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The Impact of Foreign Direct Investment on China's Carbon Emissions

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Abstract

This research delves into how international direct investment from overseas affects carbon emissions within the borders of China, taking into account an array of economic and ecological elements. The investigation scrutinizes information from 1990 until the present year to explore the interconnections between foreign investment inflows, energy intake, expansion of urban regions, technological evolution, and greenhouse gas emissions. We employed econometric methods for instance ridge regression examination. The approach embraces precise statistical procedures such as the KPSS trial for stability, the Johansen cointegration test for long haul connections, and Lasso regression for variable selection and regularization. The conclusions demonstrate that higher amounts of foreign capital (FDI) entering the nation and urban development significantly amplify carbon emissions.

In a similar fashion, technological enhancements fail to curb emissions as hoped, underscoring the importance of sustainable urban planning and reallocating assets to eco-friendly technologies. This research also considered the interplay between various economic variables and their collective impact on carbon emissions over time. The findings offer insightful perspectives for policymakers seeking to facilitate foreign investment while prioritizing environmental sustainability.

Keywords: Foreign Direct Investment, Carbon Emissions, Urban Development, Technological Evolution.

1. Introduction

China's extraordinary journey was marked since the reform and opening-up policy in 1978 with massive Foreign Direct Investment (FDI) inflow during this age of globalization, and progress. This increase in FDI has also fueled the advancement of China to world's number 2 economy. The specific problem the unparalleled economic success poses, however, is this: Among the most urgent concerns is a sharp rise in carbon pollution, endangering local and planetary environmental well-being. The estimates are important for policy makers in China where the need to achieve decoupling of economic growth from pollutants emissions is widely supported.

These efforts are more than mere examples of academic inquiry, however; they tackle the very issue that motivates so much current work in China: environmental and economic catastrophe. Since the planet is grappling with issues of climate change, analyzing to what extent foreign direct investment has an impact on carbon emissions would be very substantial. How can China manage this relationship in a way that would offer invaluable lessons for long-term economic development and enhance global status? The above analysis is aimed at comprehensively understanding the relationship between air pollution and economic growth so that in future, it may help policy-makers to develop policies in China which could see this emerging economy continue its path of economic high-growth hand-in-hand with environmental stewardship, thus setting an example for other growing nations. To support a "global opening-up" and try to achieve the balance between "new foreign investment introductions," China began establishing global economic contacts with an initiative called: “Belt and Road. By utilizing historical images of the Silk Road, it hopes to develop beneficial commercial ties with the countries that surrounded the original Silk Road. It also strives to unite people with similar views who value political cooperation, economic integration, and cultural inclusion. As of May 2022, China had signed more than 200 agreements for partnership with 150 nations and 32 international organizations to build the "Belt and Road." Economic cooperation between China and the nations along the route has developed and deepened due to the ongoing "Belt and Road" program, and social and economic development has been rapid (Tang et al., 2022).

In 2021, China made non-financial direct investments in nations along the "Belt and Road" worth USD 20.3 billion, a 14.1% increase over the previous year. The host country's economic development has benefited positively (Green et al. Center, 2021). Global warming has been one of humanity's most pressing concerns in recent decades. Previous studies have established that carbon dioxide (CO2) emissions have a significant impact on the occurrence of global warming. Given the increased economic growth, there has been a significant emphasis on reducing carbon dioxide emissions in the countries along the route. China has made significant investments in countries participating in the "Belt and Road" program, aiming to improve infrastructure and promote industrial growth. However, the importance of resources and environmental issues in the route's neighboring countries is increasing. It is difficult to reduce global warming because the "Belt and Road" region includes half of the top 10 carbon-producing countries. As a result, China's "Belt and Road" program has been widely criticized for depleting resources, shifting production capacity to developing nations, and harming their environments (Green et al. Center, 2020; Nedopil Wang, 2023). These unsubstantiated claims hamper the "Belt and Road" program.

China has extra capacity, yet this "overcapacity" may not be low-carbon or high-quality. China's outward foreign direct investment (OFDI) is critical in achieving shared development with the nations bordering the route. Given the preceding findings, we investigated how China's OFDI affects nations' carbon emissions along the route. We were particularly interested in whether China's "Belt and Road" plan increased carbon emissions in the countries along the path (You et al., 2022; Hou et al., 2021).

This study is derived to seek whether China carbon emissions do respond with foreign direct investment (FDI) started from 1990 until the year of 2020. These are the precise goals:

As China brought in large amounts of FDI, and emitted a lot since such profits are now connected with emissions monitoring between home and host economies — that is there is formal policy reaction from several countries to reduce carbon leakage (i.e. trade induced increase EU regional CO2 emission on imported goods)p, exploring the causal relationship between Foreign Direct Investment(FDI) inflow impact per capita CO2 Emissions serves as very important channel through environmental mechanism effected by FPIs direct &indirect implications over environment less efficient activities across Chinese boundary staff prior section theoretical overview). Therefore, this study further enhances understanding surrounding how the environmental connotations of FDI) as one crucial element underpinning economic globalization), can intertwine with realities on a ground in one of the important economies (Ding et al., 2023). In addition, from the perspective of energy-environment nexus analysis, it is necessary to explore how much primary energy consumption can affect carbon emissions in China. Drawing on this relationship, the present study (Zhao et al., 2023) examines how energy use influences China's carbon emission path and provides a policy proposal to deal with it. In this section, the analysis between GDP per capita nor urban population percentage and CO2 emissions is conducted in order to explore how demographic as well economic factors shape China's carbon emissions. This is important to know as reducing carbon emissions, by strategising according to economic and demographic changes are one of the fundamental aspect in environmental economics and policy (Zhang et al., 2023). Second, studying how technological progress affects carbon emissions can tell us whether the way we generate technologies has a chance of keeping overall global warming more modest (something particularly important in discussions about climate change mitigation and sustainable development) This is important to advance an understanding of the potential role that technology might play in addressing environmental concerns when it comes to examining the impact of technologies, or researching particularly R&D expenditure on carbon emissions (Han et al., 2023).

2. Literature Review

Foreign direct investment has been obviously stimulated in international business and economics literatures, because of its meaningful role on the evolution tracks of host nations. This literature review carefully considers the impacts of FDI on a wide range of factors and explores its duel roles in economic development as well as environmental sustainability. Although a review of the literature has shown that FDI can bring economic benefits, through capital flows and technology transfers as well as employment creation in host countries; this is not always good news for life on Earth — forgotten by scholars too.

To address the above gap, in this paper we carry out a detailed review of literature that deals with related concepts and summarizes current findings to establish what is known about how FDI might be linked with growth along side impacts associated environmental norms and practices. Consistent with the efforts of (Abdouli et al., 2017), this review also reviewed a number of studies to understand how FDI contributes financial success for host countries but at the same time creates myriad challenges and opportunities to promote environmental stewardship. As such, we intend to provide a nuanced view which recognizes the financial imperatives of FDI and simultaneously examines its responsibility towards environmental concerns in order to encourage new research into how FDI fits within global finance today.

2.1 FDI and Its Impact on Host Country Development

According to Dunning and Lundan., (2008) foreign direct investment is a place where it serves as an imperative stream of capital and modernization in developing countries. Increased economic growth — attracts foreign direct investment which is known to promote investment, innovation and provide new employment opportunities(Alfaro et al., 2004) Furthermore, by promoting cleaner production practices and stricter environmental regulations in host countries (Puck et al. 2013), FDI can be environmentally beneficial as well. Indirect Effects FDIs can enhance many host(states) with little diversification of their economies, like investment in infrastructure. Foreign investors can involve new funds in order to establish business, provide the corporation with inflow of working capital and update the industrial facilities that improves economic performance and stimulates employment (Doytch & Uctum). Second, inward FDI could lead to innovation as foreign investors bring effective operating practices established in the home country segros of their companies thorough know-how agglomeration within subsidiaries (De Beul and Duanmu 2012), leading higher productivity operationally unless new products or services are produced in host countries. Finally, due to profit-driven reasons, FDI might help in increasing employment when new jobs are created by foreign investors for local residents within the host country which may lead towards increased profitability that further contributes to reduced unemployment (Angizi et al., 2022; Zuo et al., 2023).

2.1.1 Adverse Environmental Effects of FDI

But as FDI promotes economic development, it has been implicated in environmental issues. According to (Ali et al. 2022); on the one hand, it is argued that FDI might lead to an increase in environmental quality through technology spillovers (Chadefaux et al. 2018), while empirical evidence shows a range of negative effects associated with FDI and leading to pollution or ecosystem degradation by greenhouse gas emission, deforestation Or reduction of biodiversity(Mayda & Rodrik 2005). Springer cites research (Christoforidis & Katrakilidis, 2022), which found that FDI inflows typically cause host countries to use more energy and suffer environmental harm, especially in the lack of efficient ecological control. Research on ASEAN countries using dynamic panels from 1981 to 2010 found that FDI tends to increase CO2 emissions, supporting the pollution haven theory, according to an IDEAS article.
Abdouli and Hammami (2017): An EconPapers-featured study examined the impact of FDI in 17 MENA nations discovered that FDI worsens environmental degradation, lending credence to the pollution haven hypothesis, with increasing trade openness and energy consumption also contributing to higher CO2 emissions.

2.1.2 Neutral and Positive Impact of FDI

The term "neutral impact" is rarely used in FDI research, which typically emphasizes either positive or negative outcomes, making it difficult to find studies specifically addressing neutrality. Nevertheless, FDI's environmental impact is not universally negative. (Wang et al., 2023) examined FDI's environmental implications from an economic perspective and found that FDI's effect on carbon emissions varies with income level, using GDP as a reference point. Their findings showed that FDI considerably increases carbon emissions in countries with per capita GDPs less than $541.87. As GDP per capita rises to $541.87, the favorable impact decreases. When GDP per capita hits $46,515, the effect shifts negatively, demonstrating that FDI's environmental impact might be neutral or advantageous in certain economic conditions.

A vast body of literature concludes that effectively developed institutions are positively correlated with foreign direct investment flows. Sabir et al., 2019, for instance, in their work "Institutions and FDI: Evidence from Developed and Developing", employed data over the period of (1996–2016) through several income-level countries to demonstrate that enhancing institutional quality would channel more foreign direct investment into a productive asset-led course which serves as means by stimulating economic growth; Shaiful M. and Beloucif A., 2023, "Determinants of Foreign Direct Investment: Systematic Review Study on Empirical Studies" investigated the advantages of FDI for host country along with very valuable data about employment creation and growth in economy.organization was [19–26] as given Position NOTES FDI is necessary to foster economic growth, it brings in technology and expertise or jobs, money into the host economy all of which need are added factors for the total eco-system hence justifying why FDI plays a key role on developing countries because such large inflow can mean huge changes for their economies. FDI contributes to TFP growth in«developed and developing countries(search this keyword using « [6]) Li C. & Tanna S., (2019). This opening is associated with FDI financial openness; the inflow of foreign capital and technology can increase total productivity in different sectors.

