and simulating the model from a less developed initial condition to analyze the pollution-income relationship. Their paper concludes that while there is some evidence supporting the theory of a corner solution, the peak pollution level occurs at a significantly lower income level than as observed in the United States data. This suggests that the importance of the negative externality from infrastructure investment is most prolific among lesser-developed countries.

The research paper "Income growth and atmospheric pollution in Spain" by Jordi Roca and Mònica Serrano aims to analyze the relationship between income growth and nine atmospheric pollutants in Spain [10]. To do this, they adopt a detailed input-output approach and utilizes the Spanish National Accounting Matrix including Environmental Accounts (NAMEA) data for the nine pollutants. The authors conclude that despite the Environmental Kuznets Curve hypothesis, which suggests a decrease in environmental pressures with income growth the likes of which Spain has experiences, such a delinking between economic growth and emission levels has not occurred for most atmospheric pollutants in Spain. The results display that there has not been a significant reduction in atmospheric pollutants in Spain as a result of increasing income levels, suggesting that the negative externality does indeed persist despite development.

3.3 Infrastructure as a Public Good

As mentioned previously, there are two effects of investments in infrastructural projects -- a negative production externality and a positive externality. This section of the literature review focuses on how infrastructural projects can cause a positive externality.

The research paper entitled "Valuing Public Goods More Generally: The Case of Infrastructure Structure" by David Albouy and Arash Farahani, focuses on the valuation of public infrastructure [11]. The authors generalize the Roback model, incorporating labor and technology in non-traded production, accounting for federal fiscal externalities, and utilizing population changes to enhance the measurement of quality-of-life improvements. They find that public infrastructure is twice as valuable as found in [12], under-scoring the importance of incorporating non-market positive externalities of infrastructure. This is especially true for firms, but also for households as long as the costs of moving location is high.

[13] focuses on analyzing the indirect spillover effects of infrastructure on India's registered manufacturing sector and its impact on productivity growth. They claim that empirical evidence on the positive externalities of infrastructure is best found in industry-specific analyses in primary and secondary sectors. Their paper uses a fixed-effect approach to estimate the parameters of the infrastructure-productivity link using a sample of 320 observations over 20 years and 16 states. The research suggests that there are externalities from infrastructure that contribute to productivity growth in India's modern manufacturing industry. Indeed, in the 20 years from 1972 to 1992, the growth of road and electricity-generating capacity is found to account for nearly half the growth of the productivity residual of India’s registered manufacturing. This implies that there is a potential under-investment in such infrastructure.

3.4 Taxing Infrastructure Use

The empirical literature on taxing the use of infrastructure is relatively nascent.

[14] examine the effects of transport taxes, economic growth, and fossil fuel energy consumption on air pollution using the Environmental Kuznets Curve (EKC) hypothesis framework. To do this, they use a panel data analysis of countries representing cross-section units to investigate the relationship between different variables. The results of their study conclude that taxation does not help in reducing air pollution levels caused by activities correlating to economic growth; indeed, transportation tax leads to an increase in air pollution.

[15] explore the role of road transport taxation in addressing transport-related air pollution and the associated externalities. The authors employ a theoretical framework to analyze the potential contributions of taxation in regulating transport-related externalities and conclude that the existing fiscal instruments only approximate the externalities associated with road transport. They suggest a comprehensive policy mix to better align tax incentives with social costs. In a similar vein, [16] present a case for implementing vehicle characteristics taxes as a means to reduce pollution from road transport. They claim that this addresses the external costs associated with vehicle emissions. They undertake an analytical examination of data on the American vehicle stock to assess the effectiveness of vehicle characteristics taxes. The results indicate that vehicle characteristics taxes, if combined with fuel taxes, can lead to more economically efficient outcomes compared to other measures in reducing the negative externality caused.

With the backdrop of this literature, I now move on to present the empirical results from this study.

4. EMPIRICAL ANALYSIS

4.1 Hypotheses

The empirical goal of this research paper is to quantify correlations between infrastructure investments, economic growth and environmental degradation, to shed light on the dual externalities created when a country invests in its infrastructure. In particular, cross-country data on economic output, air pollution, infrastructure investment and taxes on infrastructure usage will be analysed, to test whether I find patterns consistent with the following three hypotheses.

H1: An increase in infrastructure investment leads to a more than one-to-one increase in economic output.

Hypothesis 1 refers to infrastructure investment having a multiplier effect, through its positive externalities. Mechanically, an increase in infrastructure investment increases GDP, as investments are one component of a country’s economic output. H1 wishes to test whether an increase in infrastructure investment leads to an increase in economic output larger than the investment outlay, which would indicate positive externalities. As discussed in Section 3.3, this is indeed what happened in India, where living standards of third-parties benefitted from infrastructural projects.

