İSTANBUL TİCARET UNIVERSITY
INSTITUTE OF GRADUATE SCHOOL
DEPARTMENT OF INTERNATIONAL TRADE
DOCTORATE OF INTERNATIONAL TRADE PROGRAMME

BELT AND ROAD INITIATIVE (BRI) AND ITS ENVIRONMENTAL EFFECTS ON PARTICIPANT COUNTRIES

Ph.D. Thesis

Yunxin CHANG

İSTANBUL, 2025

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Ph.D. Thesis

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APPROVAL PAGE

ETHICS STATEMENT

I, Yunxin CHANG, certify that,

- I am the sole author of this thesis and that I have fully acknowledged and documented in my thesis all sources of ideas and words, including digital resources, which have been produced or published by another person or institution.
- This thesis contains no material that has been submitted or accepted for a degree or diploma in any other educational institution.
- This is a true copy of the thesis approved by my advisor and thesis committee at İstanbul Ticaret University, including final revisions required by them.

Yunxin CHANG

ABSTRACT

Despite the widespread recognition of the Belt and Road Initiative (BRI)'s economic potential by 152 countries since its first launch in 2013, the global exploration of its environmental effect is still insufficient. Building on the new concept of a "Green BRI," this research first analyzes the status quo of current green BRI investments and then evaluates whether China's increasing green investments and green BRI policies translate into tangible improvements in host countries' environmental performance in terms of reduction in carbon emission per capita. The descriptive analysis of green BRI investments highlights a noticeable structural shift in China's overseas investment portfolio, with green projects gaining strong momentum and an increasing percentage of total investments, accounting for around 46% in 2023. More than half of green investments are aimed at securing the critical minerals and applying them to renewable energy areas such as lithium batteries, electric vehicles, and photovoltaic products. Further, to examine whether BRI participation has reduced carbon emissions in BRI participant countries, using panel data from 102 developing countries between 2013 and 2023, this study employs Difference-in-Differences (DiD) method along with Bacon Decomposition, and Group-Time Average Treatment Effect (ATT) analysis. The findings indicate that BRI participation has generally led to a significant rise in per capita carbon emissions, particularly in regions such as East Asia and Pacific, and Middle East and North Africa, where rapid industrialization coincided with large-scale BRI projects. These results suggest a paradox: although green investment has expanded, the aggregate environmental effect of the BRI still trends negative in terms of carbon emissions. This paradox is aligned to the initial phase of Environmental Kuznet Curve (EKC). So, this study concludes that the "Green BRI" remains in a transitional phase and has not yet produced tangible reductions in carbon emissions. Further, this study emphasizes the need for future research that investigates the complex mechanism of green BRI's environmental effect and carbon footprint.

Keywords: Belt and Road Initiative (BRI), Green BRI Investments, Environmental Impacts of BRI, Carbon Emissions, BRI Economies

ÖZET

Kuşak ve Yol Girişimi'nin (BRI) ekonomik potansiyelinin 2013 yılında ilk kez başlatı lmasından bu yana 152 ülke tarafından yaygın olarak kabul edilmesine rağmen, çevresel etkisinin küresel çapta araştırılması hâlâ yeterli değildir. BRI'nin arka planı ve "Yeşil BRI" kavramı temelinde bu araştırma, öncelikle mevcut yeşil BRI yatırımlarının durumunu analiz etmekte, ardından Çin'in artan yeşil yatırımları ile yeşil BRI politikalarının, ev sahibi ülkelerde kişi başına karbon emisyonunun azaltılması açısından somut çevresel iyileşmelere dönüşüp dönüşmediğini değerlendirmektedir. Yeşil BRI yatırımlarına ilişkin betimsel analiz, Çin'in yurtdışı yatırım portföyünde dikkate değer bir yapısal değişim yaşandığını ve yeşil projelerin güçlü bir ivme kazandığını, toplam yatırımlar içindeki paylarının artarak 2023 yılında yaklaşık %46'ya ulaştığını göstermektedir. Yeşil yatırımların yarısından fazlası kritik minerallerin gü vence altına alınmasını ve bunların lityum piller, elektrikli araçlar ve fotovoltaik ürü nler gibi yenilenebilir enerji alanlarına uygulanmasını hedefliyor. Ayrıca, BRI katılımın ın BRI katılımcı ülkelerinde karbon emisyonlarını azaltıp azaltmadığını incelemek amacıyla, 2013-2023 yılları arasında 102 gelişmekte olan ülkeden alınan panel verileri kullanılarak, bu çalışmada Bacon Ayrıştırma ve Grup Zaman Ortalama İşlem Etkisi (ATT) analizi ile birlikte Farklılıklar İçinde Fark (DiD) yöntemi kullanılmıştır. Bulgular, BRI katılımının genel olarak kişi başına karbon emisyonlarında önemli bir artışa yol açtığını, özellikle Doğu Asya & Pasifik ile Orta Doğu & Kuzey Afrika bölgelerinde hızlı sanayileşmenin büyük ölçekli BRI projeleriyle örtüştüğü yerlerde bu etkinin belirginleştiğini ortaya koymaktadır. Bu sonuçlar, bir paradoksa işaret etmektedir: Yeşil yatırımlar genişlese de, BRI'nin toplam çevresel etkisi karbon emisyonları açısından hâlen olumsuz bir eğilim göstermektedir. Bu paradoks Çevresel Kuznets Eğrisi'nin (EKC) başlangıç aşamasıyla uyumludur. Dolayısıyla, bu çalışma "Yeşil BRI"nin hâlen geçiş aşamasında bulunduğunu ve karbon emisyonlarında somut bir azalma üretmediğini ortaya koymaktadır. Bunun yanı sıra, yeşil BRI'nin çevresel etkisi ve karbon ayak izi mekanizmasının karmaşık yapısını araştıracak gelecekteki çalışmalara duyulan ihtiyacı vurgulamaktadır.

Anahtar Kelimeler: Kuşak ve Yol Girişimi (BRI), Yeşil BRI Yatırımları, BRI'nin Çevresel Etkileri, Karbon Emisyonu, BRI Ekonomileri

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LIST OF ABBREVIATION

AEI	American Enterprise Institute
AIIB	The Asian Infrastructure Investment Bank
ATT	Group-Time-Average Treatment Effect for the Treated
ASEAN	Association of Southeast Asian Nations
BRI	Belt and Road Initiative
CAREC	Central Asia Regional Economic Cooperation
CDB	China Development Bank
CISL	University of Cambridge Institute for Sustainability Leadership
DiD	Difference-in-Difference
EKC	Environmental Kuznets Curve
ESG	Environmental, Social, and Governance
FCOP	Final Carbon Dioxide Emissions Per Capita
FDI	Foreign Direct Investment
GAIG	Global Artificial Intelligence Governance
GHG	Greenhouse Gas
GTFP	Green Total Factor Productivity
GI	Green Index
HGDI	Human Green Development Index
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
NDC	National Determined Contributions
NDVI	Normalized Difference Vegetation Cover
OFDI	Outward Foreign Direct Investment
PHAH	Pollution Halo Hypothesis
PHH	Pollution Haven Hypothesis
TCFD	Task Force on Climate-Related Financial Disclosures
TWFE	The Two-Way Fixed Effects
UNEP	United Nations Environmental Programme
UNFCCC	United Nations Framework Convention on Climate Change
VIF	Variance Inflation Factor

INTRODUCTION

The Belt and Road Initiative (BRI), proposed by Chinese President Xi Jinping in 2013, is a highly ambitious global infrastructure initiative aimed at stimulating economic growth across Europe, Asia, and Africa. Since 2013, BRI has gained significant recognition in the global arena, leading to its expansion across 152 nations as of February 2025 (Belt and Road Portal, 2025). It has gained significant attention in the international community due to its potential capacity to influence a 2/3 portion of the global population, over 30% of the global GDP and global trade dynamics (Chin et al., 2022). This influence is expected to be realized through the implementation of thousands of cooperative BRI projects (McBride, Berman & Chatzky, 2023). According to the international Bank (2019), the implementation of transport projects under the BRI has the potential to enhance global income by 2.9% and improve international trade by a range of 1.7% to 6.2%. Moreover, the closure of infrastructure disparities among countries may further result in a significant upsurge of around 30% in regional economies (World Bank, 2019).

This massive plan is officially referred to as the “One Belt and One Road Initiative” (OBOR), including the territorial components known as the “Silk Road Economic Belt” and the “21st-century Maritime Silk Road” (Hughes et al., 2020). Scholarly literature and reports usually use the abbreviated term “Belt and Road Initiative” (BRI) and this paper also adopts the abbreviation of BRI.

Given the unprecedented scale of BRI, promoting BRI host countries’ economic development while protecting the local environment is a significant challenge. So, extensive discussions have emerged within the international community regarding the environmental effect of BRI. Specifically, construction projects may lead to environmental degradation, including roadkill incidents, alterations in migration patterns, and loss of indigenous populations (Teo et al., 2019). Besides, many BRI

countries are facing significant environmental challenges due to their ecological vulnerability.

However, BRI countries are richly endowed with natural resources. As major global suppliers, BRI countries hold a considerable share of the world's copper, recoverable oil, and recoverable natural gas reserves, which represent 48%, 66%, and 65% of the global totals, respectively (Du et al., 2022). Thus, mineral resources are abundant in BRI countries where they possess 42% of global mining areas (Chen et al., 2022). These resource endowments can greatly promote international cooperation for resource exchange among BRI countries. Beyond resource exchange, the BRI platform has potential to serves as an opportunity to improve environmental quality through BRI shared governance, green infrastructures, and improved environmental facilities (Coenen et al., 2021). Overall, despite that BRI poses some challenges to environmental protection, it can still provide opportunity to enhance environmental governance among BRI participant countries.

To date, much of BRI research has focused on the geopolitical influence and increasing soft power of China. But the environmental impacts of BRI have received relatively insufficient scholarly attention. Existing studies of BRI's environmental impacts are primarily focused on the impact of individual BRI projects in specific countries or isolated aspects of China's OFDI (Beeson, 2018; Miao, 2021; Turcsanyi & Kachlikova, 2020). For instance, one study is focused on BRI's particular effect on biodiversity in a specific region of Southeast Asia (Campos-Arceiz et al., 2020). In this case, the holistic environmental effect of BRI participation on the overall host countries remains significantly under-researched. There is no consensus in the existing BRI literature as to whether joining the BRI will have a negative or positive impact on the participating countries. So, this study focuses on the new concept of "green BRI" and evaluates the environmental effects of the BRI over the last decade in terms of carbon reduction,

aiming to close the current literature gap and explore whether green BRI has down to ground and generate tangible effects.

Based on green policies and increasing green BRI investments, this research proposed a hypothesis that BRI participation has an overall positive effect on carbon emission reduction in BRI partnering countries. To test this hypothesis, the quasi-experimental study of difference-in-difference (DiD), Bacon-decomposition analysis, and Group-Time-Average Treatment Effect (ATT) are employed to estimate the overall BRI's effect. Panel data for 102 countries from 2013 to 2023 is used to estimate empirical results. Later, a thorough discussion over empirical results and relative theories is presented, followed by several case studies illustrating some real cases of green and non-green BRI projects. This research contributes to the literature of green BRI and BRI's environmental effects, laying a significant foundation for further researchers to study the deeper mechanism of how green BRI is transformed from words to actions and how the environmental effects of BRI have changed over the years since its inception.

1. BELT AND ROAD INITIATIVE (BRI)

Backing to history, the BRI is not a brand-new concept, as it can be traced to the ancient Silk Road, which existed in history from the 2nd century BC to the 19th century AD (Peters, 2021). In the contemporary age, China's president brought about the rebirth of the Silk Road in the year 2013 and renamed it the Belt and Road Initiative (BRI). Since then, it has triggered significant interests and diverse reactions in global society. This part is designed to provide a comprehensive background of the BRI proposal. This study will delve into the historical origins of the ancient BRI, China's motivations for reviving the initiative, the contents of the BRI overarching framework, and some concerns about its potential negative effects.

1.1 Ancient BRI in History

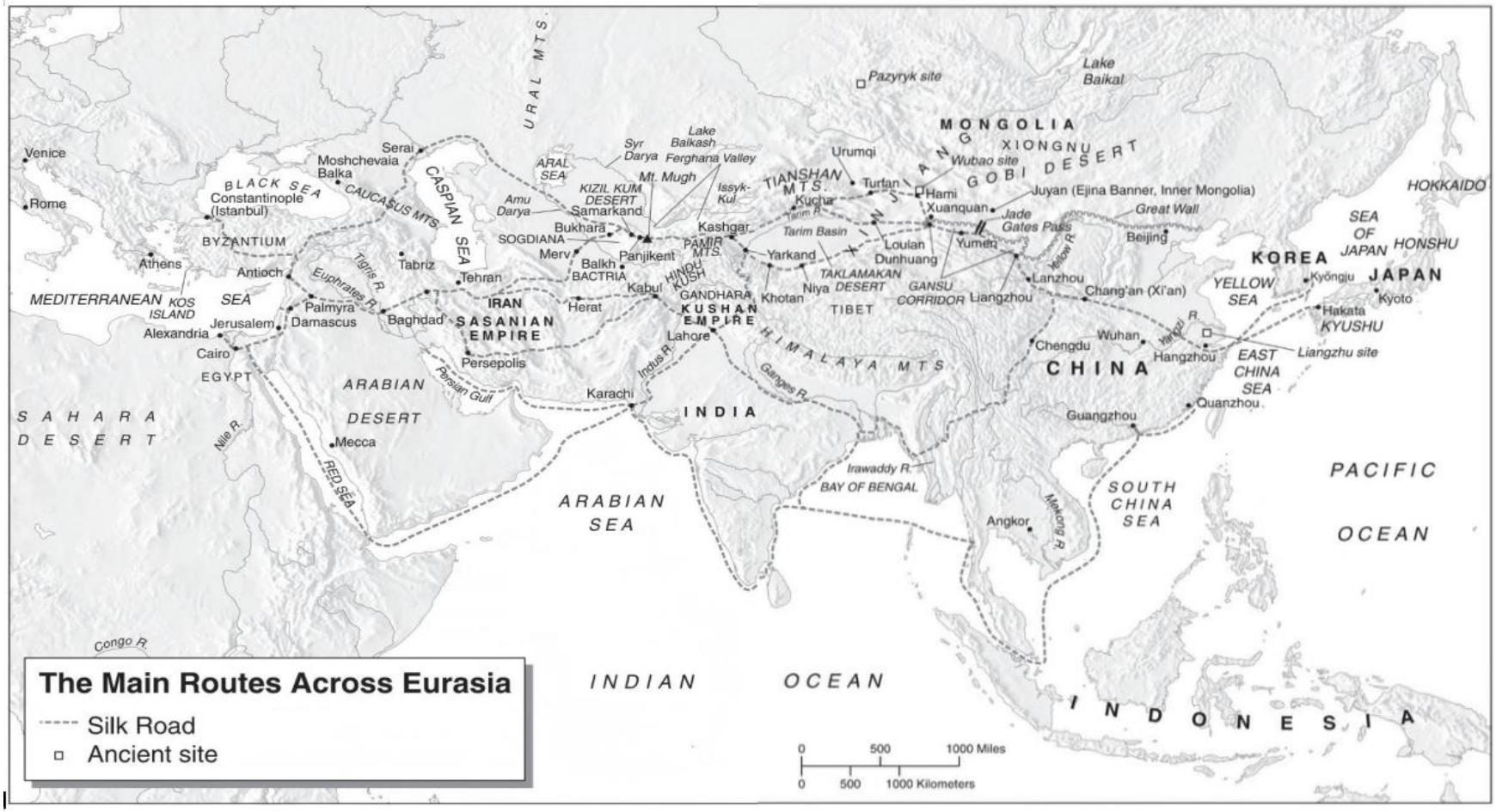
The Silk Road, a significant historical route connecting Western and Eastern civilizations for nearly two millennia, is commonly referred to as the "Silk Road," serving as the foundational precursor to the present-day BRI. The archaeological evidence pertaining to silk artifacts discovered in Central Asia, originally coming from the agricultural civilization of East Asia, exquisitely indicates that sporadic and dispersed trade activities took place in the steppe regions as early as the 10th century BC (Liu, 2010). During the Han dynasty in China (202 BCE -CE 220), the ruler, aiming to defense against the north nomadic Xiongnu tribes, dispatched a national ambassador named "Zhang Xian" to visit the neighboring kingdoms in central and western Asia (Hansen, 2012). The objective was to establish alliances with other kingdoms and obtain robust horses for military purposes in Han dynasty (Benjamin, 2018). According to Millward (2013), the Ferghana horses were frequently brought by Han in a significant amount. As trading exchanges, a great quantity of silk was also sent to the regions of Middle and West Asia in return for horses (Millward, 2013).