2.1.3 Gaps in Existing Research

Whilst a large body of previous research has focused on the economic benefits of Foreign Direct Investment (FDI), there have been far fewer studies that examine its environmental implications. The traditional view of economic growth is contradicted and a new scenario detected by (Huang, Y., Chen, F., Wei, H., Xiang, J.;), which was the positive link between Foreign Direct Investments (FDI) inflow with an increase in carbon emissions. It highlights the nuances of FDI outcomes, and hence the necessity for overtly incorporating environmental dynamics. FDI inflows are related with carbon emissions positively (Frontiers research) Linking the economic development and regulatory quality to explore their roles in affecting ecological impacts of FDI, (Xie et al., 2023) found few significant relationships between them and carbon emissions caused by spillovers from inward FDI, highlighting a limited understanding that further studies are necessary. Finally, investigation on FDI and its Environment (Saini, N. & Sighania., 2019) also provides a high level scrutiny of the environmental effect that comes with Foreign Direct Investment in an economy sector. As their review of findings and conclusions from different studies, highlighted research gaps noted specifically in terms dealing with ecological aspects calling for our study to help fill the identified gaps.

2.1.4 FDI and Environmental Implications

However, FDI can lead to different environmental effects depending on the investment nature and industry of investment, as well other things such market gaps or legal regulations in host country. Even though there are negative impacts on the environment due to FDI, at the same time it gives a positive effect also. FDI can either lead to degradation of the environment, result in a number of ecological changes or encourage industrial practices associated with low carbon emissions and thus leads towards more stringent environmental standards. According to them, the impact of foreign direct investment on the environment differs depending on factors such as type of capital flows, sectoral specialisation and environmental legislation in host countries (Tsoy & Heshmati 2023; Chiriluș & Costea 2023).FDI can harm the environment. Economic growth resulting from FDI often causes a rise in the level of resource and energy consumption, which can increase pollution as well as year-on-year target emissions. In contrast, FDI can promote sustainable development and enhance environmental performance affecting the environment positively (Tsoy & Heshmati, 2023; Chiriluş & Costea, 2023).

In terms, or foreign investors from more stringent environmentally-regulated states will see greater diffusions and greener industrial technologies (Wang Y., Liu J., Wang J. & Liu Z, 2023; Blonigen,p 江別郡). In sum, the environmental consequences of FDI are complex and varied due to a variety of forces such as industry behavior and institutional arrangements.

2.1.5 Comparing Methodologies

Most of what the literature offers comprises established social science comparative research methodologies, which typically have an either qualitative (individual case studies) or quantitative orientation (multiple cases & cross-national)(Gray et al., 2007; Goerres et al. The discrepancies among both methods in comparative studies are remarkable, and there is an increasing realization of the necessity to combine principles from each tradition in future research (Gray, P. S., Williamson, J. B., Karp, D. A., & Dalphin, J.R.. 2007; Khosla, I.(2021). This is consistent with the approach used in this study which utilizes a richer and more sophisticated scientific language developed by Ragin, C. (1991).

2.1.6 Key Features of the Study's Methodology

This work applies a ridge regression approach (a sophisticated quantitative tool) to inspect the linkage between FDI and carbon emissions in China. This methodology allowed us to conduct a detailed examination of the relationships between dependent variables (CO2MTP), FDI inflows, energy consumption, urban population, and technological progress.

Ridge Regression- Complexity and Precision Ridge regression is a linear regression that reduces multicollinearity amongst multiple predictors diminishing the risk of overfitting for more dependable results.

Comprehensive Analysis: The statistical analysis of correlation matrix, multicollinearity tests, and regression coefficients has broadened the basis for understanding relationships among economic indices and CO2 emissions.

Predictive Framework: Since the Ridge regression model had an RMSE of 0.4342, reflecting good enough performance in predicting actual emissions and thereby indicating its applicability in terms of evaluating the impacts foreign direct investment (FDI) on environmental sustainability was done right or not. More accurate than simple or subjective methods (extensive statistical analysis and ridge regression at the core of this study.

Table 1. Past Literature Table

Section	Authors	Main Focus	Findings and Conclusion
2.1 FDI and Its Impact on Host Country Development	Dunning & Lundan (2008); Alfaro et al. (2004); Puck et al. (2013); Doytch & Uctum (2011); De Beule & Duanmu (2012); Angizi et al. (2022); Zuo et al. (2023)	Importance of FDI in developing nations, its economic benefits, and environmental impacts	FDI boosts investment, promotes innovation, and creates jobs. It can also enhance environmental standards.
2.1.1 Adverse Environmental Effects of FDI	Ali et al. (2022); Christoforidis, T., & Katrakilidis, C. (2022)	Negative environmental impacts of FDI	FDI can lead to higher energy consumption and environmental damage in host countries without adequate regulations.

2.1.2 Policy and Regulatory Measures	Ding et al. (2018); Xie et al. (2019)	Role of policies in mitigating FDI's adverse effects	Environmental solid regulations and policies can minimize the negative impact of FDI.
2.1.3 Comparative Analysis	Grossman & Krueger (1991); Dasgupta et al. (2002); Hoffmann et al. (2005)	Comparing the environmental impacts of FDI across countries	Mixed results on the ecological implications of FDI, varying by country and regulatory context.
2.1.4 Green Technology Transfer	Adams (2009); Bel & Joseph (2015)	FDI as a conduit for green technology transfer	FDI can help transfer environmentally friendly technologies to host countries.
2.1.5 Sustainable Development	Ruggiero (2013); Zarsky (2017); Wang et al. (2023); Blonigen (2005)	Balancing FDI with sustainable development goals	FDI can support sustainable development if aligned with environmental goals and regulations.
2.1.6 Comparing Methodologies	(Goerres, Siewert, & Wagemann, 2019; Gray, P. S., Williamson, J. B., Karp, D. A., & Dalphin, J. R., 2007; Khosla, I. (2021); Ragin, C. (1991)	Methodological approaches in FDI research	Combining qualitative and quantitative methods offers a comprehensive understanding of FDI's impacts.

2.2 Carbon productivity, its measurement, and Contrasting Findings

Carbon Productivity: Economic output generated per unit of carbon emissions. It is a crucial environmental indicator, it measures the efficiency of carbon emission reduction in countries or enterprises during production (Chen, Liu & Zhang 2021). Simply put, carbon productivity can be converted by GDP and CO2 emissions (Guo, Meng & Sun 2021). Indian countries have a carbon productivity of 0.1 in the total operation mode; and when one country earns $100 billion, it emits one base ton (equal to a billion tons) of CO2 per year, whereby its carbon productivity would be 100. According to these calculations, sending out $28/ton of CO2 is equivalent to the government producing $100 in economic production for every ton of carbon. This new metric helps us understand and consider carbon productivity, as opposed to just labor and capital input. It can monitor the environmental performance of a country or company over time (Our World in Data, 2023).

2.2.1 Contrast with Earlier Studies

This section explores how the dual effects have influenced on economic and environmental development, including differences with previous studies to findings from current study. They focus on the interrelation between FDI and environmental pollution in China. In (An, Xu, C. & Liao X., 2021) study, they projected an inverted U-shaped pattern that pollution levels rise in early stages of FDI, but the role may reverse with economic scales growing and industrial structures adjusting. The existing studies are mainly focused on the financial effect of FDI, and neglect environmental impact: [An et al., 2021]). In (Shen, Zhou, & Jing, 2024) studied how foreign direct investments (FDI) affected green innovation efficiency (GIE) in various Chinese provinces and found that FDI has mattered a lot for environmental outcomes but it was significantly different by region. Their results are largely in a straight line with our ridge regression analysis, which also underscores the nuanced and non-linear relationship between FDI, economic growth and environmental sustainability.

Most of the earlier research has studied linear relationship between FDI and environmental consequences like direct influence of FDI on CO2 emissions. However, more nuanced and nonlinear relationship emerged after deeper Analysis. A connection between trade, FDI and CO2 Emissions in Turkey is found by (Haug & Ucal., 2019). A panel threshold analysis of 67 countries further showed that the effects of FDI on CO2 emissions are different at each level of income, switching from a positive to an inverse U-shaped relationship. A development in the same direction is found between 1996 and 2018 for GDP growth, while research at G20 level suggests these effects are offset by better economic development and regulatory quality over time. In addition, the economic level has a significant impact on the relationship between FDI and carbon emissions: middle-income countries exhibit an inverted U-shaped pattern. These results show that different economic and regional conditions have a significant effect on the environmental effects of FDI (Qiang et al., 2023); (Huang Y., 2021).

2.3 Broader Contextualization

Conflict between economic development and environmental sustainability is the crux of contemporary policy debates. Against this background, the aim of our research is to study the intricate relationship between Foreign Direct Investment (FDI) and carbon emissions in China. In a medium and long-term perspective, this study criticizes the Chinese rapid economic growth on account of its ecological consequences. This has been shown in the study of (Liang, Liu, and Zhang., 2017) that just like our findings depict a complex interaction between economic growth supported by FDI and environmental sustainability. Our own research specifically backs up the idea that economic activity, especially FDI can be associated with significant environmental impacts. The convergence of these two forces highlights the need to review investment strategies and monetary policies with prioritized focus on environmental concerns.

Additionally, our research supports calls from (Liu, Z., Deng, Z., Davis, S. J., Giron, C., and Ciais, P., 2022)) for a broader policy mix to support greener economic development that mixes environmental sustainability with conventional growth. While its emissions are rocketing China has set out in a corrective direction: their basic message is that economic growth – especially FDI-based — can trigger environmental deterioration even without any intention behind it, the study says.

Implications for future research Development of these findings in other healthcare professions is vital. First, the types of FDI most likely to have sustainable impacts need closer scrutiny. Research should be directed towards generating and boosting access to green technologies (Stoneham et al. Second, the research underscores how long-term assessments are critical to understand whether economic policies support environmental sustainability. It argues that the nature of this transition requires a dual-policy response. These must set FDI laws pointing to economic sectors that are clean and green on one side. These laws promote renewable energy, and resource-efficient methods for production and sustaining infrastructure. However, it is critical to establish legislative frameworks that hold foreign investors accountable for their environmental impact, ensuring that economic growth does not come at the expense of environmental damage. For example, in Turkey, colossal energy use increases and economic expansion have contributed significantly to rising carbon emissions. Modern logistics infrastructure and vehicle fleets have lowered CO2 emissions from road freight transit (Bayat, İlarslan, & Shahbaz, 2023). Finally, the nuanced findings of this literature review emphasize the importance of policies that connect FDI with environmental goals, paving the way for economic development and ecological conservation. This knowledge is highly important for the Chinese policy makers to encounter a growing global economy with consideration of climate changes reality as an inherent component and not-synchronized blueprint.