H2: An increase in infrastructure investment is associated with negative impacts on the environment.

Hypothesis 2 is consistent with previously discussed evidence from Spain, where investment in infrastructural projects led to worsening air quality.

H3: Taxing the investment in infrastructure dampens the negative environmental impacts from investing in the infrastructure in the first place.

The final hypothesis is a test of whether taxing the investment in infrastructure is effective in dampening the negative environmental consequences of investing in it. Pigouvian tax theory states that this should be the case, as long as the size of the tax is approximately equal to the marginal negative externality caused by investing in infrastructure. I examine whether, across countries, this is what happens in practice.

4.2 Data

The data for this analysis is taken from the database of the OECD, the Organization for Economic Co-operation and Development. In this sub-section, I describe each of the datasets and variables used to test the three hypotheses described in Section 4.1. Note, all described data is obtained at the country level.

The first variable is investment in infrastructure. In particular, transport infrastructure investments and maintenance spending are captured. The focus is specifically on land infrastructure, namely roads. Data are collected from Ministries of Transport, national statistical offices and other institutions designated as the official data source. The original data is reported in national currencies, but the OECD reports it in current Euro prices. For analysis, this figure is further converted to US dollars, for uniformity.

The measure of economic output used is Gross Domestic Product. GDP measures the monetary value of final goods and services—that are bought by the final user—produced in a country in a given period. It counts all of the output generated within the borders of a country. There are three methods of calculating GDP: the output approach, the income approach, and the expenditure method. This paper will be using the value of GDP found through the output method. The output approach to calculating GDP sums the gross value added of various sectors, plus taxes and less subsidies on products. The original data was collected in Euros and national currencies, but converted to US dollars.

While there are many candidate variables I could have chosen to capture environmental degradation, I chose total greenhouse gas (GHG) emissions for two reasons. The first is that it is a comprehensive measure of air pollution, which includes: carbon dioxide, methane, and nitrogen oxide. Secondly, since the type of investment I am interested in is transport infrastructure, air pollution is the most natural measure of the environmental externalities of building roads. The variable I use is GHGs measured in tonnes of CO_2 equivalent, as emitted from transportation and storage activities by residents of a given country.

Finally, for testing H3, I need a measure of taxes levied on the use of infrastructure investments. I select the Effective Energy Rate (EER), which is the sum of fuel excise taxes, carbon taxes, electricity excise taxes, and tradeable permits that effectively put a price on energy use. The Net EER equals the EER minus fossil fuel and electricity subsidies that decrease pre-tax energy prices. Since this variable provides an incentive to commercial builders to cut down their carbon emissions, it mitigates the externality caused by investments in infrastructure, as desired. It also captures taxes on the use of infrastructure, which has previously been shown to dampen this same negative externality.

The advantage of the data used in this paper is that it is publicly-available, and at the country-level. This ensures the focus is not too narrow, and there is external validity to the findings. Moreover, the availability of the data ensures the findings of this paper can be reproduced and built upon. The disadvantage is that the nature of the data only allows for a correlational study, since there is no exogenous variation to be used for causality.

4.3 Methodology

To test the three hypotheses I describe, the methodology I use is regression analysis. I use three linear regressions, which I describe below.

To test hypothesis 1, I estimate the following equation:

$$\log(GDP_i) = \alpha + \beta \log(INFINV_i) + e_i \quad \ldots\ldots\ldots(1)$$

where GDP_i is the GDP of country *i*. Equation (2) is also estimated using Ordinary Least Squares (OLS) estimation. A sufficient condition for Hypothesis 2 (H2) to be true is that the coefficient on $INFINV_i$ (β) be greater than 1. This would mean that a 1% increase in infrastructure investments leads to a more than 1% increase in GDP, where the levels of the latter are larger than the former for each observation in the data.

To test hypothesis 2, I estimate the following equation:

$$\log(GHG_i) = \alpha + \beta \log(INFINV_i) + e_i \quad \ldots\ldots\ldots(2)$$

where GHG_i is the GHG emissions of country *i* and $INFINV_i$ is the infrastructure investment of country *i*. Equation (1) is estimated using Ordinary Least Squares (OLS) estimation. Hypothesis 1 (H1) dictates that the coefficient on $INFINV_i$ (β) be less than zero.

Finally, to test H3, I estimate the following equation:

$$\log(GHG_i) = \alpha + \beta \log(INFINV_i) + \delta EER_i + \gamma \{\log(INFINV_i) * EER_i\} + e_i \quad \ldots\ldots\ldots(3)$$

where EER_i is the Effective Energy Rate of country *i*. Equation (3) is estimated using Ordinary Least Squares (OLS) estimation. For H3 predicts that the coefficient on the interaction between EER and the log of infrastructure investment spending be less than 0, while the coefficient on infrastructure investment be greater than zero. This would mean that a higher EER dampens the positive correlation between infrastructure investment and GHG emissions.