During the 2nd century BC, the Seleucid Empire was powerful and prosperous country with a long-term social stability. In this situation, citizens are longing for a better quality of life, thus increasing their demand for consumption (Peters, 2021). This stimulated the thriving of commerce of rare and luxury products from the Far East, such as silk and porcelain, which highlight their social status (Peters, 2021). The wearing of silk has been a prominent fashion trend among girls in Roma, as noted by Liu (2010). Subsequently, the Silk Road has experienced substantial commercial activities between the Eastern and Western regions. The below figure illustrates the vast and interconnected network of the Silk Road that connected Chang'an (now known as Xi'an, China) all along the way to major urban centers such as Rome and Constantinople (present-day İstanbul, Türkiye), passing through many countries in the Central Asia region (Liu, 2010).

The route spanned several geographical continents, including the Qinghai-Tibet Plateau in Tibet, the Pamir Plateau, the Iranian Plateau, the Anatolia regions, and extensive desert areas. Especially in the desert, the Silk Road witnessed a substantial presence of camels because camels are able to endure extreme long journeys and have resilience in the face of drought conditions. Over millennia, the route is not only services as a vital commerce corridor but also functioned to exchange cultures, technologies and faiths. For instance, the introduction of Christianity and Buddhism to China and the China's printing technology dissemination in Europe are notable cases (Foltz, 1999).

During the 15th century, with the decline of the Roman Empire and the rise of the Ottoman Empire and the Mongol Empire, unremitting wars and conflicts had interrupted trades along the Silk Road (Jeong, 2016; Biran, Brack, & Fiaschetti, 2020). In subsequent periods, there was a remarkable advancement in shipbuilding technique, which led to a significant growth in maritime trade (Nolan, 2015). An example was that Zheng He in the Ming dynasty of China undertook the maritime expeditions,

commencing in 1405 (Nolan, 2015). These journeys open the subsequent trading sea routes reaching to South Asia, Malaysia, the Arabic region, and East Africa (Nolan, 2015). Furthermore, a Spanish navigator Christopher Columbus, started on his transatlantic voyage in 1492, ultimately leading to the discovery of the new continent of America. The substitution of the land silk route by the maritime road has been partly attributed to the relatively lower cost of shipbuilding and maritime trading. Despite disruptions of the Silk Road due to continuous regional conflicts and global wars, the route's fundamental principles of peaceful collaboration, openness, and mutual learning and benefits has became a long-lasting and significant legacy of human civilization. In 1877, a German geographer Lichhofen recorded this land commercial route connecting the eastern and western regions in his publication, appeared as the "Silk Road" (Dong, 2019). Afterwards, this trading route has a splendid name of "Silk Road". The ancient silk road map can be found in the following figure 1.



Source: Hansen, 2012.

Figure 1. The Ancient Silk Road

1.2 Global Economy and Infrastructure Need

Following financial crisis in 2008, there was a notable deceleration in the expansion of the global economy. Based on the study published by the United Nations, it is evident that the global economy experienced a significant decline in 2012 and is projected to persist in this weakened state throughout the forthcoming years (United Nations, 2013). According to the United Nations (2013), developing countries face a significantly slower pace in their efforts to alleviate poverty. The deceleration of the global economy can be partially attributed to the protectionist stance adopted by numerous countries with regards to international commerce. According to Liang (2012), the financial crisis is commonly attributed to globalization, as it can intensify the financial contagion effect. The rise of protectionist policies in response to unrestricted globalization has resulted in an increase in trade barriers within the global trade system. It has been documented that over 7,000 discriminatory interventions have been introduced worldwide since 2008 financial crisis (Kutlina-Dimitrova & Lakatos, 2017).

Another potential factor that may have contributed to the global economic showdown is the presence of disparities in regional growth. According to Raffer and Wolfgang (2002), there is a significant disparity in the distribution of global economic power due to various factors including geography, historical events, colonization, limited resources, conflicts, and structural reforms. As an illustration, some industrialized nations are entering the phase of post-modernization, advocating for reduced consumption and the preservation of the environment. Nevertheless, some developing nations continue to struggle with the challenges of widespread hunger and poverty, impeding their progress in initiating processes of industrialization and modernization. From a geographical perspective, several nations in Asia and Africa possess abundant natural resources and factor endowments and they express a strong aspiration to engage in the global value chain. But they continue to face challenges in terms of governance and economic development. Therefore, the full exploitation of the global economic potential is

contingent upon the cooperation and connections among various countries, through bridging the gaps between regions by transportation and energy networks.

Since BRI primarily focuses on infrastructure development, it is necessary to conduct a comprehensive analysis of the global demand for infrastructure. Based on the current trajectory of population growth and economic development, it is predicted that the global infrastructure sector will likely need a substantial surge in investment, amounting to approximately 94 trillion dollars by the year 2024 (Global Infrastructure Hub, 2018). Furthermore, an additional 3.5 trillion dollars will be required to effectively address the sustainable development objectives outlined by the United Nations. According to Mckinsey (2016), a comparable assessment suggests that to sustain the present growth pace, the worldwide community will require an annual sum of 3.3 trillion dollars from 2016 to 2030. Furthermore, it is observed that emerging nations account for around 60% of the total global infrastructure demands. Currently, global investment in infrastructure development is at an average of 2.5 trillion dollars, a figure that significantly falls short of the expanding global demand of 3.3 trillion dollars (McKinsey & Company, 2016). In the context of Asia, where clusters of growing countries are prevalent, the consideration of climate change necessitates a substantial investment of 26 trillion dollars. This investment amount is required to adequately address the provision of critical living services, including transportation, electricity, telecommunication, and other related sectors (Asian Development Bank, 2017). In this particular scenario, the provision of financial resources from the BRI, particularly for the Asian region, has the potential to significantly address the substantial infrastructure deficits. This potential can be fully exploited through the allocation of funds towards the development of high-quality and cost-effective infrastructure projects. By doing so, the objective of sustaining economic growth and alleviating severe poverty may be effectively achieved in the future.

1.3 China's Motivations for BRI

China is the initiator of the BRI strategy in 2013. So, analyzing the fundamental factors that have led to this decision is essential to understand the overall BRI background. This section examines the various motivations of China to re-initiative the BRI.

Firstly, from the perspective of economic factors, China has experienced a considerable development in its economic prowess, becoming the second largest global economy in terms of total GDP, following the United States. According to Heston et al. (2008), the GDP per capita of China had a notable increase from 2.7% to 15.7% of the GDP per capita of the United States during the period spanning from 1978 to 2005. Additionally, China possesses a substantial volume of foreign exchange reserves, estimated at approximately 3.82 trillion dollars in the year of 2013, reaching the peak of 8.84 trillion in 2014, as shown in figure 2. This significant reserve has laid a solid foundation for BRI proposal and enable to financially support substantial overseas investments (World Bank, 2014). In the geopolitical aspect, China, as an emerging economy, intend to twist the global framework toward a more favorable playground beneficial to developing nations (Gu et al., 2008). According to Swaine (2015), the BRI serves as a strategic approach for China to utilize its economic power and expand its influence across the Eurasian region. This BRI initiative aims to achieve long-term and reciprocal benefits for all participant countries. As the BRI mission stated, it is dedicated to establishing a mutually beneficial "community of interests" that enhances economic connections between China and its neighboring nations through numerous infrastructure investments and other cooperation.

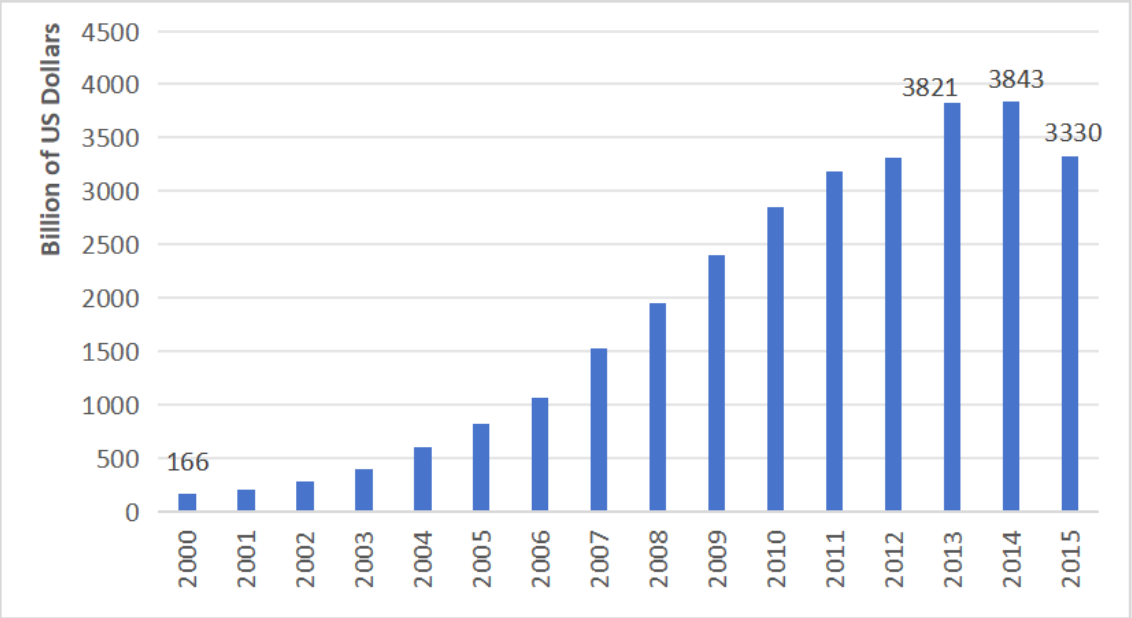


Figure 2. The Scale of China's Foreign Exchange Reserves

Source: State Administration of Foreign Exchange, 2018.

Secondly, from the aspect of China's reform, the BRI is regarded as a significant strategy aimed at furthering China's economic and foreign policy reforms, which have been started and kept evolving since its inception in 1979 (Swaine, 2015). In the context of economic reform, a specific strategy known as the "going out" policy was introduced and emphasized in 2000. This policy aimed to encourage Chinese enterprises to engage in foreign direct investments to advocating international openness. These policies' primary objective of engagement in foreign investment is to identify acquire additional resources, assets, markets, and political advantages (Shen & Mantzopoulos, 2013). Moreover, the BRI holds significant prominence within China's 13th and 14th Five Year Plan, which serves as a guiding framework for the country's overall development trajectory. Therefore, BRI holds considerable importance in terms of guiding national investment on a global scale. So, President Xi (2017) delivered following sentences in the 19th National Congress of the Communist Party of China that: *"We should pursue the Belt and Road Initiative as a priority, give equal emphasis to "bringing in" and "going global", follow the principle of achieving shared growth through discussion and collaboration, and increase openness and cooperation in building innovation capacity."*

Thirdly, during the 2000s, there was a significant increase in the occurrence of brutal crimes along national borders. This promotes the proposal of the BRI, which aimed to foster collaboration among neighboring nations in order to battle criminals (Yu, 2018). The BRI has emphasized the need for transnational collaboration among all nations involved in the BRI to address "three evil": violent terrorist forces, national separatist forces, and religious extremist forces (Clarke, 2018). Cross-broader efforts in the BRI platform have enhanced governance and achieved better safety and security (Clarke, 2018). These collaborations brought significant advantages for China, as it contributes to the enhancement of national security and social stability, both of which are crucial for fostering economic growth.

Fourthly, energy and food security are considered to be interconnected issues within the BRI. As well recognized, the provision of energy plays a pivotal role in driving national growth. China has experienced a significant increase in energy demand since the onset of industrialization in the 1980s. So, ensuring a secure and reliable source to import these crucial strategic commodities such as food and energy is a solid requirement to be satisfied for China to promote economic growth. Therefore, it is clearly stated in the China's 13th Five Year Plan (2017) that *"We will accelerate the construction of strategic land corridors for importing oil and gas. We will actively pursue agricultural co-operation and development overseas though BRI."*

Fifthly, the most obvious objective of the BRI is to facilitate and enhance regional cooperation and integration. However, prior to the initiation of the BRI, a preexisting network had already existed among several nations involved in the initiative over ten years. This network primarily focused on the exchange of infrastructure-related commodities and services (Constantinescu & Ruta, 2018). According to Swaine (2015), BRI does not aim to replace existing systems but rather seeks to enhance them by establishing complementary relationships and generating synergistic effects. Recent years, Asian countries are undergoing varying degrees of industrialization and modernization but have a large disparity in resource availability. So, BRI is designed to

promote facility connectivity, which aims to address the issue of imbalanced growth across different sub-areas of Asia (Cheng, Song, & Huang, 2017). Linked infrastructures can stimulate nations to actively engage in the cross-countries trade of products and services. Besides, the "16+1" institutes in 2012 exhibited a clear alignment with the objectives of the BRI, both aiming to enhance regional collaboration. Furthermore, based on the close culture distance, establishing a strong affiliation with neighboring partners is highly possible. It can also facilitate the development of a shared sense of identity in the Asia continent. Apart from Asia, some European countries are located in the silk route. So, to get access to the western market, the internationalization through BRI platform is seen as an inevitable step for China.