2.4 Trends of China's Total Energy Supply

This graph shows the development of China's total primary energy supply data from the International Energy Agency from 1990 to 2020. The graph depicts the evolution of China's overall energy supply, which includes coal, natural gas, hydropower, wind and solar, biofuels and waste, and oil. Despite apparent swings due to legislative changes and economic cycles, coal remained dominant throughout the century, demonstrating its importance in China's industrial development.

On the contrary, natural gas and oil have been growing steadily due to China's gradual efforts toward cleaner and broader energy supply. Hydropower has always been the most important part of China's energy layout, revealing its significance as a type of renewable energy in powering China. The international carbon accounts show that wind and solar energy supplies of electricity have grown significantly from the early 2000s, largely as a result of Chinese policies to promote renewable generation. Meanwhile, biofuel, waste energy, and other sources of renewable but intermittent power had modestly increased in supply on average as share sources so some movement away from these leverage points is likely arising at least coincident with the improvement of certain alternatives. Overall, the graph depicts China's evolving energy landscape over the last three decades, demonstrating a shift away from heavy reliance on coal and toward a broader range of energy sources, as well as China's efforts to combine energy demands with environmental sustainability.

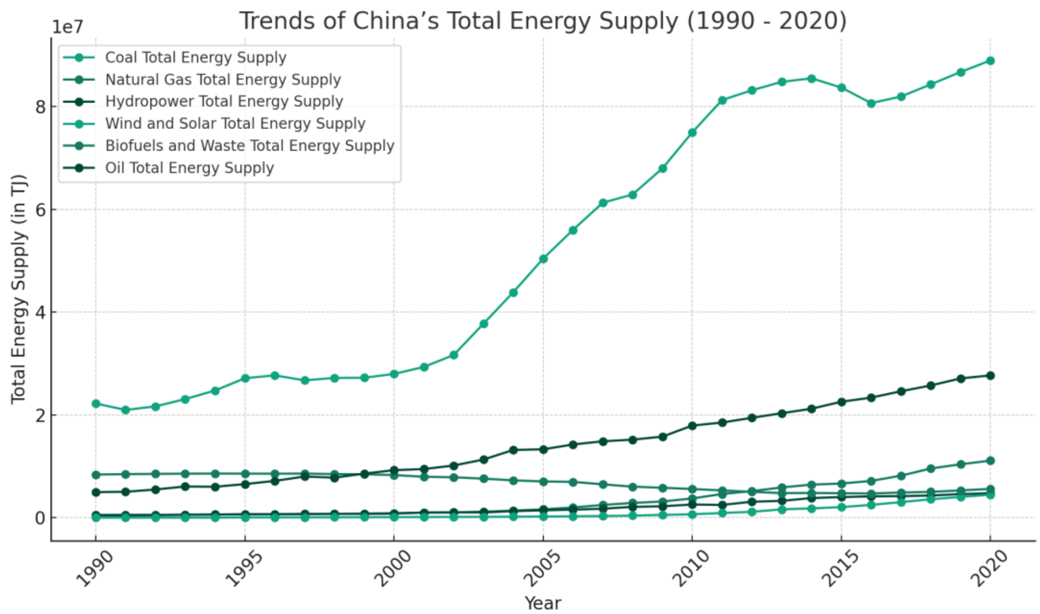

Fig 1. Trends of China's Total Energy Supply: data from the International Energy Agency and IMF

Figure 1 (Trends of China's Total Energy Supply) discusses China's energy patterns. It follows the introduction of energy concepts before delving into more complex discussions or analyses related to the topic. It serves as a visual aid to help readers understand China's energy profile changes over the specified period before delving into more complex discussions or analyses related to the topic.

3. Research Methodology, Hypotheses, Model Construction, and Data Explanation

3.1 Theoretical Mechanism for Hypotheses Proposal

China's FDI liberalization has increased economic growth (Johnson, Li, and Zhou, 2012), but it has also created environmental issues (Smith, Wang, and Chen, 2010). FDI can result in transferring technology and business practices, which can improve or degrade environmental sustainability (Brown, Zhang, & Liu, 2009). For example, FDI could increase carbon productivity by introducing cleaner, more efficient technology (Lewis, J. I. (2013), or it could worsen environmental degradation by moving pollution to China (Smith, Wang, and Chen, 2010; Brown, Zhang, and Liu, 2009). Therefore, we offer the following hypotheses:

Hypothesis #1 (H1): An increase in FDI inflows is associated with decreased CO2 emissions per capita in China.

In the study of (Gong et al., X., 2023) states that "China's global economic powerhouse expansion begets remarkable international direct investment influx; however, some other studies have analyzed the economic impacts of FDI largely hence little concern on its environmental effects (Ziwei et al., 2023). Such a view suggests that higher FDI inflows can enhance technological transfer and the adoption of clean technologies, thus reducing emissions per capita (Jun et al. 2018). Validating this hypothesis would lead to a deeper understanding of the environmental effects as well as providing policy implications (Tingbo et al., 2023) & (Caihong et al., 2023).

Hypothesis 2 (H2): Increased FDI outflows are significantly associated with China's higher CO2 emissions per capita.

In recent years, China has been among the largest recipients and providers of FDI in the world with their overseas investments (Xiao et al., 2022). The prediction is that since most of these investments, notably in manufacturing and high carbon footprint industries can have a domino effect towards China's own domestic economy through increased production activities the like. It will be important to establish this relationship in order to assess potential wider environmental impacts of Chinese investment practices overseas (Wang et al., 2023) & (Yang et al., 2021).

Hypothesis 3 (H3): The growth of CO2 emissions per capita in China is significantly affected by the increase in primary energy consumption.

China's Development of Economy contributed on a large scale to an increased use of energy, which has led the country to a heavy impact on its carbon footprint (Li, C., Chen, Z., Hu, Y., Cai, C., Zuo, X., Shang, G., & Lin, H., 2023). Economic growth is an important factor to consider in energy consumption, however the theory goes further and maintains it also activates CO2 emissions. Thus, confirming this conjecture underscores the necessity of sustainable energy systems for economic growth and that need-based policies may play vital parts in fighting against global climate change (Liu et al., 2023).

Hypothesis 4 (H4): Increased economic growth indicated by GDP per capita is associated with higher CO2 emissions per person in China.

The environmental Kuznets curve paradigm has been often used in economic literature to highlight the corresponding relationship between economic growth and degradation of environment. This research deeply illuminates the nature of this link in a Chinese context, as measured by GDP per capita and CO2 emissions per capita. If true, it would underscore the mixed economic growth effects of higher taxes and even more importantly stress a long-run in perspective to policy (Zhang H., Li Y., & Tong J., 2023).

Hypothesis 5 (H5): We therefore propose our Hypothesis 5(H5) that urbanization (measured by Urban Population) contributes to China's economic development would be one explanation for rising per capita level CO2 emissions.

Urbanization is a key dimension of China's economic change, which offers opportunities as well as poses challenges (Wang 2023). The first hypothesis suggests that the ongoing urbanization may lead to increased CO2 emissions per capita through enhanced energy consumption and industrial activity in cities. Disproving this hypothesis, that the STAT3 pathway and p-STAT3 are necessary for cisplatin resistance in ovarian cancer cells would give further directions on how to develop new therapeutic agents (Zhao, Z., Shi, X., Cao, Y., & Hu, M., 2023); Wang, Y., Liu, J., Wang, J., & Liu, Z., 2023).

H6: Technological progress (R&D expenditure as a percentage of GDP) has significant impact on CO2 emissions per capita in China

We have been told time after time that technology is the answer to every environmental woe including improved resource use and lifestyle (Huang., 2021). This line of reasoning implies that higher R&D expenditure could lead to a decrease in CO2 emissions reductions per person due to technical change, thus assisting China towards achieving its environmental objectives. This relationship could be verified if the firm increase its R&D investment to promote green technology and sustainable development (Sibt-e-Ali et al., 2024).

3.1.1 Research Methodology, Econometric Approach and Data Collection

This study borrows a quantitative analysis technique and multivariate regression to estimate the count of environmental and international economic factors affecting China in its long-term growth from 1990 to 2022. Data were gathered from the China Statistical Yearbook, Our World in Data and statistics provided by the Word Bank institutional series of reports on Chinese developments (financial databases) as basic data.

Data sources suspecting accurate analysis, sources were selected on credible and topically central grounds The relationship between China's economic activity, technological achievements, and carbon emissions were examined via rigorous econometric analysis in this study. Through the technique, we adequately achieved the objectives of this study. We obtained the time series data from The world bank and took 1990–2022 years. These include GDP, urban population growth rate, foreign direct investment and CO2 emissions per capita. Testing for stationarity was performed at the beginning of the investigation to ascertain if a non-stationary result existed using Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test.

This initial test had to review whether the time series data was good enough for further Analysis. Johansen cointegration test, which is very suited for multivariate time series data (Pfaff 2008; Green 2018) was employed to determine the long-term relationships among variables. Analysis was done using the Johansen cointegration test from the statsmodels module in Python (Prabhakaran., 2019). After testing cointegration, the significant determinants of carbon emissions were identified through Lasso regression analysis. This method is widely regarded for its versatility in feature selection and regularization, making the trained statistical model easy to predict and interpret face with new data (James et al., 2021; Ciaburro, 2018). Brownlee., (2020) Using the Lasso class from Python3 sklearn—linear_model library. We selected the Lasso technique for two reasons: First and foremost, we wished to regularize model simultaneously with variable selection (because interpretability and prediction accuracy are equally important). At this stage we punish the absolute sizes of regression coefficients so as to keep your model simpler and avoid overfitting. And along with, an individualized time series plot was generated to illustrate the trends and patterns in CO2 emissions across the given years. This is a graphical representation of the data in question that helps us with our first visual insight to see what kind anomalies or trends we need take look further next. Granger Causality Tests (Kirchgässner, Wolters and Hassler 2013) are employed to ascertain the direction of causality between economic variables and environmental variables. The Granger Causality Tests function of Statsmodels in python was used for implementation (Prabhakaran, 2022; Statology, 2022). This test was used to validate the policy relevance of the implications by estimating if a time series can be predicted from another one. All statistical tests and data manipulation was done in Python with Jupyter Notebooks. The final reasons for following this chain included the package's compatibility with large datasets and range of statistical analysis packages (such as Statsmodels if you do some econometrics or Pandas which is used in many data manipulation exercises). If these methodological requisites are adhered to the study hopes to present results that may provide useful insights for Chinese economic growth and environmental sustainability policy.