The software *R* (Version 4.3.1) is used for estimating the regressions for each hypothesis. The *Estimatr* package was used for OLS estimation, while the *LMtest* package is used to conduct statistical significance tests.

4.4 Results

Table 1 displays results from the three regressions outlined in Section 4.2, which test H1, H2 and H3.

The first column displays the results from estimating Equation (1) using Ordinary Least Squares (OLS). The coefficient on average infrastructure investments is 1.037, with a standard error of 0.052. This can be interpreted as saying that a 1% increase in average infrastructure investment is associated with a 1.037% increase in average GDP. Part of this association is mechanical in that public investments are a component of GDP. However, given that the infrastructure spending is no more than 2.2% of GDP for all countries in our sample, there is a component of this association that potentially arises from the positive externalities of investing in infrastructure. This could include: increased access to consumer markets, ability to commute to work etc. This number is economically significant and implies a similar correlation between infrastructure and economic growth as found in [17]. The association I find is also significant at the 1% level; this means one can be quite confident that the association is not zero, even under the most stringent of significance levels.

Table 1. Regression Results

	Average GDP	**Average GHG**	**Average GHG**
Average Infra. Inv.	**1.037*** (0.052)**	**0.774*** (0.085)**	**1.048*** (0.138)**
Tax Rate	-	-	0.540*** (0.280)
Average Infra. Inv. * Tax Rate	-	-	**-0.024* (0.012)**
Constant	9.463*** (1.145)	-0.107 (1.794)	-6.228* (3.180)
R^2	0.8828	0.7689	0.7922
Obs.	43	31	28

The second column displays the results from estimating Equation (2). The coefficient on infrastructure investments is 0.774, with a standard error of 0.085. This can be interpreted as saying that a 1% increase in average infrastructure investment is associated with a 0.774% increase in average GHG. This association is sizeable, when the average per-capita carbon footprint of infrastructures in industrialized countries is (53 (±6) tons of CO_2), which is approximately 5 times larger than that of developing countries (10 (±1) tons of CO_2) [18]. The association found is significant at the 1% level; this means that the correlation is not zero at least.

The final column augments the regression presented in column 2 by adding two more independent variables: the tax rate on transport use and the interaction between infrastructure investments and said tax rate. This regression is given in Equation (3). Reassuringly, the association between infrastructure investment and greenhouse gases is still positive and statistically significant at the 1% level. If anything, the magnitude of this association is 50% larger than in column 2. Most interesting though is the negative coefficient on the interaction term between infrastructure investment and tax rate energy. The coefficient may be interpreted as saying that a 1 percentage point increase in the tax rate on transport dampens the association of infrastructure investment with greenhouse gases by 0.024%. This suggests that counteracting the negative environmental externality of infrastructure investments is possible, and seems to work, through imposing a tax on the construction of the infrastructure, although the dampening effect is smaller than one may expect. This result is also statistically significant, although only at the 10% level – this could reflect lower precision due to fewer observations available for the final regression.

In summary, the correlations I find in the data suggest that the hypotheses in Section 4.2 do indeed hold. Note, this conclusion is tentative since the analysis is not causal, but nevertheless are an important contribution to understanding the dual externalities arising from the choice to invest in infrastructure. An interesting avenue for future research is to test H1, H2 and H3 using some causal variation, such as a change in tax rates or an IMF loan for infrastructure building in a developing country.

5. CONCLUSION

To conclude, this paper provides three key findings. The first is that infrastructure investments across different countries are associated with a public good effect, or a positive production externality – a 1% increase in infrastructure investment spending is correlated with an increase in economic output of 1.04%, which exceeds simply the mechanical effect of the investment outlay itself. Secondly, as expected, a 1% higher level of infrastructure investment correlates with a 0.77% increase in total greenhouse gas emissions, which indicates the negative environmental production externalities of these investments. Finally, in countries where energy, which is an input both to the construction and usage of infrastructure, is taxed more heavily, the negative environmental impact of these investments are dampened. The case of infrastructure investments highlights a more general trade-off between We see that there is a tradeoff two key objectives – economic growth and environmental sustainability. While policy, such as taxation, could be one avenue to attenuate the tradeoff, future avenues of research should focus on the combination of policy instruments which can maximize the positive externalities of infrastructure investment, while minimizing the negative environmental ones.

6. ACKNOWLEDGMENTS

I would like to express my gratitude towards Sreevidya Ayyar, who guided me throughout this journey.