Sixth, a significant driving force of BRI is closely linked to the China's efforts to reconfigure the industrial landscape. Because of China's socialist economic system, the economy is characterized by a prevailing presence of public ownership. While this arrangement has led to acute economic growth, it has also resulted in difficulty related to capital misallocations and a lower efficiency in resource allocation. To solve this problem, privatization was initiated in 1978 in a slow process with the aim of promoting efficiency enhancement, which improves company's productivity (Cao, 2000). After privatization, with significant improvement in production efficiency, corporations have experienced huge increases in their capacity and have been able to establish economies of scale. However, the constrained market demand fails to exhibit commensurate growth with the supply generated by enterprises, resulting in a pronounced market imbalance tilted towards an excess of supply rather than demand (Boulter, 2018). For example, China has made significant progress in the development of infrastructure, particularly in the areas of high-speed railways, bridges, and subways, reaching a high level of maturity by 2013. The data provided by the World Bank (2014) indicates a clear increase in the overall lengths of high-speed rail systems from 2008 to 2013, with the figures rising from 128 to 672 meters. In response to this issue, China implemented the "Supply-side structural reform" strategy, which encourages enterprises to decrease their

inventory, leverage, and average costs (Jiang, 2021). Present Xi (2017) also points out that: *"We should pursue supply-side structural reform as our main task, and work hard for better quality, higher efficiency, and more robust drivers of economic growth through reform."*

In this case, the BRI is regarded as a potential resolution for Chinese enterprises seeking to access broader markets and use their surplus capacity and labor force to sustain their growth trajectory (Jiang, 2021). There are some theories of international trade supporting the rationale of this motivation. According to Stigler (1958), with an increase in the scale of production, there is a corresponding decrease in the average cost of a single product due to enhanced efficiency. These economies of scale theory in China have led to the production of commodities at a low average cost. Therefore, Chinese products enjoyed a great price competitiveness in the global market, stimulating goods export to other nations through BRI platform.

Another relevant theory is products' value chain. Labor-intensive products derive their principal value from the utilization of low-cost labor. The profitability associated with the exports of labor-intensive goods is quite modest. According to theory of the value-added chain, the value derived from the processes of assembly and production is significantly smaller in comparison to the value attributed to innovative design and brand. China has comprehensively acknowledged this scenario and possesses a strong desire to ascend its place within the higher value chain. In this case, China introduced a comprehensive national initiative known as "Made in China 2025" in 2015. The primary objective of this plan is to foster advancements in high-tech industries, including computer chip manufacturing and next-generation information technology, with the ultimate goal of establishing China as a hub for innovative production. Hence, the BRI is widely considered as a favorable platform for relocating the basic manufacturing sector to other emerging economies and advancing its own sectors to a higher value chain. According to a study conducted by Nugent and Lu (2021), an examination of China's external foreign direct investment (FDI) reveals a notable rise in

outflow investment in manufacturing industries which regarded to have excessive production capacity and potential harmful environmental effect.

For the purpose of upgrading industry, the theory of the technology gap can provide additional support for the motivation of BRI in terms of facilitating the transfer of high-tech products to other nations. High-tech products, like other products in their life cycle, can provide the country of their initial invention with a competitive advantage in terms of generating significant revenue from the global market due to their early entry timing (Posner, 1961). Typically, countries that are more innovative tend to have superior performance in terms of exporting, as compared to countries with similar factor endowments. However, this advantage is transient, as other nations acquire the capability to replicate, learn and be able to independently manufacture high-tech products. Recent years, China has emerged as a global leader in various technologies, including 5G technology, solar power cells and ultra-high voltage lines. These technological advancements are expected to bring China great early-mover benefits, and the BRI serves as a valuable platform for China to effectively capitalize on these advantages.

The seventh point of motivations of BRI is associated with China' desire for its culture recognition in the international community. China has a strong impetus to enhance its soft power, Chinese civilization and culture. Chinese culture distinguish itself from the majority of other countries, especially western countries. The significance of obtaining culture recognition has been underscored by earlier studies, which have highlighted the problems of culture shock encountered by Chinese enterprises operating in other countries (Weng et al., 2021). Therefore, promoting mutual understanding of culture difference through a shared platform is extremely important. And BRI can significantly facilitate the communication and spread of Chinese culture.

Eighth, China aims to mitigate the income inequality and foster a more balanced economy by addressing the disparities between its western and eastern regions. China

has generated a significant and persistent economic development disparity since the commencement of the Reform and Open program in 1978 (Zhao & Tong, 2000). The western regional provinces, comprising 12 provinces (Tibet, Qinghai, Ningxia, Gansu, Guizhou, Xinjiang, Yunnan, Chongqing, Shanxi, Sichuan, Inner Mongolia, Guangxi), as defined in the China's "Go west program", include around 56% of the total land area (Lin & Chen, 2004). However, their contribution to the national GDP in 2002 amounted to only 14.8%, which is almost one-fourth of the GDP generated by the eastern provinces (Lin & Chen, 2004). The figure 3 illustrates a significant disparity between the province of Tibet, characterized by lower economic conditions, and the province of Guangdong, which exhibits higher levels of economic prosperity. Therefore, Chinese government has fully realized that it is imperative to reduce the income inequality and they're clearly stated in the 19th Party Congress Document that *"We will strengthen measures to reach a new stage in the large-scale development of the western region."* (Xinhua, 2017).

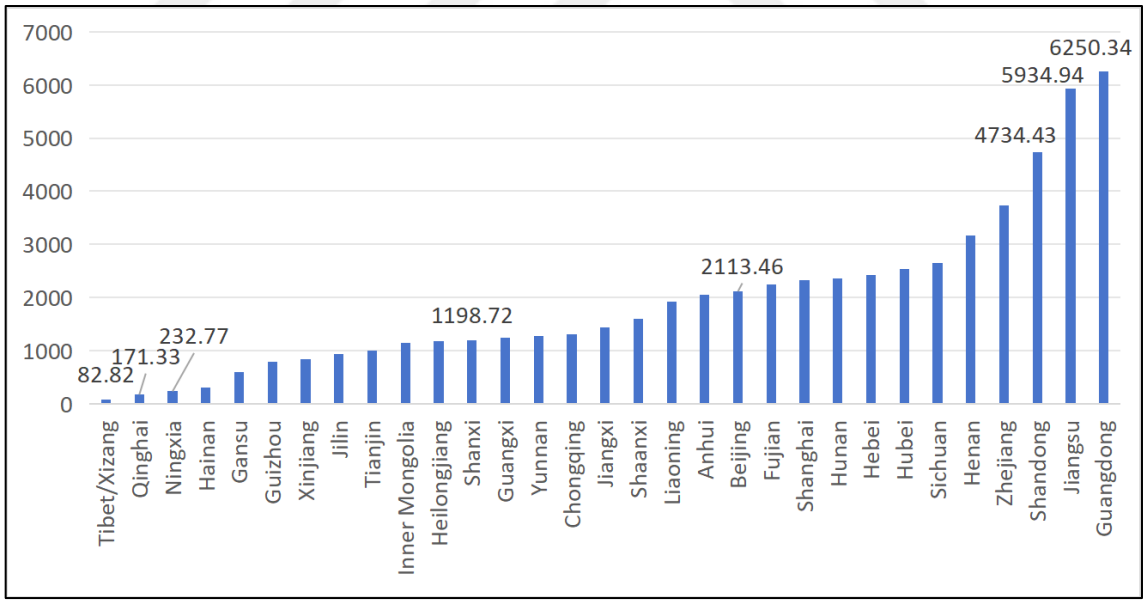


Figure 3. The Provincial GDP of China in 2013

Source: National Bureau of Statistics of China, 2024.

1.4 BRI Framework and Purpose

Generally, the BRI is a strategic global initiative aimed at fostering collaborations between China and the countries along its route. Its primary objectives are promotion of shared prosperity, peace, mutual understanding, enhanced friendship, and trust (Huang, 2016). In contrast to the European Union, the BRI does not fall under any economic integration stages, not the customs union or a common market. Bilateral cooperation agreements between China and other BRI participating countries are contingent upon the existence of mutually signed documents (Wang, 2022).

The overarching structure of the BRI encompasses a significant vision, three prominently emphasized principles, five distinct objectives, six modes of transportation, and six economic corridors. The BRI is characterized by a visionary goal of *establishing an international community that shares common interests, destiny, and responsibilities* (Zhai, 2018). The BRI is grounded in the conceptual principles of peaceful cooperation, openness, inclusivity, and mutual learning and benefit (Belt and Road Portal, 2023). Drawing on the aforementioned concepts, a set of five significant objectives are formed, namely: unhindered trade, the advancement of infrastructure, political discourse, financial integration, and fostering interpersonal connections.

In the context of infrastructure development, significant emphasis is placed on six distinct modes of transportation, namely highway, railway, maritime, aviation, pipeline, and space integrated information network (Belt and Road Portal, 2023). Regarding the geographical distribution of roads under the BRI, it is worth noting that it has six distinct economic corridors, in addition to the prominent Silk Road Economic Belt and Maritime Silk Road. The detailed road is visible in the figure 4 and the six corridors are explained in the text below.

New Euroasia Land Bridge: The proposed bridge aims to establish an extensive railway network connecting China and Europe, spanning over Kazakhstan, Russia, and Belarus.

This ambitious endeavor is characterized by its substantial scale and length. The primary objective of this economic corridor is to enhance the frequency of rail services connecting China and Europe. Notably, this initiative aligns with the path of the renowned train transportation system known as the "Euroasia Express," which benefits from favorable customs processes.

China-Mongolia-Russia Corridor: This economic corridor is a new steppe road where the main objective is to develop Mongolia's transportation, energy and information network and build it a hub facilitating international trades among China, Mongolia and Russia.

China-Central Asia- West Asia Corridor: This economic corridor is the most historical road because it coincides the route of ancient silk road. It connects Xinjiang province of China to the countries of Mediterranean Sea, though Kazakhstan, Tajikistan, Uzbekistan, Turkmenistan, Iran and Türkiye. Certainly, it is trying to create more opportunities of regional cooperation that connects central Asia and west Asia countries and share economic development together.

China-Indochina Peninsula Corridor: This economic corridor is designed to revitalize economy and strengthen cooperation in the Greater Mekong subregion by highway, railway and airway. Besides, it can support the existing free trade agreement among China and ASEAN members (including Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Viet Nam).

Bangladesh- China-Myanmar Corridor: This economic corridor holds the potential to foster mutual collaboration among the nations of Myanmar, China, India, and Bangladesh. However, because of Indian's refusal to join the BRI, the potential of this corridor remains mostly untapped.

China Pakistan Corridor: This economic corridor connects Xinjiang Province of China to Gwadar port of Pakistan. It includes building infrastructure networks, constructing an international airport in Gwadar and establishing the special economic zone.

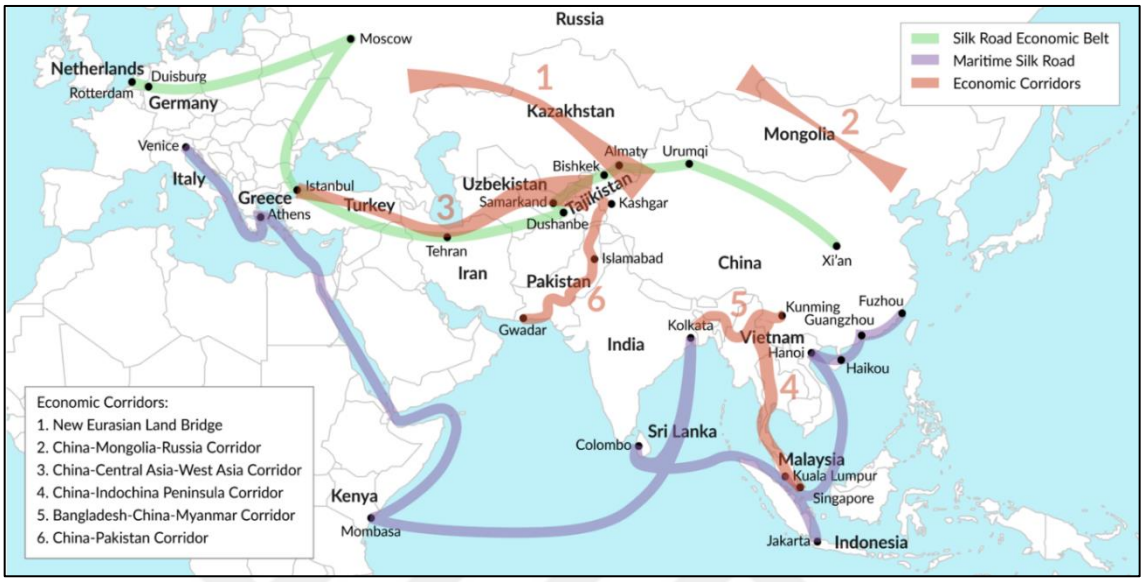


Figure 4. Modern Silk Road and Corridors

Source: Chaudhuri, 2019.

Since BRI has the potential to benefit worldwide infrastructure significantly, stimulating the global economy, fostering a global free trade regime, encouraging globalization and cultural interchange (Swaine, 2015), in the 2017 Belt and Road Forum, To stress the design and functionality of the BRI, President Xi outlined five key aspects of BRI's expected future outlook, during the 2017 Belt and Road Forum, (Xinhua, 2017).

Peace: *"We should build the Belt and Road into a road of peace. All countries should respect each other's sovereignty, dignity and territorial integrity, each other's development paths and social systems, and each other's core interests and major concerns."*

Prosperity: *"We should build the Belt and Road into a road of prosperity and achieve economic integration and interconnected development and deliver benefits to all."*

Opening up: *"We should build the Belt and Road into a road of opening up. Opening up brings progress while isolation results in backwardness."*

Innovation: *"We should build the Belt and Road into a road of innovation. Innovation is an important force powering development."*

Connecting different civilizations: *"We should build the Belt and Road into a road connecting different civilizations and ensure that when it comes to different civilizations, exchange will replace estrangement, mutual learning will replace clashes, and coexistence will replace a sense of superiority."*

In general, the forums have arrived at a consensus that the primary objective of BRI is to facilitate the deepening of market integration, promote the free trade of production factors, enhance the efficiency of resource allocation, and strengthen connectivity and partnerships with all countries. Through the BRI, individuals from diverse nations are anticipated to develop a mutual understanding of other countries' cultures, achieving a coexistence in a state of harmony and prosperity.