3.2 Modeling

In order to test our hypothesis, we performed a ridge regression analysis on the dependent variable (Carbon emissions) with selected independent variables. The equation is:

$$CO_2MTP = \beta_0 + \beta_1(FDIIN) + \beta_2(FDIOUT) + \beta_3(PEC) + \beta_4(GDP) + \beta_5(UPOP) + \beta_6(TA(R\&D)) + \varepsilon + \lambda \sum^{i=1}{}_{6}\beta^{i2}$$

The dependent variable is CO_2 emissions expressed in metric tons per capita (CO_2MTP). FDIIN represents the FDI influx. FDIOUT denotes the FDI outflow. Primary Energy Consumption is PEC. GDP is the GDP per capita. A UPOP is an urban population proportion. TA (R&D)Measures tech progress as R& D investment(% of gdp). Where λ is the penalty term and regulates the coefficients (β0, β1, …β6) and ε refers to an error term.

Steps:

1. **Enhance modeling with Ridge Regression vs. Ordinary Linear Regression.**

Likewise, Ridge Regression has great effectiveness when the predictors are multicollinear as shown in our case study of Foreign Direct Investment (FDI) and carbon productivity relation among China. The idea of regularization is to use a penalty component (λ times the square of coefficient size) in the loss function which helps offset this overfitting caused by multicollinearity. This regularization approach reduces coefficients a lot and serves well to lessen multicollinearity in the model. In such conditions, Ridge Regression allows us to make a much more precise and reliable estimate. This paper motivates from the work of (Hyndman, R. J.,

& Athanasopoulos G. 2018) to address multicollinearity among the economic and demographic factors that decreases on overfitting in basic linear regression models combined with wrong predictions which was computed earlier by this study.

2. Knowing what λ means in Ridge Regression.

Lambda is hyper-parameter in Ridge Regression which controls the amount of coefficient that are shrunk. When λ increases, coefficient sizes are penalized which results in a restrict of model flexibility and help us to assess how well we have the bias variance tradeoff. The ideal λ value was found through cross-validation — by dividing the data into subgroups, training on some and validating in others. We seek the λ that gives us a minimum prediction error. The accuracy of the model is hugely dependent on λ. A low λ can lead to a model looking very similar to standard linear regression except that it really runs the risk of overfitting what its been trained on. Too much λ can make a model too simple, introducing bias and causing it to underfit data (Statology, 2020).

3. **Visualizing Effects of Different λ Values.**

Excerpt from Nicolas Stadler's book "Prediction and Feature Assessment, Ridge Regression and Shrinkage" is shown of how λ values influences the shrunken coefficients as well model prediction returned error.

If we decrease λ in our model, it may describe the bundling way of FDI and carbon emissions more accurately. However, it exposes the model detection on noise and overfits. Raising the λ value will flatten out the model, potentially causing it to round off helpful little wiggly spice-of-life type undulations in our data. We trained our ridge regression model for four different values of regularization variable (λ) using sensitivity analysis. Tune λ, observe a noise in coefficients & metrics like R-squared and Mean Squared Error (MSE) to evaluate the model stability.

This technique was used to determine the ideal λ value which would minimize prediction errors. Significantly changing λ will shift the equilibrium between model complexity and expected accuracy: Question to be Asked? (Nicolas Stadler, 2021).

4. **Disadvantages of the Current Model.**

In summary, the current ridge regression model allows for an exhaustive analysis of how multiple economic indicators affect carbon emissions. Nevertheless, there remains potential for improvement by refining λ selection, increasing the number of variables considered and incorporating other methods. These improvements could yield significantly deeper understanding about what is driving China's carbon emissions and more secure footing for policy-making as well as further research.

3.3. Data Description

The study used annual financial data over three decades from 1990 to 2022, collected based on historical publications of the People's Bank of China and other reputable sources, including the China Statistical Yearbook, publications from China's National Bureau of Statistics, and World Bank financial archives were acquired.

Table 2. Variable Description

Variable	Description	Symbol
FDI net inflow	China's Net inflows of foreign direct investment	FDIIN
FDI net outflow	China's Net outflow of foreign direct investment	FDIOUT
China's Urban Population (% of total population)	The percentage of China's population living in urban areas.	UPOP
CO2 Emissions (metric tons per capita)	Total carbon dioxide emissions per capita in China.	CO2MTP
CO2 Emissions (kg per PPP $ of GDP)	Carbon emissions per PPP (Purchasing Power Parity) dollar of GDP.	CO2KG
GDP per Capita	China's Gross Domestic Product per capita in China.	GDP
China's Primary Energy Consumption	Total primary energy consumption in China.	PEC
Tech Advancement (Research and development expenditure) (% of GDP) - China	Expenditure on research and development as a percentage of GDP in China.	TA(R&D)

3.3.1 Visual Histogram for Each Variable

The following histograms show the frequency distribution of numerous variables:

CO2MTP has a right-skewed distribution, indicating that lower CO2 emissions per capita are more common than higher values.

PEC: Appears to be right-skewed, with the majority of data indicating reduced primary energy consumption and only a few instances of extremely high consumption.

FDIOUT: The distribution of FDI outflows is somewhat uniform but has a slight right skew.

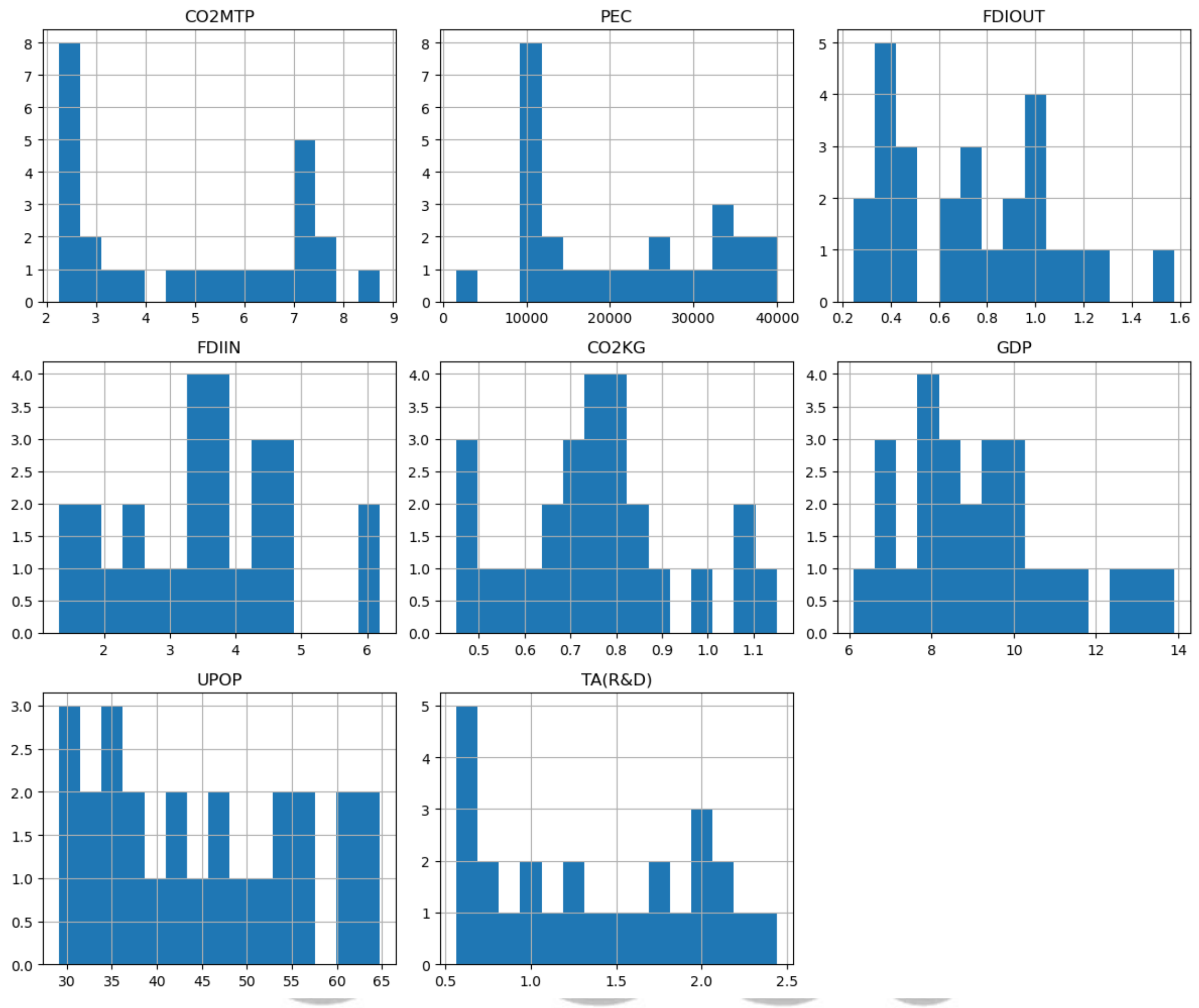

Fig 2. Visual Histogram for Each Variable: data from the International Energy Agency and IMF

FDIIN: Indicates a right-skewed distribution of FDI inflows, similar to CO2MTP.

CO2KG: Shows a multi-modal distribution, suggesting different groups or types of emissions factors.

GDP: Appears to be normally distributed with a slight right skew, indicating varied levels of GDP per capita.

UPOP: Displays a left-skewed distribution, suggesting a higher frequency of observations with a more significant percentage of the urban population.

TA(R&D): This shows a right-skewed distribution, indicating that lower R&D expenditure as a percentage of GDP is more common than higher expenditures.

3.3.2 Boxplots for Each Variable

The boxplots give a clear indication of the spread and central tendency of the data. It also highlights outliers, which are points that lie beyond the whiskers of the boxplot. For example, PEC (Primary Energy Consumption) shows a wide interquartile range with outliers, suggesting significant variation in energy consumption among the observations.