7. REFERENCES

[1]. Fay M, Han S, Lee HI, Mastruzzi M, Cho M. Hitting the Trillion Mark -- A Look at How Much Countries Are Spending on Infrastructure. World Bank Policy Research Working Paper. 2019 Feb pp.1(8730).

[2]. Alamgir M, Sloan S, Campbell MJ, Engert J, Kiele R, Porolak G, Mutton T, Brenier A, Ibisch PL, Laurance WF. Infrastructure expansion challenges sustainable development in Papua New Guinea. PLoS One. 2019 Jul 24; 14(7):0219408.

[3]. Blankespoor B, Bougna T, Garduno Rivera R, Selod H. Roads and the geography of economic

activities in Mexico. World Bank Policy Research Working Paper. 2017 Oct 26(8226).

[4]. Martincus CV, Carballo J, Cusolito A. Roads, exports and employment: Evidence from a developing country. Journal of Development Economics. 2017 Mar 1;125:21-39.

[5]. Beckerman W. Economic growth and the environment: Whose growth? Whose environment?. InGrowth, the Environment and the Distribution of Incomes 1995 Jan 1 (pp. 275-290). Edward Elgar Publishing.

[6]. Brock WA, Taylor MS. Economic growth and the environment: a review of theory and empirics. Handbook of economic growth. 2005 Jan 1;1:1749-821.

[7]. Panayotou T. Economic growth and the environment. Economic survey of Europe. 2003 Mar 3:45-72.

[8]. Grossman GM, Krueger AB. Economic growth and the environment. The quarterly journal of economics. 1995 May 1;110(2):353-77.

[9]. Bartz S, Kelly DL. Economic growth and the environment: Theory and facts. Resource and energy economics. 2008 May 1;30(2):115-49.

[10]. Roca J, Serrano M. Income growth and atmospheric pollution in Spain: an input–output approach. Ecological Economics. 2007 Jun 15;63(1):230-42.

[11]. Albouy, David, and Arash Farahani. Valuing public goods more generally: The case of infrastructure. 2017: pp. 17-272.

[12]. Haughwout AF. Public infrastructure investments, productivity and welfare in fixed geographic areas. Journal of public economics. 2002 Mar 1;83(3):405-28.

[13]. Hulten CR, Bennathan E, Srinivasan S. Infrastructure, externalities, and economic development: A study of the Indian manufacturing industry. The World Bank Economic Review. 2006 Jan 1;20(2):291-308.

[14]. Aydin M, Bozatli O. Do transport taxes reduce air pollution in the top 10 countries with the highest transport tax revenues? A country-specific panel data analysis. Environmental Science and Pollution Research. 2022 Aug;29(36):54181-92.

[15]. Crawford I, Smith S. Fiscal instruments for air pollution abatement in road transport. Journal of Transport Economics and policy. 1995 Jan 1:33-51.

[16]. Johnstone N, Karousakis K. Economic incentives to reduce pollution from road transport: the case for vehicle characteristics taxes. Transport Policy. 1999 Apr 1;6(2):99-108.

[17]. Timilsina GR. Financing climate change adaptation: International initiatives. Sustainability. 2021 Jun 8;13(12):6515.

[18]. Müller DB, Liu G, Løvik AN, Modaresi R, Pauliuk S, Steinhoff FS, Brattebø H. Carbon emissions of infrastructure development. Environmental science & technology. 2013 Oct 15;47(20):11739-46.

8. APPENDIX 1 – R CODE

```
## ADITI ECONOMICS PROJECT - ANALYSIS ##

rm(list = ls()) # clears R workspace

#libraries:

library(haven)

library(sandwich)

library(lmtest)

# set working directory:

setwd("…")

# load data:

df <- read_dta("REGRESSION.dta")

# ANALYSIS #

# regression 1:

reg1 <- lm(log(AVG_GDP) ~ log(AVG_INF),data = df)

coeftest(reg1, vcov = vcovHC(reg1, type="HC1"))

# A 1% average increase in infrastructure spending is associated/correlated with a 1.04% increase in GDP.

# regression 2:

reg2 <- lm(log(AVG_GHG) ~ log(AVG_INF),data = df)
```

coeftest(reg2, vcov = vcovHC(reg2, type="HC1"))

A 1% average increase in infrastructure spending is associated/correlated with a 0.77% increase in GHG emissions.

regression 3:

df$ENERGY_INF = df$ENERGY * log(df$AVG_INF) # create new variable which multiplies tax rate and infrastructure spending

reg3 <- lm(log(AVG_GHG) ~ log(AVG_INF)+ENERGY+ENERGY_INF,data = df)

coeftest(reg3, vcov = vcovHC(reg3, type="HC1"))

For a country with a certain level of infrastructure spending, a 1% increase in their environmental tax on road use decreases infrastructure spending by 0.024%.