1.5 International Concern of BRI Impact

Since its announcement, countries have exhibited varying attitudes toward BRI activities. Certain nations are expressing concerns about this worldwide ambitious endeavor. For instance, western nations tend to perceive the BRI as a means for China to advance its geopolitical agenda and assume global leadership (Beeson, 2018). Conversely, many developing countries view the BRI as a chance or platform to bolster worldwide connectivity and integrate themselves into the global supply chain (Zhang, 2018). In addition, it is noteworthy that western mainstream media even used the term "China's Marshall Plan" to convey their interpretation of the perceived threat (Curran, 2016). In fact, the Marshall Plan was a significant initiative introduced in the aftermath of World War II, which aimed to stimulate economic investments and reconstruction of European nations. United States government provided funds to support the

reconstruction in Europe, being identified to balance the influence of the USSR (Leffler, 1988).

Nevertheless, a scholarly investigation highlights the distinctions between the BRI and the Marshall Plan regarding their respective objectives and global context (Shen & Chan, 2018). Furthermore, the Belt and Road project is not the sole international commerce and cooperation project. China is actively encouraging the engagement of the international community in the BRI, while other nations such as the United States, European Union, and various countries are also considering their own policies to strengthen regional cooperation. Examples of these initiatives include the United States' "Build Back Better World" and the European Union's "Global Gateway". According to Zhang (2018), this will enhance the perception of geopolitical competition on a global scale.

Apart from geopolitical competition, the international community has also expressed worries on the debt vulnerability of the countries involved. Concerns have been raised regarding the potential detrimental impact of the BRI on the debt sustainability of recipient countries because of financial debts. According to Bandiera and Tsiropoulos (2020), a study revealed that a significant number of the examined countries involved in the BRI were already experiencing high levels of debt vulnerability prior to BRI investments and debt financing. Because of this, the anticipated growth in infrastructure investments during the medium-term period of 2019-2034 would not be fully realized (Bandiera and Tsiropoulos, 2020).

It is notable that BRI investments include certain risks and financial fees in the form of interests. According to the OECD assessment published in 2018, the BRI is associated with significant debt risks due to a substantial proportion of BRI countries being classified as having unreasonable credit ratings. Typically, credit rates are utilized as a means to assess a country's ability to timely repay its debt. An essential foundation is the suggested investment threshold, denoted as BBB- (OECD, 2018). The report

revealed that among the group of nations participating in the BRI, only 17 economies have attained or surpassed a credit rating of BBB- (OECD, 2018). Conversely, 29 economies fall below the BBB- grade, while 14 countries lack any assigned credit ratings (OECD, 2018). Hence, there exists a strong probability that the debt acquired by some BRI participating countries may not be entirely discharged.

What's more, the international community has triggered an extensive discussion over BRI's potential environmental degradation that may arise from the infrastructure construction projects. Undoubtedly, the BRI has resulted in some direct ecological consequences, including roadkill incidents, alterations in migration patterns, and the loss of indigenous populations (Teo et a., 2019). In addition to these direct impacts, Hughes et al. (2020) have identified other indirect influences in both environmental and societal contexts. In central Asia, the BRI traverses numerous vulnerable aquatic ecosystems, where the extraction of groundwater is expected to increase due to the need for infrastructure development and mining activities (Hughes et al., 2020). This phenomenon could result in the depletion of groundwater resources and contamination of subsurface water sources through the reversal of pollutants from surface water.

Another illustrative case has happened in Arctic regions. Due to global warming, the Arctic ice cap is undergoing a process of thawing, hence becoming maritime transportation feasible in the region. Subsequently, the "Polar/Arctic Silk Road" activities were ongoing, with extraction of natural gas, oil, and various resources. These extractions involved the deployment of several icebreaking tankers specifically designed for the transportation of liquefied natural gas (LNG) (Hughes et al., 2020). However, such activities had the potential to damage the delicate Arctic ecology and adversely impact the indigenous tribes residing in the region (Hughes et al., 2020). Previous studies have already identified eleven indirect environmental consequences of the BRI, including detrimental effects on biodiversity, bacterial populations, coastal regions, desertification, politically contested areas, and others.

1.6 BRI Development Over 10 Years

Starting from 2003, the BRI has undergone a decade of development. Throughout this period, China and BRI countries have actively sought to explore effective and efficient ways to engage into various international collaboration. Despite encountering numerous challenges during the implementation phase, the BRI has made some significant progress. This section is an introduction to several dimensions of BRI developments, including policy connectivity, infrastructure connectivity, trade connectivity, finance connectivity, people-to-people connectivity, and distressed assets.

Policy Connectivity

In terms of policy connectivity, China has made attempts to establish communication mechanisms and policy coordination with other participating countries and global organizations. These efforts aim to harmonize strategies for development, as well as trade and investment administration norms.

China has organized the Belt and Road Forum for international cooperation on four occasions respectively in the year of 2013, 2017, 2019 and 2023. This communication channel has played a significant role in promoting the sharing policies and mutual trust among participating nations. According to a report by Xinhua News in 2023, each forum witnessed a notable increase in the number of participating countries and representatives. This collective engagement resulted in the formulation of over 1000 tangible BRI cooperative measures. It is noteworthy to observe that the third Forum has indicated a change in the investment techniques employed by Chinese outbound enterprises (Avdaliani, 2023). Furthermore, these Forum are platforms to instill new ideas into the BRI. For example, a recent declaration has been issued on the establishment of the Global Artificial Intelligence Governance (GAIG) in response to the limitations imposed by the United States on China's access to advanced and sophisticated semiconductor chips for technological advancements. Besides, several new purposes of BRI are proposed such as building the Europe-Asia logistic corridors

and the Silk Road E-commerce Zone, emphasizing on green development, facilitating cultural exchange, and tourism (Avdaliani, 2023).

Regarding policy coordination, at the global level, there is the *United Nations Security Council* recognizing the importance of the BRI and advocating for increased regional collaboration. The World Health Organization has entered into a formal agreement with the China about the BRI. In order to foster investments, China has played a facilitating role in the establishment of an important international framework known as the "Investment Facilitation for Development Agreement" within the WTO. The objective of this agreement is to establish a harmonized system for managing investments across approximately 110 nations. Furthermore, In the national level, to generate mutual benefits, BRI has aligned itself with some other countries' strategic objectives. For instance, it is aligned with Mongolia's Steppe Road plan, Russia's Eurasian Economic Union framework, Saudi Arabia's Vision 2030, Türkiye's Middle Corridor, and so on.

Infrastructure Connectivity

A better infrastructure connectivity is fundamental for facilitating trade, thus becoming a primary objective of the BRI, aiming to construct six distinct modes of transportation to achieve this objective. In the following texts, this study examine the accomplishments of the BRI in the realm of infrastructure development over a decade, focusing on the land economic corridor, maritime belt, and air connectivity.

As stated in the official publication of the 3rd BRI Forum, there are significant advancements in the development of infrastructure networks, including international routes and power plants. For example, the Mehra DC energy transmission project and the Kalot Hydropower Station are operating efficiently (Belt and Road Forum, 2023). The Sahiwal coal-fired power facilities along the China-Pakistan Corridor are currently functioning without any disruptions (The Daily CPEC, 2023). In addition, both the Lahore Orange Line Metro and the Karakoram Highway in Pakistan are contributing to a more efficient transportation system (People's Daily Online, 2023). The Western

Europe-Western China (WE-WC) Highway, spanning a distance of 8445 kilometers from Lianyungang to St. Petersburg, marked a significant milestone in the development of the across-national infrastructures in 2018 after a decade of construction (Kazakh Invest, 2020).

The China-Europe Railway Express has achieved significant expansion, extending its reach to encompass 200 cities across 25 European nations. This expansion has resulted in the establishment of a comprehensive network consisting of 86 distinct routes (Belt and Road Forum, 2023). It effectively transports a diverse range of commodities, including electronic products and vehicles, encompassing a collective worth over 300 billion dollars (Belt and Road Forum, 2023). The below figure 5 illustrates a notable trend in the growth of both the number of trips and freight volume through the China-Europe Railway Express from 2013 to 2022.

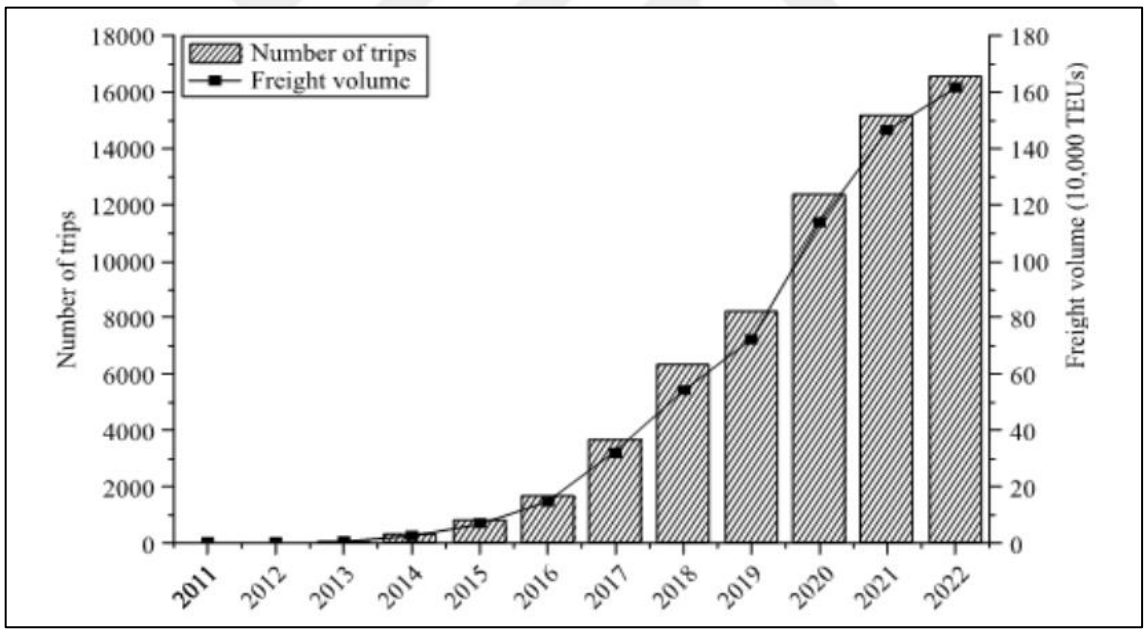


Figure 5. Number of Trips and Freight Volume of China-Europe Railway
Source: Belt and Road Forum, 2023.

Regarding the maritime BRI, there is a notable increase in both the volume of trade being transported and the construction of ports. By July 2023, a total of 117 ports had been reached for trading. Also, the professional Silk Road Maritime Association was

established to facilitate the sharing of expertise, with over 300 maritime businesses worldwide being affiliated with this organization (Xinhua News, 2023).

Trade Connectivity

The BRI has experienced a consistent growth in the amount of international trade and investment between China and other BRI countries since 2013. According to a report from Xinhua News (2023), the total value of imports and exports reached 19.1 trillion dollars by the end of 2022, exhibiting an average annual growth rate of 6.4%. The total investment amount has reached 380 billion dollars, with around 240 billion dollars originating just from China (Xinhua News, 2023). The proportion of commerce with BRI countries within China's total foreign trade has rising by 6% and reaching 45% in 2022 (Xinhua News, 2023).

From 2013 to 2023, a total of 21 free trade agreements has been signed with 28 regions and nations, demonstrating a commitment to multilateralism and free trade. Furthermore, in 2017, the *"Initiative on Promoting Unimpeded Trade Cooperation Along the Belt and Road"* was introduced with China's commitment to increasing imports from other BRI countries and increasing investments. Besides, the Regional Comprehensive Economic Partnership (RCEP), the largest free trade zone in the world, was founded in 2022, also with the commitment to fostering a more integrated economic and commercial cooperation.

The level of bilateral investments and industrial collaboration is steadily increasing. According to a report by Xinhua News in 2023, bilateral investment agreements have been successfully signed with a total of 135 nations, while 112 countries have reached consensus on the avoidance of double taxation. The scope of industrial collaboration are spanning several sectors, from conventional industries like steel to new technologies such as the digital economy and 5G technology.

Finance Connectivity

Finance plays a crucial role in facilitating BRI development. China and the nations involved in the initiative are engaged in the creation of several modes of financial cooperation, including joint venture and operational finance. These modes involve many parties and development banks, with the aim of effectively managing the risks associated with BRI projects. Specifically, there is a growing collaboration between transnational banks and organizations, for example, the China-Central and Eastern Europe Interbank Consortium, the China-Africa Interbank Association, and the China-Arab Countries Interbank Association (Xinhua News, 2023). Furthermore, there are a total of 13 banks supported by China, which have established 145 offices and branches as of June 2023 in BRI countries (Xinhua News, 2023). For the payment, the UnionPay service is currently accessible in 131 countries, while 20 nations have established bilateral currency swap agreements. To ensure the uniformity and harmonization of financial regulations, China and its partner nations are currently engaged in discussions of establishment of a regional coordination mechanism to enhance the efficiency of fund allocation and manage financial risks.

Besides, BRI related organizations responsible for funding BRI projects and the related investment capital pool are experiencing significant growth. According to a report by Xinhua News in 2023, the Silk Road Fund has been particularly established to invest in projects related to the BRI. As of June 2023, the fund has entered into financing agreements for a total of 75 projects, with a combined investment of 22 billion dollars. The Asian Infrastructure Investment Bank (AIIB) was founded in collaboration with 106 partner nations to provide financing for projects under the BRI. The AIIB has invested a total of 227 projects, amounting to a financial commitment of 43.6 billion dollars (Xinhua News, 2023). Also, the China Development Bank (CDB) has provided financial services for over 1300 BRI projects, utilizing both domestic and foreign funding sources. The China Eximbank has financially support the implementation of

400 billion BRI projects, as well as fostering 2 trillion worth of international trade among BRI partner nations (Xinhua News, 2023).

In terms of financing, various bonds are invented to generate continuous innovation in financing approaches. China's securities have developed a significant number of bonds with a focus on the BRI. To date of June 2023, a total of 46 "BRI Bonds" have been issued, amounting to around 53 billion RMB (Xinhua News, 2023). Besides, the "Panda Bond" denominated in RMB has also been introduced and listed on the Chinese Exchange Trade Market, generating a total of 153 billion RMB for supporting BRI projects (Xinhua News, 2023). Furthermore, the growing consciousness surrounding environmental issues has led to the emergence and subsequent popularity of green bonds in financial market.

People-to-people Connectivity

The people-to-people connectivity is a kind of social framework for BRI countries to strengthen their mutual understanding, facilitate the interchange of different cultures, and increase trust and reliability. To achieve this purpose, BRI promoted dynamic connections across many countries in multiple areas, including tourism, education, think tanks, and so on. By June 2023, there are 144 partner countries signing agreements with China for cultural and tourism cooperation. In terms of education, Chinese institutions offer specific programs for students from BRI participating countries, as well as educational exchanges and abundant scholarships of Silk Road initiative. China has entered into a mutual agreement with 45 nations for the recognition of higher education degrees. Besides, to actively promote the dissemination of Chinese language and culture, a total of over 300 Confucius Institutes has been established in 132 partner countries (Xinhua News, 2023).