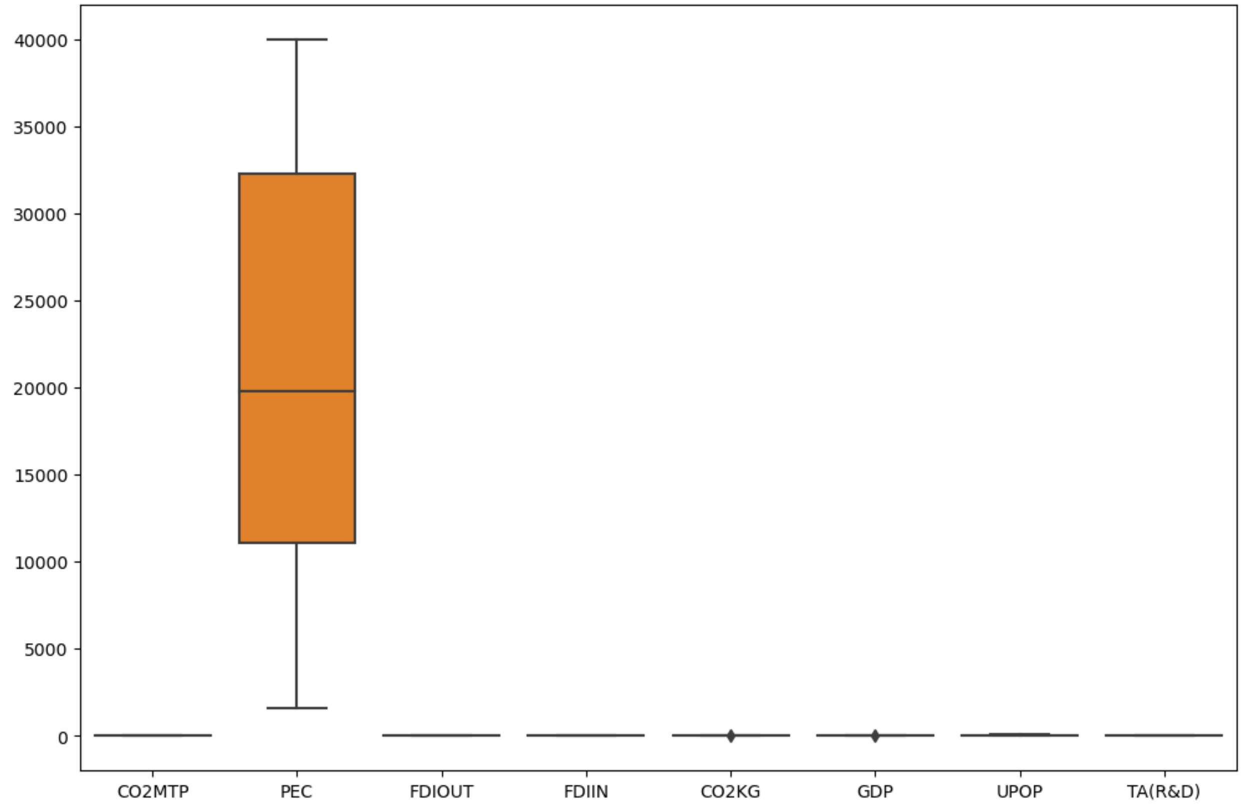

Fig 3. Boxplots for Each Variable: data from the International Energy Agency and IMF

The descriptive statistics of the variables provide a summary of central tendency, dispersion, and range, which are critical for understanding the dataset's characteristics.

1. TA(R&D) (Technology Adoption and Research & Development Spending)

Mean: China's average R&D spending is 1.38% of its GDP, indicating a commitment to technological advancement and innovation.

Standard Deviation: The 0.61% fluctuation in R&D spending indicates that policy and economic factors influence R&D investment over time.

The range of 0.56% to 2.44% is most likely due to increased emphasis on R&D due to economic developments or international competitiveness initiatives.

2. Foreign Direct Investment inflows (FDIIN)

The average FDI inflow is 3.54%, demonstrating that foreign investment is significant concerning China's economic size.

The standard deviation indicates how the volume of FDI inflows has fluctuated throughout China's economic development.

Global economic trends could explain the range from 1.31% to 6.19%, China's liberalization efforts, and periods of rapid economic growth.

Table 3. Descriptive Statistics of Variables

Variable	Mean	Standard Deviation	Minimum	Maximum
TA(R&D)	1.381928	0.611912	0.56324	2.44
FDIIN	3.544824	1.277332	1.310716	6.186882
CO2MTP	4.877667	2.193982	2.244842	8.73
CO2KG	0.756049	0.181968	0.45	1.151476
UPOP	44.93512	11.25847	29.103	64.72
PEC	21453.37	11387.5	1577	39978.49
FDIOUT	0.732933	0.346437	0.244747	1.576545
GDP	9.238462	2.000615	6.1	13.9

3. CO2MTP (carbon dioxide emissions in metric tons per capita)

The average CO2 emissions per person are 4.88 metric tons, reflecting China's development and energy consumption patterns.

Standard Deviation: Shifts in energy policy, industrial upgrading, and the adoption of emission control measures could contribute to the significant volatility in emissions

Range: The broad range suggests a transition over time, possibly from high-emission industrial activities to cleaner technologies and energy sources.

We ascribe the Mean CO2 emissions of 0.76 kg to specific sectors or energy usage.

Standard Deviation: A low standard deviation suggests that the documented emission factor for specific sectors or activities is stable. This Analysis shows that, while overall emissions are high, they are generally steady within particular industries or types of energy usage, indicating consistent practices or limits.

Range: The range may represent the effectiveness of reducing emissions in specific industries or activities.

5. Urban population (UPOP).

Mean: The urban population proportion averages 44.94%, indicating China's urbanization trend.

Standard Deviation: The variation reflects the dynamic nature of China's urban expansion, with some years experiencing a more robust increase.

Range: The vast variation of urban population percentages illustrates China's extensive urbanization as part of its economic development strategy.

6. Primary Energy Consumption

China's average primary energy consumption is substantial, reflecting its status as a major industrial power. The standard deviation in the energy intensity is large, highlighting economic volatility and that there are shifting needs for energy efficiency. The presence of this wide range is a clear indication that China has shifted from low-energy to one of the largest-scale energy consumers on the planet, in response to quick economic growth.

7. Foreign Direct Investment Outflows (FDIOUT).

Their average FDI outflows of 0.73 percent suggest China is gradually making inroads as an investor on the global stage -and thus, its increasing economic power and investment outreach to each corner of world economies.

Standard Deviation: This moderate variability may reflect the transformation in strategies of Chinese outward investment throughout different years.

Range : The narrative of capex is with a large range from aggressive outward investment to consolidation or policy restriction periods.

8. Gross Domestic Product Growth (GDP)

Mean: The mean GDP growth rate 9.24% suggests that the economy has been growing on a long term horizon.

Low Standard deviation: The low spread shows growth rates are robust, but have been more constant in comparison to other economic data.

GDP growth is well in line with expectations, and a wide band indicates that China has capacity to maintain strong enough levels of performance no matter if global economic cycles or internal policy would result only minor differences.

The fact that this robust growth is caused by a constant source indicates China has been able to sustain high rates of economic expansion while maintaining financial stability. China has in a very direct way learned from its economic development, regulatory reforms and environmental concerns for the past 30 years. These figures are descriptive, food for thought that should guide future research into how FDI affects carbon emissions in China.

4. Results and Analysis

4.1 Correlation Matrix Heatmap

Strong Relationships (Heatmap of the Correlation Matrix For instance): Positive very high correlation between UPOP and TA(R&D) suggest that when u. pop grows the expenditures on R&D grow or vice versa (TA). A negative correlation of CO2KG with FDIIN suggests that higher investment inflows are associated with lower carbon dioxide emissions.

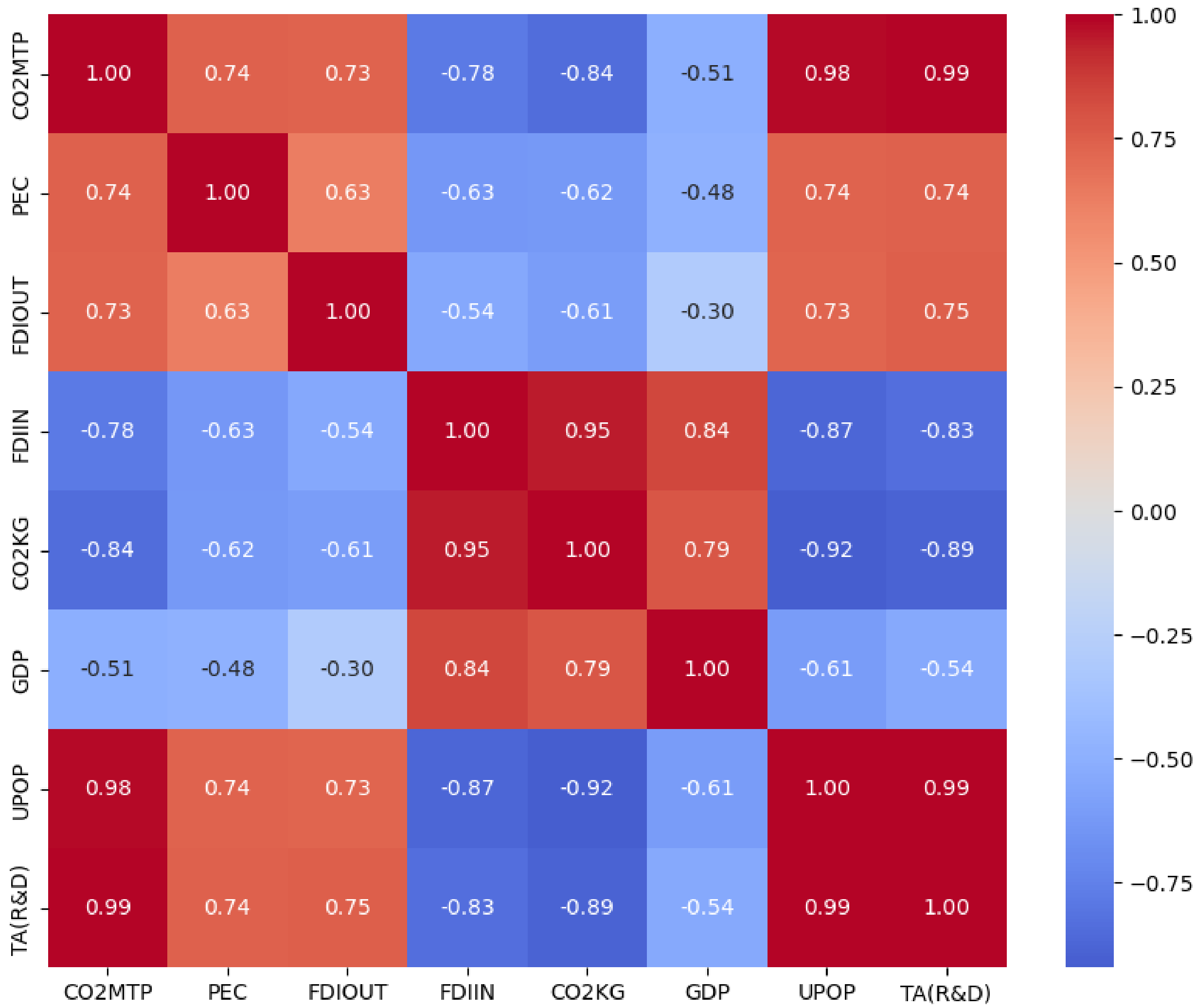

Figure 4: Correlation Matrix Heatmap

4.2 Correlation Analysis

This table provides a numerical value for the correlations between pairs of variables. High positive values indicate a strong positive correlation, and increased negative values suggest a strong negative correlation. For example, a significant positive correlation between GDP and FDIIN suggests that China's better GDP leads to more significant FDI inflows.