In the realm of science and research, nations participating in the BRI have together established a University Alliance and an International Science Organization. Moreover, there is an increasing trend among researchers and academics to engage in

communication via the BRI platform. According to the Xinhua News, the Silk Road Think Tank Association has successfully enlisted the participation of 122 institutions and individuals across several regions including Asia, Europe, Africa, and Latin America.

Furthermore, the collaboration of Non-Governmental Organizations (NGOs) from all nations involved in the BRI are enhancing the quality of life for individuals through various social assistance. More than 600 partnerships and initiatives are undertaken, such as offering educational opportunities to underprivileged primary school students and delivering complimentary cataract surgeries to individuals who lack access to healthcare services. A collaborative network, known as the Silk Road NGO Cooperation Network, has been established by these NGOs with the aim of effectively consolidating resources and facilitating coordinated efforts in carrying out various operations.

BRI countries possessing various resources endowments can provide compensatory benefits to other partner nations. The BRI platform promotes a range of good visions, including the development of a healthy, green, innovative, and digital Silk Road. For example, it is noteworthy to mention the proactive measures taken by China along the Silk Road. Amidst the global Covid-19 pandemic, China has deployed a total of 38 medical professional teams to 34 BRI participating countries. Furthermore, Vaccine Cooperation was established and involve over 30 nations. This initiative has facilitated the distribution of approximately 2 billion vaccine doses to partner countries. Now it is still working in the post-pandemic age and concurrently engaging in vaccine production collaboration within developing nations.

BRI Troubled Assets

Despite above achievements, the BRI nevertheless possesses potential financial risks that deserve careful evaluations. Before 2019, a considerable number of BRI projects were financed through debt, generating a potential risk to the financial stability of investments in case these projects were undergone a difficult business condition. Within

the realm of investments, certain assets are commonly labeled as "*troubled assets"* when they are associated with significant financial risks. These risks may arise from cost overruns, wherein the expenses exceed the anticipated benefits. It may also arise from collateral assets pertaining to troubled assets when their value falls below their corresponding liabilities. Further, it may arise from the cancellation of investment deals due to national economic fluctuations and political unrest.

The pie chart presented herein depicts the current state of distressed assets, as derived from data sourced from the American Enterprise Institute (AEI) and the China Global Investment Tracker Database, as outlined in the OECD study of 2018. The pie chart presented in the figure 6 on the left side reveals that the primary sectors posing challenges to investments of Chinese state-owned corporations and BRI projects are energy, metals, transport, finance, and technology, listed in descending order of investment magnitude. The pie chart in figure 6 on the right side illustrates that distressed assets are predominantly concentrated in countries that are participants of the BRI, as well as in North America and Australia. For example, it has been reported that a Chinese state-owned business has invested over 25 billion dollars in risky assets specifically linked to energy projects in Iran (OECD, 2018). In a similar situation, the real estate and rail construction sectors in Libya faces significant challenges, amounting to a financial burden of 12 billion dollars (OECD, 2018). Oil projects in Syria encountered obstacles, resulting in a financial setback of 3.8 billion dollars (OECD, 2018).

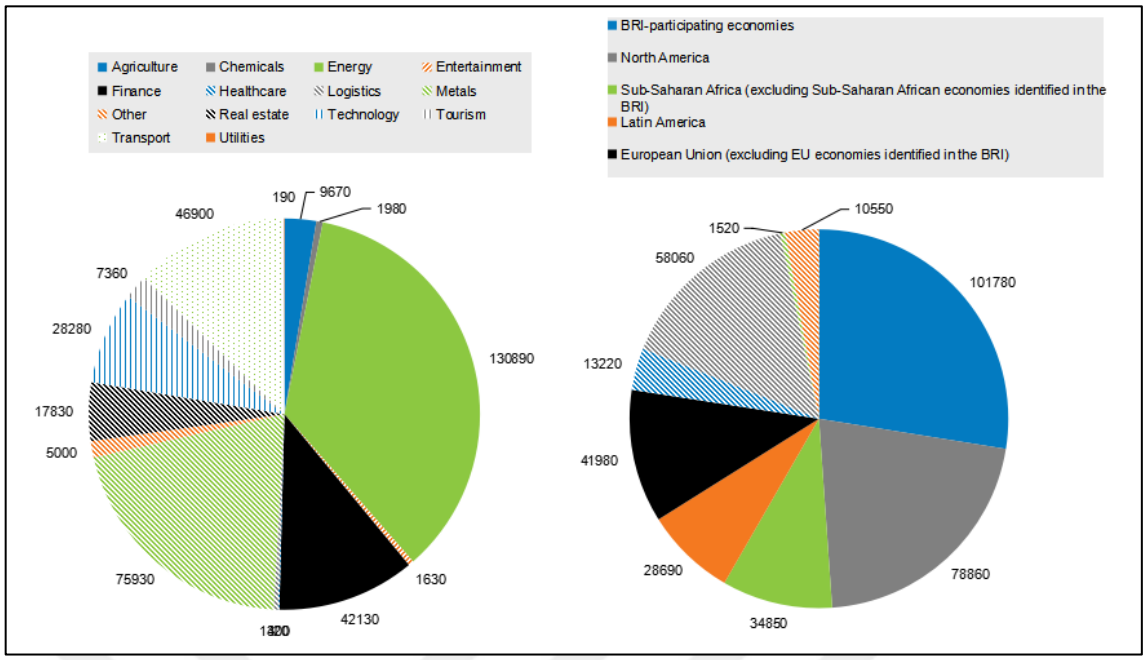


Figure 6. Sectors and Distributions of BRI Troubled Assets

Source: OECD report, 2018.

2.GREEN BRI

It is well known that our earth is confronted with a significant challenge pertaining to an impaired environmental system, leading to a series of climate change phenomenon. The BRI, being a massive global economic initiative, is not an exception in its potential environmental effect due to growing human activities. To mitigate its environmental consequences, China has come up with the notion of "Green BRI" as a mean to achieve sustainable economic development through BRI platform. This part will provide an overview of the background of the green BRI, its proposal, the significance of green development for BRI participating countries, and current BRI policies.

2.1 Green Development of BRI Participating Countries

It is widely acknowledged that BRI participating countries have a great diversity in terms of distribution, development stages, resource endowment, institutional features, cultural background, and ecological environment. Therefore, it is essential to learn the distinct characteristics of BRI participating countries to have an overall picture and a comprehensive understanding of their current stage of green development. Then it is logical to explore how the BRI could influence their environment. In this section, the geographical distribution and characteristics of BRI participating countries are described. Their green development situation is analyzed, and the potential roles that the BRI could play in influencing their green development are explored.

2.1.1 Distribution and Characteristics of BRI Countries

As released on the Belt and Road Portal of the government website, a total of 152 countries, excluding China itself, are participating in the BRI Initiative, as defined by the signing of the Memorandum of Understanding (MoU) with China. These countries are distributed globally, encompassing Asia, Europe, Africa, North America, South America, and Oceania. A visualized world map is provided in figure 7, with the colored

countries representing BRI member countries and their corresponding joining time. Apparently, most of Asian and African countries have joined the BRI, and some of Middle and South America have become part of the BRI. Overall, it is noticed that the majority of BRI participating countries are developing countries in which exists substantial opportunities for social and economic development.

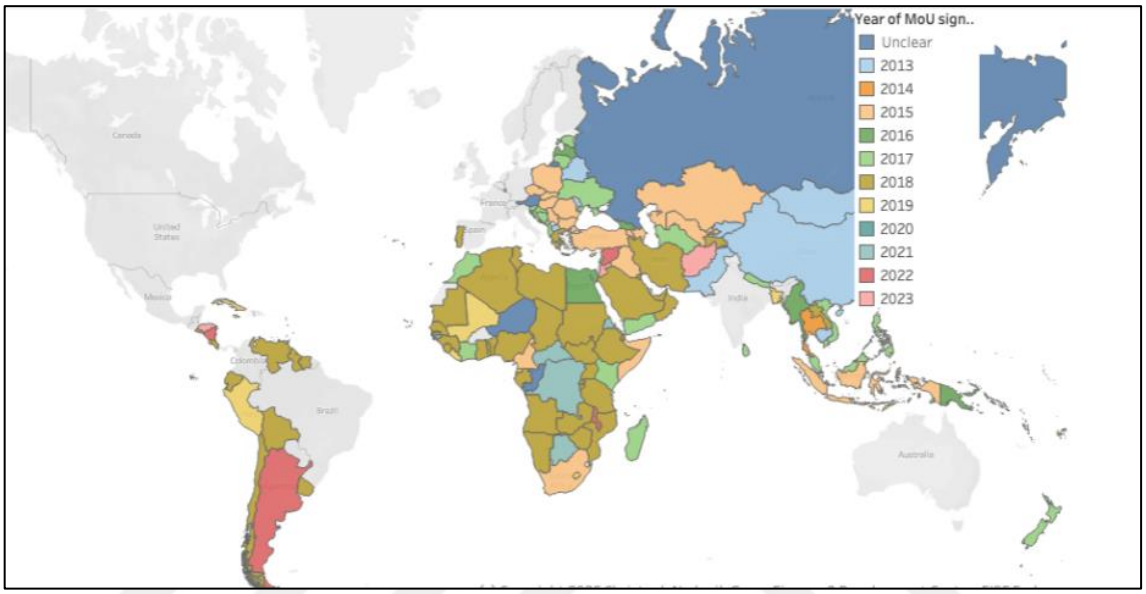


Figure 7. Distribution of BRI Participant Countries

Source: Nedopil, 2025.

Based on the distribution of BRI participating countries, the table 1 shows the countries joined the BRI and the numbers of BRI nations in each single region. This includes 52 countries in Africa, 40 in Asia, 26 in Europe, 12 in North America, 12 in Oceania, and 10 in South America. Notably, the initial regions supporting the BRI were Asia and Europe. The first batch of BRI participating countries in 2014 are Kazakhstan, Belarus, Qatar, and Sri Lanka (Yazdani, 2020). Besides, that Italy officially exited the BRI in November 2023 and Panama exited the BRI in February 2025.

From an economic perspective, BRI countries are experiencing different development stages and unique historical backgrounds, leading to distinct economic conditions. According to data from the World Bank and the Green Finance and Development

Center, the income levels of BRI countries vary vastly. The distribution of BRI countries across income levels is as follows: 22% are high-income nations, 21% are low-income nations, and the majority are middle-income nations with 57%, including 29% upper-middle-income countries and 28% lower-middle-income countries. Notably, most low-income countries are in Africa and Asia, while most high-income countries are in Europe. This indicates that approximately 80% of BRI countries are still developing countries that are in demand of more economic support to build their infrastructure development and promote their international trade.

Table 1. Geographical and Income Distribution of BRI Countries

BRI Regions	Income Level	Number of the BRI countries	BRI Member States
Africa	High income	1	Seychelles
	Upper middle income	7	South Africa, Algeria, Gabon, Libya, Namibia, Equatorial Guinea, Botswana
	Lower middle income	17	Cameroon, Egypt, Arab Rep., Côte d'Ivoire, Kenya, Morocco, Angola, Cabo Verde, Djibouti, Ghana, Mauritania, Nigeria, Sudan, Tunisia, Zambia, Lesotho, Congo, The Democratic Republic of Sao Tome and Principe
	Low income	27	Comoros, Somalia, Madagascar, Ethiopia, Benin, Burundi, Chad, Togo, Gambia, Guinea, Zimbabwe, Rwanda, Mozambique, South Sudan, Sierra Leone, Senegal, Tanzania, Uganda, Liberia, Mali, Eritrea, Congo Dem, Guinea-Bissau, Niger, Central African Republic, Burkina Faso, Malawi
Asia	High income	9	United Arab Emirates, Oman, Bahrain, Korea, Kuwait, Saudi Arabia, Brunei Darussalam, Singapore, Qatar
	Upper middle income	12	China, Thailand, Azerbaijan, Kazakhstan, Türkiye, Armenia, Iraq, Lebanon, Maldives, Malaysia, Turkmenistan, Iran Islamic Rep.
	Lower middle income	15	Pakistan, Kyrgyz Republic, Cambodia, Mongolia, Uzbekistan, Indonesia, Georgia, Myanmar, Timor-Leste, Philippines, Sri Lanka, Viet Nam, Lao PDR, Bangladesh, Palestine
	Low income	5	Nepal, Yemen, Rep., Tajikistan, Syrian Arab Republic, Afghanistan

Europe	High income	15	Austria, Croatia, Cyprus, Czech Republic, Estonia, Greece, Hungary, Latvia, Lithuania, Luxembourg, Malta, Poland, Portugal, Slovak Republic, Slovenia
	Upper middle income	9	Albania, Belarus, Bosnia and Herzegovina, Bulgaria, Montenegro, North Macedonia, Romania, Russian Federation, Serbia
	Lower middle income	2	Moldova, Ukraine
North America	High income	4	Antigua and Barbuda, Barbados, Panama, Trinidad and Tobago
	Upper middle income	6	Costa Rica, Cuba, Dominican Republic, Dominica, Grenada, Jamaica
	Lower middle income	3	El Salvador, Nicaragua, Honduras
Oceania	High income	1	New Zealand
	Upper middle income	4	Cook Islands, Fiji, Samoa, Tonga
	Lower middle income	6	Kiribati, Micronesia Fed. Sts, Niue, Papua New Guinea, Solomon Islands, Vanuatu
South America	High income	3	Argentina, Chile, Uruguay
	Upper middle income	5	Ecuador, Guyana, Peru, Suriname, Venezuela RB
	Lower middle income	1	Bolivia

Source: Yidaiyilu (2025), and Green Finance and Development Center (2025).

Regarding the cultural perspective, BRI participating countries vary significantly in terms of institutional systems, religious beliefs, cultural backgrounds, political systems, and governance structures. For instance, the Russian Federation has a centralized political system dominated by a ruling party, like China. Türkiye is a constitutional republic and representative democracy with a multi-party system. The president and parliament together use government powers (Marszałek-Kawa & Burak, 2018). Somalia, an African country, has a federal state system. It has two layers of governance: federal member states and a central federal government (European Asylum Support Office, 2021). The federal member states enjoy significant autonomy, including the ability to maintain their own armed forces and even constitutions. In Saudi Arabia, the political institutions remain a monarchy ruled by the Saud dynasty, a family that legitimizes itself by aligning with a religious establishment (Al-Twaijry, Brierley & Gwilliam,

2003). The above political differences often lead to different legislative frameworks, such as the Islamic law in Saudi Arabia and constitutional law in Türkiye. As their influence on business, disparities in legal systems can impact the ease of conducting business, the protection of investments, and dispute settlement mechanisms. Therefore, reconciling these differences inevitably presents a realistic challenge for BRI cross-border projects.

Besides the institutional and legal distinctions, BRI participating countries encompass a variety of faiths, such as Islam, Buddhism, Hinduism, Christianity, and others. Recognizing religious diversity is vital for effective cross-country cooperation, as religious beliefs can influence cultural practices, social norms, and business ethics. Additionally, due to diverse historical backgrounds and language differences, communication and business negotiations may differ significantly. Therefore, conscious religious sensitivity and language translation are crucial when carrying out BRI projects. Scholars have noted that cultural differences are mainly demonstrated in four dimensions: power distance, uncertainty avoidance, individualism, and masculinity. These cultural differences can lead to cultural shocks (Hofstede, 1983), potentially hindering overseas investments, export performances, and international cooperation (Du, Qin & Huang, 2022). In the same way, cultural similarities can enhance relationships among countries. Du, Qin, and Huang (2022) revealed that Uygur-owned enterprises can gain more orders from the BRI initiative due to their cultural affinity with central and west Asian countries. Overall, understanding and respecting cultural subtleties are essential for building trust and nurturing positive relationships for cooperation.

Regarding environmental characteristics, many BRI countries are facing various environmental challenges due to their ecologically fragile and complex environmental conditions. Given that the BRI covers 6 continents with differing landforms, geographical types, climate features, and biodiversity situations, specific environmental threats are distinct for each region. Generally, around 60% of BRI countries have

semi-arid or arid grasslands, deserts, and high-altitude areas (Huang et al., 2021) in their territory. These areas typically display a dry climate and low precipitation, making them less resilient to increased human activities and rapid climate changes. In addition, the water resources in BRI countries represent only about 30% of the global total (Huang et al., 2021). Normally, a country's water resource availability is largely derived from precipitation. But precipitation is obviously distributed unevenly across BRI countries, possibly favorable for some nations and harmful for others. For example, nations in Southeast Asia, South Asia, and central North America usually encounter high precipitation, having a risk of monsoons and seasonal floods. In contrast, some Central Asian countries, like those in the ancient land of the Silk Road region, may face the problem of very little precipitation, resulting in local water scarcity.

Concerning climate type, BRI regions span various climate zones, like tropical and subtropical zones in Southeast Asia, South Asia, parts of Africa, and Central North America, characterized by high temperatures and obvious distinctions between wet and dry seasons. Temperate and continental zones are present in many BRI countries, particularly in Europe and parts of Asia, where agricultural productivity is relatively higher. Polar climate zones are also found in some BRI countries in the high altitudes of Asia and Europe, experiencing extremely cold climates. Due to the diverse and changing climate characteristics throughout the years, natural disasters could frequently occur, such as recurrent droughts in Central Asia and the Middle East regions, typhoons, and floods in regions of East and Southeast Asia during the monsoon season. Besides climate-induced disasters, some BRI countries, especially those located along seismic zones like Central Asia, the Himalayas, and parts of Europe, may be susceptible to earthquakes. Therefore, comprehending these environmental characteristics is crucial for mitigating the impact of economic development on ecosystems, preventing natural disasters, and enhancing climate resilience in the BRI participating countries.

2.1.2 Challenges of Green Development in BRI Countries

Given that BRI participating nations have varied economic, social, and environmental characteristics, they are inevitably and inherently encountering challenges in green development within their territory even if there was no BRI initiative. The ultimate environmental impact of BRI infrastructure projects results from the interplay between project implementation and the local receiving environment. Therefore, it is necessary to make an examination of the original environmental challenges faced by BRI countries in green development (Teo et al., 2019). Researchers found that certain environmental systems exhibit threshold behavior, indicating their ability to absorb and recover from a certain level of human impact without displaying visible deterioration until surpassing the threshold (Groffman et al., 2006). Therefore, understanding the green development in BRI countries is crucial for conducting further assessments of BRI's environmental impact. To clarify, green development embodies the essence of sustainability, encompassing challenges related to the environment, development, and the responses of key factors such as government, businesses, and citizens. It can be viewed as sustainable development. This section will scrutinize the challenges of green development, focusing on environmental conditions in terms of water resources, vegetation resources, non-renewable resources, and greenhouse gas emissions.

The unequal distribution of water resources in the earth system is influenced by various factors like rainfall, evaporation, and the surrounding terrain (Du, Qin & Huang, 2022). Among these, rainfall is the most crucial factor, causing spatial variations worldwide and seasonal fluctuations throughout the year. This irregular rainfall often results in dry climates and water scarcity. The figure 8 shows the average precipitation depth (mm per year) in 2019, illustrating the fundamental state of global water resources.

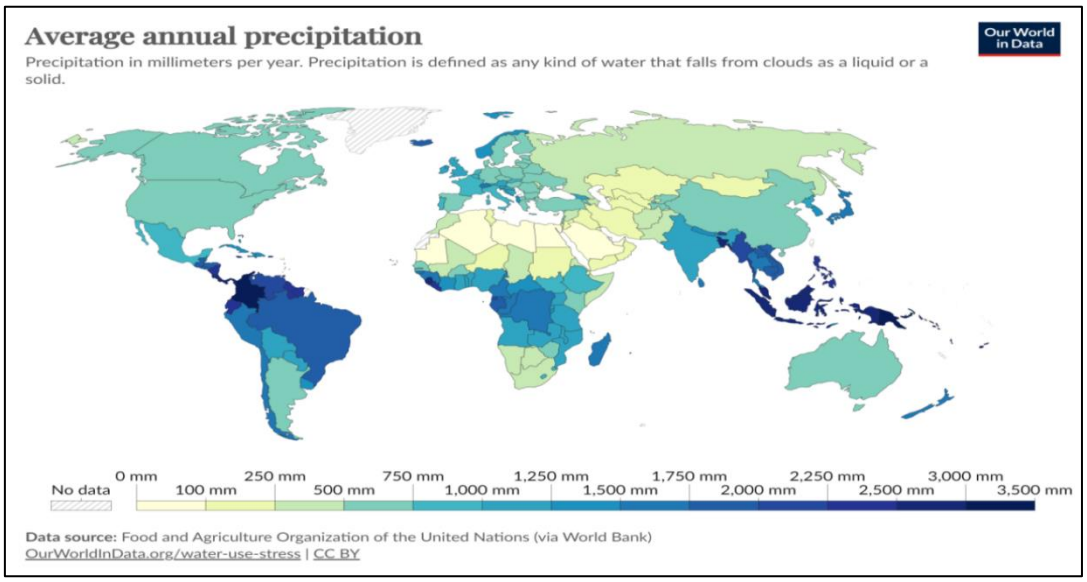


Figure 8. Average Precipitation in Depth (mm per year) in 2019

Source: Ritchie, Rosado, and Samborska, 2024.

As shown in the figure 9, the region from north Asia, central Asia and North Africa is suffering from low precipitation, being lower than 250 mm per year, not to mention the extreme seasonal variance. At the same time, this region also has different topography such as desert and plateau, which increases the possibility of occurring natural disasters, including extreme drought, wildfires, floods, landslides and so on (Du, Qin & Huang, 2022). A researcher examined the water footprint in the international trading, by applying a multi-regional input-output method from a consumption perspective, found that the top 5 countries of water consumption via import are China, India, Russia, Iran, and Türkiye (Fang et al., 2021). Besides, BRI participating countries as a whole are the net importer of virtual water via international trade due to the fact of water shortage (Fang et al., 2021). Therefore, water shortage is undoubtedly referred to as one of the imperative challenges of green development in BRI countries.

Vegetation cover has a great function in effectively protecting the land degradation. The reduction of enduring vegetation cover is regarded as an early indicator of desertification (European Soil Data Center, 2023). It plays an important role in the governance of water run-off and soil sediment loss through protecting soil surface,

increasing soil organic matters and its capability of holding water (European Soil Data Center, 2023). In addition, the changes of vegetation cover can alter the radiation properties of the surrounding land surface, thus leading to a change of surface energy balance and climate temperature (Duveiller, Hooker & Cescatti, 2018). A study revealed that the surface energy balance has increased around 0.23 degrees celsius at average in the worldwide as the vegetation changes over the 2000 to 2015, causing a slight warming effect (Duveiller, Hooker & Cescatti, 2018). Usually, the normalized difference vegetation cover (NDVI) is used to indicate remote-sensing measurement about green heath vegetation and refer to the coverage of vegetation (Pettorelli et al., 2011). Research based on the farming-pastoral ecotone in the BRI countries, using some enhanced method, found that around 21% degradation of NDVI has occurred during the year of 2000-2016 (Liu et al., 2019). Another group of researchers have investigated the spatiotemporal variation of vegetation cover in the BRI countries during 1982- 2015 and detected a slow decrease of NDVI in this period (Fan et al., 2020). Besides, they also found a spatial change that increased NDVI mainly occurred in some the Europe, China and India. The decreased NDVI mainly distributed in the northern Russia, northern China, central Asia, Malay Island and southeast Asia (Fan et al., 2020). Apart from influences of climate change in the long term, human activities such as agriculture and animal husbandry have also played an important factor of the above global vegetation variance. More importantly, the vegetation cover is closely related with the whole ecological environment, becoming an essential precondition of biodiversity. Furthermore, the NDVI in the overall key biodiversity areas in the BRI regions has been slightly increasing, while a few areas decreasing mainly distributed in the Qinghai-Tibet Plateau, Indochina Peninsula, central and west Asia (Boyu et al., 2022). A world map of vegetation cover measured by NDVI and various types of vegetation can be found in the below figure 9.

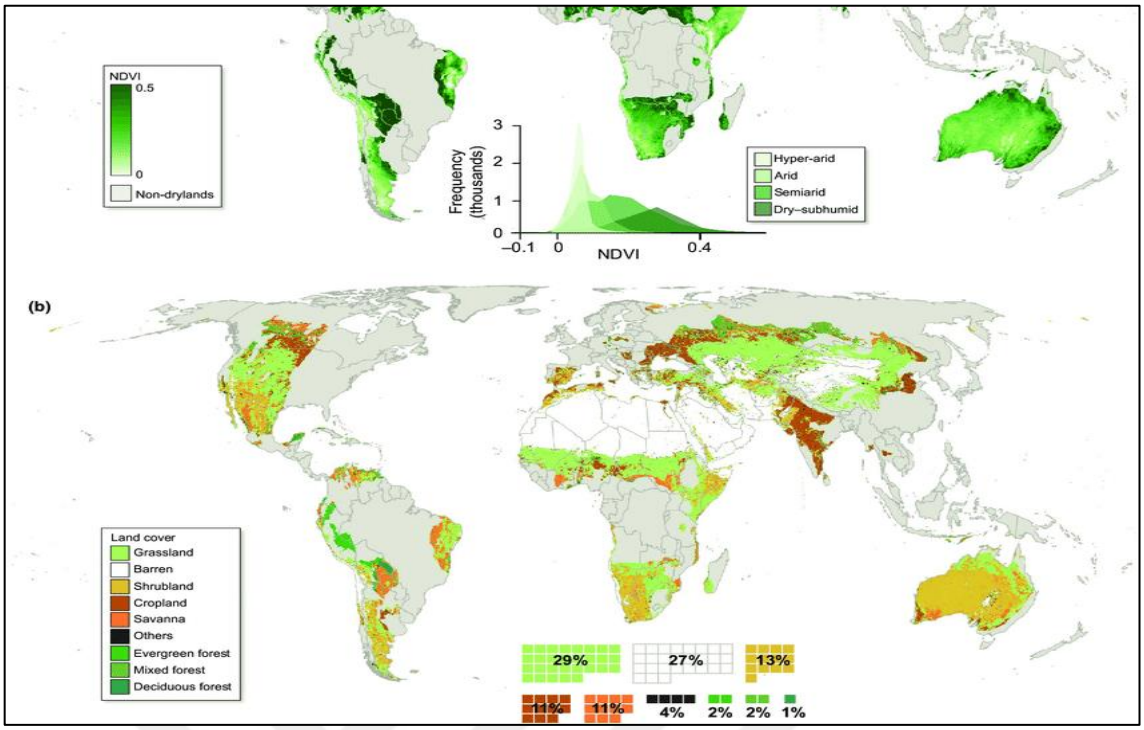


Figure 9. NDVI (a) and Land Cover Types (b) across Global Drylands

Source: Maestre et al., 2021.

Since many BRI countries have venerable ecological conditions and increased economic activities, they have witnessed the climate warming within BRI regions at a rapid speed almost twice rate of the global land average (Du, Qin & Huang, 2022). Consistent with the challenges of water resources, the increased temperature caused by climate warming accelerates the evaporation of surface water, resulting in a exacerbated water shortage and seasonal uneven distribution. In some harsh ecological environments, water scarcity will further lead to drought, or even desertification. Most BRI countries are land-locked and agriculture-produced in the land silk road with a high risk of desertification (Li et al., 2020). In the east and central Asia, China and Mongolia are facing challenges of desertification seriously. Due to the land-use for numerous livestock and wild animal, Mongolia has around 90% of territory venerable to desertification (Li et al., 2020). China has also experienced a triple land surface desertification area from 1950s to 2000 (Li et al., 2020). Dregne and Chou (1992) have examined the desertification in the

Middle East and North Africa, including Sahara Desert, and found that about 70% of cropland and 50% ranches are subject to different extent of desertification.

Furthermore, climate warming also caused a significant sea level rise in the BRI countries along the maritime silk road. The abnormal rise of sea level could lead to precipitation-related extreme weathers such as floods and particularly strong monsoon in the southeast Asia, east Asia, south Asia and coastal areas of Africa (Tan et al., 2021). Countries in small islands are facing a great risk of losing their homestead caused by the catastrophic effect of rising sea level and those countries with highest risk are part of BRI participating countries such as Fiji, Philippines, Bahamas, Palau and Kiribati (Santos & Bakhshoodeh, 2021).

Greenhouse gas (GHG) emission is a key factor in climate change. GHGs can force the earth's temperature to increase through the way of trapping heat and atmosphere around our planet. GHGs are normally composed of carbon, methane, nitrogen, and water vapor (Johnson et al., 2007). To better investigate GHGs, researchers have expanded the carbon cycle to other polluted elements such as nitrogen and phosphorus, which are usually contained in the various fertilizers for farming purposes (Townsend, Houlton & Vitousek, 2012). Fang et al. (2021) have studied the distribution of carbon, nitrogen, and phosphorus footprints in the BRI regions and found their pattern as follows: China is the largest emitter in the BRI countries and accounts for 50% of carbon, 42% of nitrogen, and 45% of phosphorus of the total value, followed by India and Russia (Fang et al., 2021). The next two countries with the largest carbon footprints are Iran and Saudi Arabia, and those with the largest nitrogen and phosphorus footprints are Pakistan and Türkiye (Fang et al., 2021). These countries are obviously in the industrialization process and undergoing rapid economic development, thus consuming lots of energy.