	CO2MTP	PEC	FDIOUT	FDIIN	CO2KG	GDP	UPOP	TA(R&D)
CO2MTP	1.000000	0.740136	0.730553	-0.779906	-0.843115	-0.507407	0.979507	0.985974
PEC	0.740136	1.000000	0.631671	-0.629390	-0.623537	-0.482728	0.736153	0.739328
FDIOUT	0.730553	0.631671	1.000000	-0.542640	-0.605955	-0.297631	0.725952	0.746763
FDIIN	-0.779906	-0.629390	-0.542640	1.000000	0.951985	0.839291	-0.870960	-0.832887
CO2KG	-0.843115	-0.623537	-0.605955	0.951985	1.000000	0.785990	-0.921458	-0.889232
GDP	-0.507407	-0.482728	-0.297631	0.839291	0.785990	1.000000	-0.608181	-0.536546
UPOP	0.979507	0.736153	0.725952	-0.870960	-0.921458	-0.608181	1.000000	0.990912
TA(R&D)	0.985974	0.739328	0.746763	-0.832887	-0.889232	-0.536546	0.990912	1.000000

Pearson Correlation with data from the International Energy Agency and IMF

4.3 Multicollinearity Analysis Test

Table 4: VIF Test Analysis

VARIABLE	VIF
CONST	719.51104
FDIIN	11.62937
FDIOUT	2.466645
PEC	2.426412
GDP	5.859883
UPOP	103.200877
TA(R&D)	96.005774

This table shows each variable's Variance Inflation Factor (VIF), representing the degree of multicollinearity. A VIF of more than ten shows high multicollinearity, as observed in the FDIIN, UPOP, and TA(R&D) situations. The constant term has a high VIF, but this is not an issue because it represents the regression model's intercept.

4.3.1 Hypothesis Testing and Ridge Regression Analysis

Analyses were performed separately for each hypothesis, with the appropriate regression equation specified.

H1: $CO2MTP = \beta 0 + \beta 1 \cdot FDIIN + \varepsilon + \lambda\beta 1^2$

H2: $CO2MTP = \beta 0+\beta 2\cdot FDIOUT + \varepsilon + \lambda\beta 2^2$

H3: $CO2MTP = \beta 0+\beta 3\cdot PEC + \varepsilon + \lambda\beta 3^2$

H4: $CO2MTP = \beta 0 + \beta 4 \cdot GDP + \varepsilon + \lambda\beta 4^2$

H5: $CO2MTP = \beta 0+\beta 5\cdot UPOP + \varepsilon + \lambda\beta 5^2$.

H6: $CO2MTP = \beta 0 + \beta 6 \cdot TA(R\&D) + \varepsilon + \lambda\beta 6^2$.

In each equation, the intercept term (β0) indicates the expected CO2MTP value when all independent variables are zero.

The coefficients β1, β2, …, β6 show the change in CO2MTP for a one-unit change in the independent variable, while other variables remain constant.

The error term (ε) represents the unobserved factors that affect CO2MTP.

Each hypothesis looks at the impact of a different independent variable on CO2MTP, offering a complete understanding of how each component affects CO2 emissions in China.

4.3.2 Ridge Regression Analysis Test

Table 5: Ridge Regression Analysis

VARIABLE	*COEFFICIENT*
RMSE	0.4342
FDIIN	0.2184
PEC	0.0948
FDIOUT	0.0468
GDP	0.0693
UPOP	1.0005
TA(R&D)	1.1443

The ridge regression model used in this study sheds light on the complicated dynamics of foreign direct investment (FDI), energy use, urbanization trends, and per capita carbon emissions in China. A significant Root Mean Squared Error (RMSE) of 0.4342 approximates the model's predictions of actual emission values, with a lower RMSE indicating a more exact model.

When we look at the regression coefficients, we see that increases in FDI inflows (coefficient of 0.2184), energy consumption (coefficient of 0.0948), and GDP per capita (coefficient of 0.0693) result in a corresponding increase in CO2 emissions per capita, which supports our initial predictions.

These positive correlations highlight the link between growth and emissions, necessitating policies that balance economic incentives and environmental sustainability.

After synthesizing these insights, our regression model is consistent with the current discourse on the consequences of economic activities on environmental well-being, giving a predictive framework that correlates to documented CO2 emission trends in the context of China's economic and demographic growth.

FDI inflows (FDIIN) correlate positively (0.2184), demonstrating a direct association with CO2MTP. This finding verifies our hypothesis and follows the observed trend of increasing FDIIN with rising CO2 emissions, implying the necessity for environmentally conscious investment regulations.

Primary Energy Consumption (PEC), with a coefficient of 0.0948, and GDP per capita (GDP), with a coefficient of 0.0693, both have significant positive relationships with CO2MTP, affirming our hypotheses that economic growth and energy consumption are key drivers of carbon emissions.

The significant coefficient for Urban Population (UPOP) at 1.0005 highlights the impact of urbanization on CO2MTP, affirming our hypothesis and mirroring the urbanization trend in China, thereby underscoring the necessity for sustainable urban design. Contrary to expectations, Technological Advancement (TA(R&D)) shows a strong positive correlation with CO2 emissions, with a coefficient of 1.1443. This unexpected result implies that policymakers must revisit R&D funding priorities for green technologies. The regression model, with an RMSE of 0.4342, accurately predicts CO2 emissions using economic and demographic variables, consistent with reported CO2MTP values and previous studies on the environmental impact of economic development. Our extensive ridge regression study uncovers intricate correlations between foreign investments, energy consumption, urbanization, and carbon emissions. The RMSE score of 0.4342 indicates that our forecasts are near-real values, recognizing that 100% accuracy is uncommon in such sophisticated models. Increased foreign investment, economic growth, and urbanization are all linked to higher carbon emissions. The model assigns a positive coefficient to each element, showing that these variables directly link emissions. Urban population growth and technical R&D are particularly closely related to emissions. The surprising link between R&D spending and more significant emissions shows that technological investments may not be as environmentally beneficial as needed, necessitating strategic rethinking. Overall, the model accurately captures China's emissions to economic and demographic indicators, adding to ongoing discussions about the environmental costs of economic development and emphasizing the importance of policies that promote economic growth while protecting the environment and aligning technological progress with sustainability goals.

4.4 Overarching Implications of the Findings

The recent Ridge Regression analysis, accommodating multicollinearity through regularization, provides critical insights into the intricate relationships between economic growth, foreign direct investment, energy consumption, urbanization, technological advancement, and China's carbon emissions.

FDI Inflow (FDIIN): The revised positive coefficient for FDIIN (0.2184) still suggests that increased foreign direct investment inflows correlate with higher CO2 emissions per capita, underlining the environmental cost of economic gains from foreign investments, which may be related to the energy-intensive nature of the sectors that attract these investments.

FDI Outflow (FDIOUT): The coefficient for FDIOUT (0.0468) shows a positive association, while it is less significant than FDI inflows, implying that FDI outflows contribute to higher carbon emissions indicating that there is a complicated international investment ecosystem with domestic environmental consequences for even outbound investments. The GDP and Primary Energy Consumption (PEC) These variables, with corresponding values of 0.0948 and 0.0693, illustrate the relationship between China's carbon footprint, energy consumption, and economic growth.

Urban population (UPOP): The high UPOP coefficient (1.0005) indicates that urbanization considerably impacts carbon emissions, emphasizing the vital role of sustainable urban planning and development techniques in reducing the environmental impact of urban growth.

Technology advancement (TA(R&D)): With the highest coefficient (1.1443), this variable's strong positive connection with CO2 emissions is counterintuitive, hinting that current R&D investments may be unintentionally contributing to increased emissions, necessitating a systematic refocus of R&D efforts toward more environmentally efficient solutions. Policy Implications for Economic Growth The findings highlight the need for nuanced policies that properly balance economic growth and environmental sustainability. Policies that promote sustainable practices in FDI, energy use, and urban development are critical. Furthermore, diverting technology breakthroughs toward more environmentally friendly solutions can significantly mitigate the adverse effects of economic and demographic growth.

Urbanization and Technology Advancement

Given the significant impact of urbanization and technological progress on CO2 emissions, these sectors appear as primary policy intervention targets. Sustainable urban planning and green technology R&D investments can form the basis for China's solution to environmental issues.

Specific Findings

Clarifying Hypotheses Outcomes: Our findings confirmed certain assumptions but contradicted others. Increases in FDI inflows and urban population initially predict increased CO2 emissions per capita, and the results supported this with substantial positive coefficients consistent with the idea that economic growth is typically associated with environmental problems. However, the data refuted the notion that technical developments would reduce emissions, as it revealed a positive relationship between R&D spending and emissions.

Exploring anomalies: The positive coefficient for R&D investment is an anomaly, implying that present technical developments do not sufficiently counterbalance or reduce emissions; this could be due to a focus on technology that does not prioritize carbon efficiency or because investment is insufficient to make a significant effect. The discovery prompts more investigation into the types of technologies under development and their lifecycle emissions.

Drawing Comparisons to Literature: Our findings both complement and contradict previous research. As in previous studies, economic growth tends to raise emissions. However, our R&D findings vary from prior research, indicating that technological development should cut emissions. This disparity could be related to the precise chronology of our data, which spans a period of rapid industrial growth in China, presumably before the widespread use of green technologies. Our findings highlight the intricacies of the relationship between economic development and environmental sustainability, underlining the importance of strong policies that use economic growth for ecological benefit.

4.5 The Implications of the Findings for Managers and Organizations

The report underlines the importance of enterprises adopting environmentally sustainable practices, emphasizing the positive impact of Foreign Direct Investment (FDI) on carbon productivity in China. Even now, managers need to make green technologies the foundation of such restructuring underpinned by energy conservation and lean sustainable logistics practices. Also, commercial activities should be linked with the conservation goals based on significant involvement in policy lobbying along with strict adherences made towards environmental legislations. Strategic R&D investments ought to upper social values, with the best precedence given to inexperienced and carbon-neutral initiatives like renewable power enchancment or deploying CCS technologies. With less damage to nature, experts say our main cities are the most affordable promises of settling fairly and responsibly in a world that is loosing its ability to withstand CO2 emissions. The large FDI outflows and carbon emissions are highly related, which means that we must implement eco-friendly global investments strategies to ensure the highest environmental protection levels in their countries of origin. There must be transparency and stakeholder participation in environmental governance that compels corporations to provide full disclosure of corporate activities on the environment, requires open communication around sustainability initiatives and progress. In addition, we propose that companies transcend traditional linear business models in favor of circular economy practices and the production of low-carbon products/services to integrate sustainability into their strategy. Companies can utilise these understandings in aiding the climate change and reaching long term economic stability.

4.6 Policy Recommendations

Results from Ridge Regression for China can help focus policy recommendations by indicating the most important drivers of CO2 emissions in that country. Seek massive foreign direct investment through promoting green technologies or burdensome environmental regulations. To strengthen energy efficiency, it needs incentives to adopt best practices on a gain-sharing model and development of renewable energy source can only be done by the government subsidies or public-private partnership. Urbanization strategy need to reflect sustainability by enhancing public transportation, establishing green buildings and fostering innovative urban development. The progress eventually leads to technological advancement where a carbon neutral technology dominate the research and development red. making it formative with government collaboration while driving innovation through industry, Academia,contributions -Shloka Hegde A comprehensive growth strategy requires that economic and environmental development are balanced, supporting green economy endeavours. Therefore the answer to these problem requires strategic planning, collective efforts as well a focus on sustanability which in tun helps addressing economic and environmental goals ultimately.

5. Conclusion

This section highlights the key results of Ridge Regression analysis and their importance in identifying determinants affecting China's carbon emissions. FDI inflows and outflows include a significant proportion of CO2 emissions, indicating the environmental influence of foreign investment activities.

Energy Consumption and Economic Growth: Former studies have concluded that energy consumption (as measured by GDP per capita, population) is a major force behind global CO2 emissions. The positive relationships of the two variables emphasize the dilemma in trade off between economic development, energy consumption and environmental sustainability.

The high (UPOP) coefficient implies that CO2 emissions are significantly influenced by urbanization. This finding highlights that strategies for achieving sustainable urban development should focus on also dematerializing the scale of environmental impact, decreasing not just GDP growth but equally or more so reductions in per capita resource consumption.

R&D and Environmental Innovation: Contrary to our expectations, the analysis revealed a strong positive connection between R&D expenses of all firms (regardless their involvement in RD&I schemes) on one hand CO2 emissions, underscoring that heretofore an effort should be promoted encouraging allocation of resources towards more environment-friendly technology.

Performance of Ridge Regression: By incorporating the effect of multicollinearity and estimating the true nature between variables, more nuanced economic (anchorage dependent benefit use) and environmental modeling problem that requires decision-makers to incorporate comprehensive spatial land-use changes.

5.1 Implications of Future Research

Several facets of the study await further investigation. For example, the nature of FDI and its environmental effects needs to be understood further. Especially in industries that are seeking foreign investment may combine with existing factors to mitigate certain impacts of future urban development. Research is still needed to find out how urban planning and policy can help lessen the environmental burdens of urbanization. In contrast, the surprising relationship between R&D spending and CO2 emissions requires more detailed research on current research methods and what they cost the earth we humans live in. For instance, future Ptently and Innovation at The NIH reviews the subtleties of technological breakthroughs in terms ecological sustainability.One overarching contribution is that with this work we have in place the framework for future research into how these conditions move. Overall, this study serves to advance our understanding of the carbon emissions regulation systems in China, which provides a basis for research on these dynamics in future years.

Reference

1. Abdouli, M., & Hammami, S. (2017). Investigating the causality links between environmental quality, foreign direct investment, and economic growth in MENA countries. International Business Review, 26(2), 264-278. https://doi.org/10.1016/j.ibusrev.2016.07.004

2. Abdouli, M., & Hammami, S. (2017). The Impact of FDI Inflows and Environmental Quality on Economic Growth: An empirical study for the MENA countries. Journal of the Knowledge Economy, 8(1), 254-278. Springer; Portland International Center for Management of Engineering and Technology (PICMET). https://doi.org/10.1007/s13132-016-0418-2

3. Alfaro, L., Chanda, A., Kalemli-Ozcan, S., & Sayek, S. (2004). FDI and economic growth: The role of local financial markets. Journal of International Economics, 64(1), 89–112. https://doi.org/10.1016/S0022-1996(03)00081-3

4. Ali, N., Phoungthong, K., Techato, K., Ali, W., Abbas, S., Dhanraj, J. A., & Khan, A. (2022). FDI, Green Innovation and Environmental Quality Nexus: New Insights from BRICS Economies. Sustainability, 14(4), 2181. https://doi.org/10.3390/su14042181

5. An, T., Xu, C., & Liao, X. (2021). The impact of FDI on environmental pollution in China: Evidence from spatial panel data. Environmental Science and Pollution Research, 28(35), 44085–44097. https://doi.org/10.1007/s11356-021-13903-9

6. Angizi, S., Alem, S. A. A., & Pakdel, A. (2022). Towards integration of two-dimensional hexagonal boron nitride (2D h-BN) in energy conversion and storage devices. Energies, 15(3), 1162. https://doi.org/10.3390/en15031162

7. Bayat, T., İlarslan, K., & Shahbaz, M. (2023). How do logistics and financial indicators contribute to carbon emissions in Turkiye? Environmental Science and Pollution Research, 30, 97842–97856. https://doi.org/10.1007/s11356-023-29255-5

8. Blonigen, B. A. (2005). A Review of the Empirical Literature on FDI Determinants. Atlantic Economic Journal, 33(4). https://doi.org/10.3386/w11299

9. Brown, S., Zhang, H., & Liu, J. (2009). Foreign direct investment and environmental pollution in China: A simultaneous equation estimation. Environment and Development Economics, 14(4), 421-437. https://doi.org/10.1017/S1355770X09005128

10. Brownlee, J. (2020). How to Develop Lasso Regression Models in Python. Retrieved from https://machinelearningmastery.com/lasso-regression-with-python/

11. Caihong, T., Anitha, R., Rizwana, Y., & Yunfei, L. (2023). The threshold analysis of economic growth, FDI, and trade on the environment in China (2007-2019). SpringerLink. Retrieved from https://link.springer.com/article/10.1007/s11356-023-22065-9

12. Chen, Z., Liu, Y., & Zhang, Y. (2021). Inter-regional economic spillover and carbon productivity embodied in trade: An empirical study from the Pan-Yangtze River Delta Region. Environmental Science and Pollution Research, 28(7), 7390–7403. https://doi.org/10.1007/s11356-020-10947-1

13. Chiriluș, A., & Costea, A. (2023). The effect of FDI on environmental degradation in Romania: Testing the pollution haven hypothesis. Sustainability, 15(13), 10733. https://doi.org/10.3390/su151310733

14. Christoforidis, T., & Katrakilidis, C. (2022). Does Foreign Direct Investment matter for environmental degradation? Empirical evidence from Central–Eastern European countries. Journal of the Knowledge Economy, 13(4), 2665–2694. https://doi.org/10.1007/s13132-021-00820-y

15. Ciaburro, G., & Joshi, P. (2019). Python Machine Learning Cookbook: Over 100 recipes to progress from smart data analytics to deep learning using real-world datasets. Packt Publishing Ltd.

16. De Beule, F., & Duanmu, J. L. (2012). Locational determinants of internationalization: A firm-level analysis of Chinese and Indian acquisitions. European Management Journal, 30(3), 264-277. https://doi.org/10.1016/j.emj.2012.03.006

17. Ding, X., Chen, G., Zhang, P., Domeisen, D., & Orbe, C. (2023). Extreme stratospheric wave activity as harbingers of cold events over North America. Communications Earth & Environment, 4, 187. https://doi.org/10.1038/s43247-023-00845-y

18. Dunning, J. H., & Lundan, S. M. (2008). Multinational Enterprises and the Global Economy (2nd ed.). Edward Elgar Publishing. ISBN: 978-1847201225

19. Goerres, A., Siewert, M. B., & Wagemann, C. (2019). Internationally comparative research designs in the social sciences: Fundamental issues, case selection logics, and research limitations. Kölner Zeitschrift für Soziologie und Sozialpsychologie, 71(Suppl 1), 75–97. https://doi.org/10.1007/s11577-019-00600-2

20. Gong, M., Wang, L., & Li, X. (2023). The impact of FDI on ecologically unequal exchange in China's manufacturing industry. Frontiers in Environmental Science, 11, Article 1269691. https://doi.org/10.3389/fenvs.2023.1269691

21. Gray, P. S., Williamson, J. B., Karp, D. A., & Dalphin, J. R. (2007). Comparative research methods. In The Research Imagination: An Introduction to Qualitative and Quantitative Methods (pp. 325-348). Cambridge University Press.