The above discussed uneven distribution of natural resources in BRI participating countries, means potential environmental risks, but on the other hand, it also triggers international cooperation for resource exchange. In fact, they are endowed with a wealth

of natural resources, positioning them as significant suppliers on the global stage. This includes a substantial share of mineral resources and fossil fuels. According to Du, Qin, and Huang (2022), BRI countries hold a considerable share of the world's copper, recoverable oil, and recoverable natural gas reserves, which represent 48%, 66%, and 65% of the global totals, respectively. However, specific types of resource endowments vary among countries, attaching the importance of leveraging synergies through cooperative efforts. For instance, regions such as Central Asia, the Middle East, and North Africa are particularly abundant in oil and natural gas but are insufficient of water and vegetation cover (Du, Qin, and Huang, 2022). In contrast, Southeast Asian countries are blessed with abundant forest and water resources but lack of oil and natural gas reserves. This interplay of complementary resources among BRI countries has triggered a great demand of cross-countries mutually benefit cooperation. Despite the substantial mineral and fossil energy reserves, the efficiency of energy utilization within BRI countries are relatively low (Liu et al., 2020). When evaluated by total-factor energy efficiency, Singapore, Israel, and Türkiye, emerge with the highest levels of efficiency. In contrast, Uzbekistan, Ukraine, and South Africa exhibit a relatively lower efficiency, leading to significant energy wastage (Zhao et al.,2018).

Clearly, the inefficient use of energy can result in substantial greenhouse gas (GHG) emissions, exacerbating climate change. To gain a fair understanding of carbon emission distribution among BRI countries, it is imperative to consider CO2 per capita emissions, excluding the confounding factors of population size and economic prowess. The global map of per capita CO2 emissions coming from fossil fuels and industry reveals that the world's highest per capita carbon emitters are oil-producing nations in the Middle East, such as Qatar (Ritchie & Roser, 2023). However, these nations, despite their high per capita emissions, have relatively smaller populations and limited global effect, when compared to countries ranked lower in per capita emissions but with larger populations, such as Australia, the United States, Canada, Russia, Mongolia and Kazakhstan and China (Ritchie & Roser, 2023).

2.1.3 Role of BRI in the Green Development

According to the planetary boundary theory, our Earth's ecosystem possesses an inherent capacity to spontaneously restore ecological equilibrium by utilizing its natural resources, even in the face of disruptions caused by human activities (Teo et al., 2019). However, when disruptions exceed the ecosystem's limited boundary, it would cause irreversible damage which post a threat to human living environment. BRI projects, considering its scale and intensity, are significant interventions in ecological systems. It will inevitably exert an impact on the regional environment, whether positive or negative. On the one hand, the construction of BRI infrastructure carries the risk of intensifying human activities, exacerbating ecological vulnerability across various scales. On the other hand, the BRI framework can serve as an opportunity for participating countries to make significant contributions to overall environmental sustainability through a well-sound environmental governance. This section will analyze several potential roles of the BRI in fostering green development.

The theory planetary boundaries consist of nine distinct boundaries that are defined as the "safe operating space" for human activities in relation to critical earth system, including climate change, ocean acidification, stratospheric ozone depletion, biogeochemical nitrogen and phosphorus cycles, global freshwater use, land system change, biodiversity loss, chemical pollution, and atmospheric aerosol loading (Rockström et al., 2009). These boundaries are established based on scientific research with aim of identifying a safe operating limit for the aggregate human impact on the planet. However, it is estimated that human activities have already surpassed thresholds in three boundaries: climate change, the global nitrogen cycle, and the rate of biodiversity loss. Considering this, the potential influence of BRI projects on the already pressured ecological environment is a realistic concern. Historical precedents from developed nations such as the UK and the USA demonstrate that rapid industrialization phases are often accompanied by swift environmental changes. By extension, BRI is

likely to catalyze accelerated industrialization in participating countries, potentially escalating global carbon emissions, water consumption, ocean exploitation, chemical usage, and other environmental stressors, pushing the current limits closer to the defined planetary boundaries. For instance, BRI projects may have some degrees of impact on the ecological integrity and biodiversity of major Eurasian River systems, such as the Mekong River (Teo et al., 2019).

Having said that, however, if implemented carefully, BRI could have the potential to contribute significantly to the achievement of several United Nations' Sustainable Development Goals (SDGs). Specific goals that could be facilitated consist of Goal 9: Industry, Innovation and Infrastructure, Goal 6: Clean Water and Sanitation, Goal 7: Affordable and Clean Energy, and Goal 11: Sustainable Cities and Communities (Yin, 2019). The BRI's infrastructure-focused implementation has a crucial effect on overall development in various sectors such as transportation, water management, energy utilization, clean energy, and telecommunications (Yin, 2019). Estimates from the World Bank suggest that BRI projects could potentially lift 8.7 million people out of extreme poverty and 34 million people out of moderate poverty (Maliszewska & Van Der Mensbrugghe, 2019). Therefore, if BRI projects are designed with a focus on sustainable green infrastructure and are managed effectively, they could undoubtedly foster the advancement of human civilization on a global scale.

However, environmental risks and ongoing governance challenges are still embedded to BRI projects, and these can only be mitigated if there exists robust environmental governance. The governance can require BRI projects to account for environmental protection thorough project selection process, implementing process, and assessing process. Certain BRI projects have already been completed in collaboration with partner countries, focusing on pollution control, water treatment, renewable energy, smart city development, and environmental infrastructure (Cheshmehzangi, Xie & Tan-Mullins, 2021).

It is recognized that the BRI should have a sound environmental governance that encompasses voluntary policy guidance, a strong governance framework, and the establishment of necessary standards and protective measures (Maliszewska & Van Der Mensbrugghe, 2019). Importantly, since BRI platform consist of lots of countries, the ultimate effectiveness of BRI environmental governance is contingent not only on the actions taken by China but also on the capacity and willingness of BRI participating countries to enact, implement, and enforce stringent local environmental laws (Coenen et al., 2021).

2.2 Background of Green BRI Proposal

The rapid advancement of global rough industrialization over several decades has resulted in detrimental effects on the environment, such as climate change, pollution, waste, and the loss of nature and biodiversity. According to the International Panel on Climate Change (IPCC, 2020), the decade spanning from 2011 to 2020 is recognized as the warmest time on record in human history. According to the United Nations (2023), climate change refers to the long-term modification of global temperature and patterns caused by human activities. In comparison to the 19th century, the earth's average temperature has increased by 1.15 degrees Celsius in the present era, as reported by the World Meteorological Organization (2023). This is caused by the greenhouse gas emissions generated in the process of various human activities. Indeed, studies found that there has been a substantial increase in carbon emissions during the 2020s, reaching a level that is 14 times higher than that recorded in 1990 (Ritchie and Roser, 2020).

However, the escalating global temperature is profoundly detrimental to human beings. It can result in reduced food production, higher sea levels, and the potential displacement of cities and populations. For example, the mean worldwide sea level has experienced a rise of 19 centimeters between the years 1901 and 2010 (IPCC, 2013). If this tendency is not effectively mitigated, the sea level will undergo a further increase of

25-30cm by the year 2065, as reported by the IPCC (2018). Therefore, to address the challenges posed by climate change, Paris Agreement proposed that the world population should promptly mitigate the increase in temperature to a maximum of 1.5 degrees Celsius (Schleussner et al., 2016). This goal is extremely crucial to prevent the occurrence of additional climate-related catastrophes.

The increase of sea level is an alarming warning for us to take necessary measures for safeguarding our plane. Numerous nations have come to realize that economic advancement and industrialization must not be pursued at the cost of environmental degradation. The Kyoto Protocol, established in 1997, brought together industrialized countries with the aim of addressing the significant accumulation of carbon emissions in the atmosphere (Grunewald, & Martínez-Zarzoso, 2015). These countries were decided to take responsibility for their respective high levels of carbon stock and committing to a 5% reduction in carbon emissions (UNFCCC, 1997). Furthermore, the Paris Agreement in 2015, is a legally enforceable agreement that has been ratified by a total of 196 nations (UNFCCC, 2015). So far, an international consensus has been reached regarding the urgency of addressing climate change and environmental protection, emphasizing the need for countries to jointly contribute their efforts. An important takeaway of Paris Agreement is the implementation of measures aimed at constraining the increase in global temperatures to a level below 2 degrees Celsius by the year 2050 (UNFCCC, 2015). Besides, nations are committed to achieve carbon neutrality by the year 2050 (UNFCCC, 2015). For enforcement and monitoring, the United Nations Environmental Programme (UNEP) is a prominent international body responsible for the oversight of environmental conservation.

Apart from international pressure of environmental protection, China, at the meantime, has faced to its domestic pressure. Globally, China has the greatest proportion of the carbon emission, contributing to around 29% of the total global CO2 emissions (Climate Trade, 2021). In 2017, the introduction of the “Green BRI” idea coincided with the emergence of heightened levels of air pollution in numerous cities in China,

posing a significant threat to public health and everyday routines. Based on the Report on the State of the Ecology and Environment in China authored by the Minister of the Ministry of Ecology and Environment (2017), it was observed that around 70% of the total cities, amounting to 293 cities, failed to meet with the national air quality criteria. In relation to carbon emissions, the national average quantity of carbon dioxide exceeded the historical normal by around 13 parts per million (ppm) and beyond the global average by 1.1 ppm (Minister of the Ministry of Ecology and Environment, 2017). Excessive carbon emissions are causally linked to the phenomenon of climate warming. The national average temperature exceeded the historical record by about 1 degree, measuring 9.5 degrees (Minister of the Ministry of Ecology and Environment, 2017). This place has the third warmest year since 1951. According to figure 10, it is evident that the temperature has been consistently increasing since the year 2000, surpassing the average yearly temperature of earlier periods. This notable rise is caused by excessive human activity due to rapid economic development. With this situation worsening, Chinese citizens a has growing environmental awareness and public discontentment with the perceived inadequacy of government administration (Xiao et al., 2013).

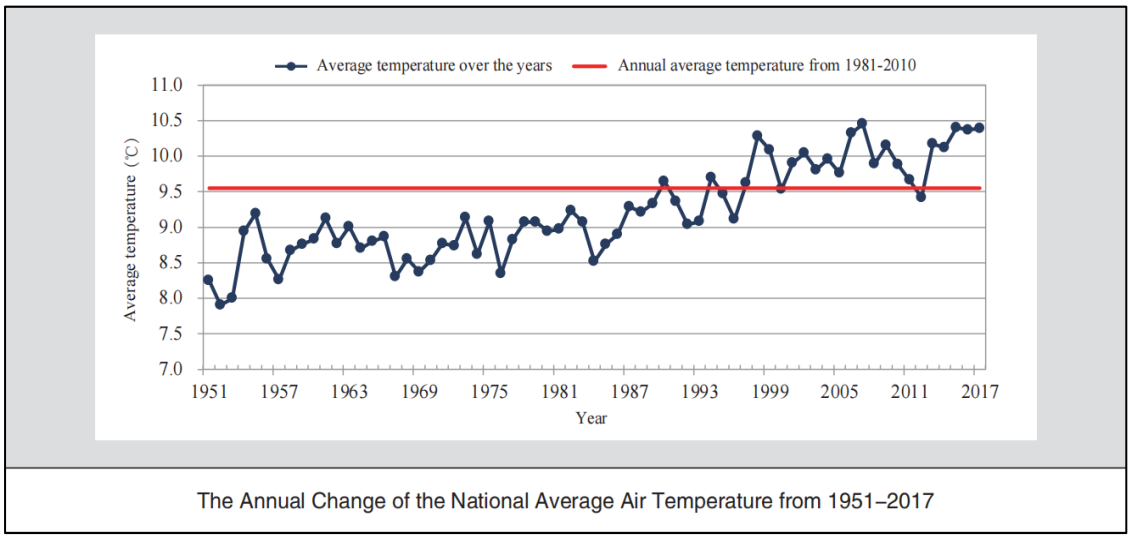


Figure 10. The Annual Change of China's Air Temperature from 1951-2017

Source: Minister of the Ministry of Ecology and Environment, 2017.

Besides air pollution in China, other aspects of the environment are facing great pressure from disordered economic expansion. The coastline region experienced a rise in sea level of 58 mm when compared to historical data from the period spanning 1993 to 2011 (Minister of the Ministry of Ecology and Environment, 2017). In addition, because of significant industrial pollution, the prevalence of acid rain in urban areas exceeded 30% of the total number of cities during a one-year period. Moreover, the rapid and severe climate change in China has significantly degraded the quality of the ecological environment, resulting in roughly 60% of all cities being classified as having poor environmental conditions (Minister of the Ministry of Ecology and Environment, 2017). This phenomenon posed a significant threat to biodiversity, leading to a 30% increase in the number of endangered plant species and the degradation of animal habitats (Minister of the Ministry of Ecology and Environment, 2017). With respect to the groundwater aquifer system, it is observed that approximately 50% of the shallow groundwater exhibits substandard water quality, mostly attributed to the presence of contaminants originating from industrial and household sources, such as heavy metals (Minister of the Ministry of Ecology and Environment, 2017). Within the current environmental context, an increasing number of Chinese citizens are advocating for governmental intervention to safeguard the air quality and lift the environmental standard of economic progress (Xiao et al., 2013).

To strengthen environmental conservation, the Chinese government enacted more stringent provisions in the revised edition to regulate economic operations: "*Environmental Protection Law of the People's Republic of China"* in 2015. In contrast to its predecessor -the 1989 version which placed emphasis on economic advancement, the new legislation has introduced a new concept of *"ecological civilization"* and established several measures, including an assessment mechanism, an environmental credit system, and legal accountability. For example, the process of making investment decisions requires the inclusion of environmental risk assessment, as well as the conduct of environmental research and surveys. In addition, the implementation of license

management aims to regulate the behaviors of firms that have a detrimental impact on the environment. This entails that related companies must obtain the necessary license prior to starting their operations. Actually, there are various categories of licenses, including those pertaining to water, air, noise, and other related domains. The newly enacted legislation grants enforcement authorities certain powers to confiscate assets that contribute to pollution or to shut down factories in cases corporations persistently emit excessive levels of pollution against the law. Furthermore, it mandates enterprises to comply with regulations pertaining to the disclosure of environmental information and the promotion of public engagement. Furthermore, public have right to initiate public interest litigation against certain entities that have contributed to environmental pollution.