22. Green Belt and Road Initiative Center. (2020). China Belt and Road Initiative (BRI) Investment Report 2020. Retrieved from https://greenfdc.org/?s=China+Belt+and+Road+Initiative+%28BRI%29+Investment+Report+2020

23. Green Finance & Development Center. (2021). China Belt and Road Initiative (BRI) Investment Report 2021. Retrieved from https://greenfdc.org/?s=China+Belt+and+Road+Initiative+%28BRI%29+Investment+Report+2021

24. Greene, W. H. (2018). Econometric Analysis (8th ed.). Pearson Education Limited, London. Retrieved from https://www.scirp.org/reference/referencespapers?referenceid=2920183

25. Guo, F., Meng, S., & Sun, R. (2021). The evolution characteristics and influence factors of carbon productivity in China's industrial sector: From the perspective of embodied carbon emissions. Environmental Science and Pollution Research, 28(50), 50611–50622. https://doi.org/10.1007/s11356-021-14271-0

26. Han, L. M., You, J. Q., Meng, J. N., Fu, Y. L., & Wu, S. L. (2023). Evaluating the Role of Research and Development Investments and Transportation Infrastructure in Shaping Carbon Emissions in China. Frontiers in Environmental Science, 11. https://doi.org/10.3389/fenvs.2023.1138876

27. Haug, A. A., & Ucal, M. (2019). The role of trade and FDI for CO2 emissions in Turkey: Nonlinear relationships. Energy Economics, 81, 297-307. https://doi.org/10.1016/j.eneco.2019.04.006

28. Hou, F., Su, H., Li, Y., Qian, W., Xiao, J., & Guo, S. (2021). The impact of foreign direct investment on China's carbon emissions. Sustainability (Switzerland), 13(21), 1–12. https://doi.org/10.3390/su132111911

29. Huang, Y. (2021). Technology innovation and sustainability: Challenges and research needs. Clean Technologies and Environmental Policy, 23(7), 1663–1664. https://doi.org/10.1007/s10098-021-02152-6

30. Huang, Y., Chen, F., Wei, H., Xiang, J., Xu, Z., & Akram, R. (2021). The Impacts of FDI Inflows on Carbon Emissions: Economic Development and Regulatory Quality as Moderators. Frontiers in Energy Research, 9. https://doi.org/10.3389/fenrg.2021.820596

31. Hyndman, R. J., & Athanasopoulos, G. (2018). Forecasting: Principles and practice. OTexts. https://otexts.com/fpp3/

32. James, G., Witten, D., Hastie, T., & Tibshirani, R. (2021). An Introduction to Statistical Learning with Applications in R (2nd ed.). Springer. Retrieved from https://link.springer.com/book/10.1007/978-1-0716-1418-1

33. Johnson, M., Li, X., & Zhou, Y. (2012). Does foreign direct investment accelerate economic growth? In the case of China. International Economics, 65(2), 123-135. https://doi.org/10.1016/j.inteco.2012.05.002

34. Jun, W., Zakaria, M., Shahzad, S. J. H., & Mahmood, H. (2018). Effect of FDI on pollution in China: New insights based on wavelet approach. Sustainability, 10(11), Article 3859

35. Khosla, I. (2021). Book review: Social research methods: Qualitative and quantitative approaches. Frontiers in Psychology, 12, 696828. https://doi.org/10.3389/fpsyg.2021.696828

36. Kirchgässner, G., Wolters, J., Hassler, U. (2013). Granger Causality. In: Introduction to Modern Time Series Analysis. Springer Texts in Business and Economics. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-33436-8_3

37. Lewis, J. I. (2013). Green innovation in China: China's wind power industry and the global transition to a low-carbon economy. Columbia University Press.

38. Liang, S., Liu, X., & Zhang, S. (2017). Foreign direct investment and environmental pollution in China: A spatial econometric analysis. Oxford Bulletin of Economics and Statistics, 79(6), 1121-1136. https://doi.org/10.1111/obes.12196

39. Li, C., Chen, Z., Hu, Y., Cai, C., Zuo, X., Shang, G., & Lin, H. (2023). Energy conservation and emission reduction are co-benefits of China's emission trading system. Scientific Reports, 13, Article 13758. https://www.nature.com/articles/s41598-023-40811-4

40. Li, C., & Tanna, S. (2019). The impact of foreign direct investment on productivity: New evidence for developing countries. Economic Modelling. https://doi.org/10.1016/j.econmod.2018.11.028

41. Liu, Y., Poulová, P., Pražák, P., Ullah, F., & Nathaniel, S. P. (2023). Infrastructure development, human development index, and CO2 emissions in China: A quantile regression approach. Frontiers in Environmental Science. https://www.frontiersin.org/articles/10.3389/fenvs.2023.1114977

42. Liu, Z., Deng, Z., Davis, S. J., Giron, C., & Ciais, P. (2022). Monitoring global carbon emissions in 2021. Nature Reviews Earth & Environment, 3(4), 217–219.

43. Nedopil Wang, C. (2023). China Belt and Road Initiative (BRI) Investment Report 2023 H1: Key findings. Retrieved from https://greenfdc.org/china-belt-and-road-initiative-bri-investment-report-2023-h1/

44. OECD iLibrary on Carbon Productivity (2017). Retrieved from https://www.oecd-ilibrary.org/development/perspectives-on-global-development-2019/the-carbon-intensity-of-economic-output-has-been-decreasing-with-gdp-per-capita_persp_glob_dev-2019-graph45-en

45. Our World in Data on Carbon Intensity, (2023). Retrieved from https://ourworldindata.org/grapher/co2-intensity

46. Pfaff, B. (2008). Analysis of Integrated and Cointegrated Time Series with R. Springer Science & Business Media. Retrieved from https://link.springer.com/book/10.1007/978-0-387-75967-8

47. Prabhakaran, S. (2019). Time Series Analysis in Python – A Comprehensive Guide with Examples. Retrieved from https://www.machinelearningplus.com/time-series/time-series-analysis-python/

48. Prabhakaran, S. (2022). Granger Causality Test in Python. Retrieved from Machine Learning Plus.

49. Puck, J., Rogers, H., & Mohr, A. (2013). Flying under the radar: Foreign firm visibility and the efficacy of political strategies in emerging economies. International Business Review, 19(3), 296-313. https://doi.org/10.1016/j.ibusrev.2013.02.005

50. Qiang, W., Ting, Y., Li, R., & Xiaowei, W. (2023). Reexamining the impact of foreign direct investment on carbon emissions: does per capita GDP matter? Palgrave Communications, 406. https://www.nature.com/articles/s41599-023-01895-5

51. Ragin, C. (1991). Comparative research methods. In The Research Imagination (Chapter 15). Cambridge University Press.

52. Sabir, S., Rafique, A., & Abbas, K. (2019). Institutions and FDI: evidence from developed and developing countries. Financial Innovation, 5, Article 8. https://doi.org/10.1186/s40854-019-0123-8

53. Saini, N., & Sighania, M. (2019). Environmental impact of economic growth, emission, and FDI: systematic review of reviews. Qualitative Research in Financial Markets. https://doi.org/10.1108/QRFM-05-2019-0054

54. Shaiful, M., & Beloucif, A. (2023). Determinants of foreign direct investment: A systematic review of the empirical studies. https://doi.org/10.1177/00157325231158846

55. Shen, Z., Zhou, Z., & Jing, H. (2024). The impact of foreign direct investment on green innovation efficiency: Evidence from Chinese provinces. PLOS ONE. https://doi.org/10.1371/journal.pone.0298455

56. Smith, J., Wang, L., & Chen, Q. (2010). The environmental effects of foreign direct investment: Evidence from China. Environmental and Resource Economics, 45(3), 457-474. https://doi.org/10.1007/s10640-010-9410-z

57. Stadler, N. (2021). Prediction and feature assessment, ridge regression, and shrinkage. https://bookdown.org/staedler_n/highdimstats/ridge-regression-and-shrinkage.html

58. Statology. (2020). Introduction to Ridge Regression. Retrieved from https://www.statology.org/ridge-regression/

59. Sibt-e-Ali, M., Xiqiang, X., Javed, K., Anser, M. K., & Zafar, R. (2024). Greening the future: Assessing the influence of technological innovation, energy transition, and financial globalization on the ecological footprint in selected emerging countries. Environmental Development and Sustainability. https://doi.org/10.1007/s10668-024-05076-5

60. Tang, D., Yi, R., Kong, H., Da, D., & Boamah, V. (2022). Foreign direct investment entry mode and China's carbon productivity based on spatial econometric model. Frontiers in Environmental Science, 10(August), 114. https://doi.org/10.3389/fenvs.2022.922151

61. Tingbo, G., Bowen, Z., & Muhammad, A. K. (2023). Have environmental regulations restrained FDI in China? New evidence from a panel threshold model. SpringerLink. Retrieved from https://link.springer.com

62. Tsoy, L., & Heshmati, A. (2023). Is FDI inflow bad for environmental sustainability? Environment, Development and Sustainability. https://doi.org/10.1007/s10668-023-03844-3

63. Wang, Q., Yang, T., Li, R., & Wang, X. (2023). Reexamining the impact of foreign direct investment on carbon emissions: Does per capita GDP matter? Humanities and Social Sciences Communications. Retrieved from https://www.nature.com/articles/s41599-023-01285

64. Wang, Y., Liu, J., Wang, J., & Liu, Z. (2023). Exploring the effect of city size on carbon emissions: Evidence from 259 prefecture-level cities in China. Environmental Science and Pollution Research International. https://doi.org/10.1007/s11356-023-28564-z

65. Xiao, Y., Gao, K., & Sun, R. (2022). Modeling the Impact of Foreign Direct Investment on China's Carbon Emissions: An Economic and Environmental Paradigm. Frontiers in Environmental Science, 10. https://doi.org/10.3389/fenvs.2022.922208

66. Xie, Q., Yan, Y., & Wang, X. (2023). Assessing the role of foreign direct investment in environmental sustainability: A spatial semiparametric panel approach. Journal Title, 56, 1263–1295. https://doi.org/10.1007/s11356-023-28105-8

67. Yang, T., Dong, Q., Du, Q., Du, M., Dong, R., & Chen, M. (2021). Carbon dioxide emissions and Chinese OFDI: From the perspective of carbon neutrality targets and environmental management of the home country. PubMed. Retrieved from https://pubmed.ncbi.nlm.nih.gov/34186314/

68. You, J., Ding, G., & Zhang, L. (2022). Heterogeneous Dynamic Correlation Research among Industrial Structure Distortion, Two-Way FDI and Carbon Emission Intensity in China. Sustainability (Switzerland), 14(15). https://doi.org/10.3390/su14158988

69. Zhang, H., Li, Y., & Tong, J. (2023). Spatiotemporal differences in and influencing effects of per-capita carbon emissions in China based on population-related factors. Scientific Reports, 13, Article number: 20141. https://www.nature.com/articles/s41598-023-47209-2

70. Zhao, Z., Shi, X., Cao, Y., & Hu, M. (2023). The impact of urban population spatial distribution on CO2 emissions in China from the perspective of individual and interactive effects. Environmental Science and Pollution Research International. https://doi.org/10.1007/s11356-023-28105-8

71. Ziwei, Z., Florian, M., Levente, D., Irfan, U., Si, X., Yao, J., Zhou, Y., & Chen, Y. (2023). Relationship between FDI inflow, CO2 emissions, renewable energy consumption, and population health quality in China (1980–2020). Frontiers. Retrieved from https://www.frontiersin.org

72. Zuo, L., Li, H., & Xia, X. (2023). An Empirical Analysis of Digital Finance's Impact on Commercial Banks' Efficiency. Sustainability (Switzerland), 15(5). https://doi.org/10.3390/su15054667