Furthermore, China has formally presented its National Determined Contributions (NDC) to the United Nations Framework Convention on Climate Change (UNFCCC) accompanied by revised objectives. Despite being deemed inadequate by certain stakeholders, China has demonstrated progresses in carbon emission management (Climate Action Tracker, 2021). The objectives encompass the following: (1) Attain the maximum level of carbon dioxide emissions prior to the year 2030 and accomplish carbon neutrality by the year 2060. (2) Achieve a significant reduction in carbon dioxide emissions per unit of GDP and aim for a decrease of over 65% by the year 2023, as compared to the levels observed in 2005. (3) Achieve a 25% share of non-fossil fuels in primary energy consumption by the year 2030. (4) Achieve a 6 billion cubic meter increase in forest covering by the year 2030, in comparison to the baseline level of 4.5 billion cubic meters recorded in 2005. (5) Enhance the capacity of wind and solar power facilities to a total of 1.2 billion kilowatts by the year 2030.

Based on domestic environmental legislation and international commitment to climate change, China has opted to enhance the environmental sustainability of its outward investment through the BRI platform. In this case, an abstract concept known as “Green BRI” has been put forward with the aim of highlighting the importance of ecological

civilization and sustainable development within the BRI in 2017 in two documents. This "Green BRI" proposal seeks to encourage responsibility among the BRI participating countries. This idea of greening the BRI was initially introduced in 2015 through "*Vision and Actions on Jointly Building Silk Road Economic Belt and 21st-Century Maritime Silk Road*", implicitly stressing the importance of low carbon infrastructure.

Then, the official concept of "Green BRI" was illustrated in the two key documents *"Ecological Environmental Protection Cooperation Plan for BRI"* and *"Guidelines on Promoting Green Belt and Road,"* published in 2017. These documents in a detailed manner are explained in the following section. Importantly, bringing the concept of "Green BRI" to the global stage happened at the 2017 Belt and Road Forum, where China officially positioned the "Green Silk Road" as a core pillar of BRI cooperation. So far, the foundation of environmental governance of the BRI framework is formed by 2017. Later, to support green BRI, China pledged to halt overseas coal-fired power investments in September 2021. President Xi made this commitment in a speech at the United Nations General Assembly, and he stressed that China supports other developing countries in terms of green and low-carbon energy technologies (Nedopil, 2023).

Regarding the coal production, China's coal output always face criticism in the international community because of its significant share, accounting for almost 50% of global coal production (Maizland, 2021). China itself, also significantly rely on coal-fired power plants, accounting for approximately 62% of national electricity generation in 2021 (Oxford Institute for Energy Studies, 2022). So, halting oversea coal-fired power investments is a tangible milestone to fulfill promises of mitigating climate change. It is meaningful to reflect China's deliberate policy shift to reconcile economic development with ecological sustainability under the UN SDGs and Paris Agreement.

2.3 Environmental Concerns Relative to BRI

Studies have revealed that the implementation process of some BRI projects can result in environmental changes (Coenen et al., 2021). Although BRI project recipient countries may differ in terms of local governance and planning processes, experts in the University of Cambridge Institute for Sustainability Leadership (CISL) have identified four common and critical concerns that are crucial in the implementation phase.

The initial concern relates to the insufficient evaluation of the impact of BRI projects and the corresponding environmental rules. Companies failed to adequately communicate the requirements of environmental law and the potential impact of the BRI project with the affected people. In addition, the national government has granted permission for these activities without imposing any limitations and has even adopted simplified approval processes for projects related to BRI. Therefore, relevant negative environmental effects and adverse effects on local populations can be attributed to insufficient governance by national authorities and investment firms. For instance, The BRI project at Piraeus Port in Greece, which is being managed by China COSCO Shipping Corporation, has faced public criticism regarding issues of noise and air pollution (Coenen et al., 2021). It turns out that the project lacks a comprehensive strategic environmental impact assessment, which can be attributed to the investing company and previous government's inadequate management practices (Apostolopoulou, 2021).

The second concern is the inadequate provisions for compensating or relocating local residents impacted by BRI projects, such as the road construction initiatives in Kathmandu, Nepal (Apostolopoulou, 2021). Normally, Chinese companies and local governments should establish official plans for the displacement of populations or give grant compensation prior to the start of projects, if projects have adversely affected local community. The third concern is associated with the alteration of employment relations among the indigenous workforces. According to Neilson (2019), the International

Container Terminal project in Colombo, Sri Lanka, witnessed the utilization of a hybrid employment model by Chinese enterprises, wherein direct hiring was paired with subcontracting. This practice was always related to diminished pay and reduced labor rights. The fourth concern is about the insufficient involvement of the public in the decision-making process of the BRI projects. To ensure that individuals have the necessary knowledge to understand potential threats and economic growth, it is imperative to provide them with relevant information.

In general, common concerns regarding BRI projects are mainly about insufficient consideration for environmental concerns, equitable worker rights, and the welfare of local people. To address these concerns and provide effective oversight over future BRI projects, the Chinese government has placed significant emphasis on the "Green BRI" initiative, which has dual purposes of fostering a responsible image among BRI countries and promoting sustainable development.

2.4 Green BRI Documents

With introduction of the green BRI concept, a series of policies have been consistently issued to facilitate the environmentally sustainable advancement of the BRI strategy. These policies are basically guidance issued by government to corporations, financial institutions, and affiliated stakeholders, aiming to enhance their approach towards addressing environmental problems. Notably, these policies are not legally binding statutes but rather guidelines. This section will illustrate existing documents issued by the government to embody the fundamental spirit of the green BRI.

In 2015, *"Vision and Actions on Jointly Building Silk Road Economic Belt and 21st-Century Maritime Silk Road"* was issued by China's National Development and Reform Commission, Ministry of Foreign Affairs and Ministry of Commerce. This document firstly proposed the word "Green Silk Road". It strongly promotes green and low-carbon infrastructure construction and operation and requires companies to fully

consider climate change effects. It also highlights the concept of ecological civilizations and advocate BRI participating countries to jointly build the green Road Road, especially facilitating cooperation in clean and renewable energy such as hydropower, nuclear power, wind power, and solar power.

Later in 2017, when the Green BRI was officially proposed in the Belt and Road Forum, two fundamental documents that pave the way of environmental governance of BRI are published. The first one is *"Guidance on Promoting Green Development of the Belt and Road Initiative"*, outlining the overarching framework that integrate the green principle into the BRI. It set priority for the 3-5 years goals of greening BRI such as building a series of eco-environmental cooperation base as models, establishing environmental risk management system and so on. Then the priority of 5-10 years goals is more general, such as creating a service-support-guarantee system for ecological protection and conducting more environmentally friend projects. As for specific terms, it promotes environmental impact assessments (EIAs) for infrastructure projects in sensitive areas, enforces green standards for energy, transport, and construction, and encourage green trade and green financial tools such as green bond. It requires relevant government to build a Big Data Platform for environmental data sharing to international green technology cooperation and environmental research. Also, it stresses corporate accountability, requiring firms to comply with host-country environmental laws, publish sustainability reports, and prioritize green technologies and biodiversity protection.

In the same year 2017, *"One Belt One Road Ecological and Environmental Protection Cooperation Plan"* was issued as a more specific document. It proposed to establish the "Belt and Road" Ecological Environmental Cooperation International Alliance for a better policy communication, set up an intellectual supporting system including think tank, researchers and consultants, also require 19 key enterprises to sign the document "*Implementation of Corporate Environmental Responsibilities and Jointly Building a Green Belt and Road Initiative"* as their commitments. To better trade green products, it is suggested to explore the establishment of a mutual recognition mechanism for

environmental labeling products among BRI countries. For protecting biodiversity, it mentioned to establish a biodiversity database and information sharing platform. Moreover, it is a step further to a more specific plan with 25 major projects in six aspects, including policy communication, infrastructure connection, trade, financing, people-to-people understanding and capability building.

Then in 2018, the *"BRI Green Investment Principle"* document was introduced. The Second Belt and Road Forum put come up with seven principles that firms have can employ on a voluntary basis in relation to the funds provided by the BRI (Green Finance Committee of China Society for Finance and Banking et al. 2018). The guidelines advocate for the application of green finance, emission right financing, and green investment funds, embedding sustainability principles into corporate governance. This guideline considers environmental, social, and governance (ESG) factors, encouraging firms to offer transparent information relevant to environment and climate change. Subsequently, in 2019, "*Green Industry Guidance Catalogue*" was then issued to clearly define "green BRI project" scope, helping to identify eligible BRI investments for favorable financing terms, promoting green investments and avoid green washing.

In 2022, "*Opinions on Promoting the Green Development of the Belt and Road Initiative"* was jointly released by the National Development and Reform Commission, the Ministry of Foreign Affairs, the Ministry of Ecology and Environment, and the Ministry of Commerce. The statement highlights the significance of governmental involvement in guiding enterprises. To facilitate the dissemination of ecological knowledge, green technologies, research on environmental laws and regulations, and internationally recognized standards, several collaborative platforms within the green BRI will be established. These platforms include the "BRI Green Development International Alliance" and the "BRI Environmental Protection Big-data Service Platform". Moreover, it included instructions for a total of 15 specific domains. For instance, infrastructure projects must carefully select suitable locations and routes in order to avoid ecologically vulnerable and sensitive areas. During the construction

process, they are required to improve resource efficiency to save energy, water, and materials. Moreover, it strongly promotes green energy BRI projects that prioritize the construction of renewable energy power plants, investigations and investments into nuclear power, hydrogen energy, and related areas. In terms of transportation, low-carbon and energy-saving modes of transportation are highly encouraged, especially clean-energy cars (e.g., electric cars). Regarding international trade, it point out to increase the import and export of energy-efficient and ecologically sustainable products and services. It also mentions that, if green BRI projects are supported by international financial initiatives, the borrowed loans should be fully used for environmentally sustainable activities, not transferred to other projects. Also, the document emphasizes the importance of harmonizing different national green standards, given distinct environmental standards among the BRI participating countries. Overall, the core purpose of this document is to narrow down previous documents and highlight scientific and technological measures in environmental governments.

In 2023, "*The Beijing Initiative for Green Development along the Belt and Road"* was issued in 3rd Belt and Road Forum in October 2023 (Chinese Foreign Ministry, 2023). This document was collaboratively initiated by over 30 stakeholders, including governmental bodies, environmental authorities from 21 nations, international organizations, academic institutes, financial entities, and corporations. The program seeks to adopt a framework to deal with pollution reduction, carbon reduction, green development, and economic growth, with a specific emphasis on addressing climate change and conserving biodiversity. Furthermore, this initiative emphasizes promoting the development of low-carbon and circular economic infrastructure for enhancing green collaboration. It is also recommended that Chinese firms participating in the BRI should adhere to the most stringent environmental protection measures to mitigate potential contamination. The Beijing Initiative signifies the importance of the BRI as a crucial platform for augmenting China's influence in the realm of global environmental governance.

Another important series of guidance are issued by BRI Green Development Institute (established as request of previous policies) with three documents "*Guidelines for Green Development of Belt and Road Initiative (BRI) Projects", which were* consecutively issued between 2019 and 2023. The first guideline proposed a approach to categorize projects into distinct classifications, offering a comprehensive list of favorable and unfavorable aspects to enhance the management of BRI projects. According to the BRI Green Development Institute (2020), projects under the BRI can be categorized as "Red", "Yellow" or "Green" based on their environmental implications, including pollution avoidance, climate change mitigation, and biodiversity protection. As stated in studies in 2020 by the BRI Green Development Institute, "*red projects"* refer to projects that are likely to result in significant and enduring adverse effects on the environment in terms of above three areas. "*Yellow projects"* are projects that have a moderate level of impact. It means, if certain measures are taken, the environmental disruptions caused by yellow projects can be effectively alleviated. "*Green projects"* are projects that actively contribute to at least one of three overarching objectives, namely the prevention of pollution, mitigation of climate change, and enhancement of biodiversity. Based on classifications, funding terms and risk management of a BRI project depends on its specific category to which it belongs. Specifically, green projects are exclusively available to legislative advantages, financial rewards, and subsidies. In contrast, red projects must undergo thorough scrutiny and supervision in the stages of approval and implementation (BRI Green Development Institute, 2020).

The second guideline provides practical recommendations to key stakeholders engaged in projects related to the BRI, including firms, financial institutions, policymakers of countries investing in the BRI, and countries receiving investments from the BRI (BRI Green Development, 2021). Enterprises are advised to utilize questionnaires and classification tools throughout the first stages of project development to conduct self-assessments based on the red, yellow, and green categories. When firms take

environmental impact mitigation methods, they have the opportunity to access more favorable funding conditions for projects that would have positive climatic and ecological outcomes. Moreover, firms are strongly urged to proactively develop and disclose environmental, social, and governance (ESG) reports, as well as construct a complaint response process to facilitate external oversight.

Furthermore, financial institutions should actively participate in the initial phase of project design and identify pertinent environmental influences. Financial institute also can design distinct conditions for projects that include varying levels of risk, hence minimizing transaction costs through the adoption of suitable contractual provisions. For example, it is possible to provide a reduced borrowing rate for environmentally sustainable projects, while implementing specific contractual covenants for projects that have a negative environmental impact. In addition to this initial engagement, it is strongly recommended that financial institutions actively participate in the management of all project life cycles stages and establish a direct contact system with important stakeholders and local populations.

The third guideline places emphasis on the foreign investment fund and provides guidance pertaining to environmentally sustainable investment opportunities (BRI Green Development, 2023). The document provides an account of the ongoing experiences of the China-ASEAN Investment Cooperation Fund and the China-Africa Development Fund. The former fund utilized a projects classification system and life cycle management system that were based on the environmental and social effects of the projects. The later fund compiled a list of projects that are in violation of the environmental regulations of the invested countries and forbids funding them.

However, countries across the globe are currently in various phases of development. Since developed countries have already achieved wealth through industrialization with heavy pollution, developing countries possess the right to acquire financial resources from wealthy countries to address their environmental concerns and enhance their

capacity to foster a sustainable economy. So, there is an urgent need for increased international cooperation and communication, particularly among wealthy nations.

2.5 Environmental Impact of the BRI

The above green BRI documents aim to generate a positive effect of BRI projects on environmental quality. This part is designed to examine current literature to understand the relationship between BRI on its effect on the environmental quality of its participating countries. This part begins with a comprehensive literature review to ascertain the current landscape of research in this domain. Then, an important hypothesis of this research is formulated, which will be empirically tested using panel data analysis in the next part.

2.5.1 BRI's Environmental Impact

Literature of studying the BRI is largely controversial, depending on the angles from which studies are conducted. With respect of BRI's sustainability, Sachdeva (2018) explores Indian (Non-BRI country) perceptions of the BRI, saying that the BRI is a truly evolving development beyond just official slogan. India also found the sovereignty-related issues in some BRI corridors and geopolitical effects (Sachdeva, 2018). In the same year, Colombo (2018) critically analyzes the BRI, emphasizing challenges such as financial sustainability and geopolitical reactions from neighboring countries. Regarding trade facilitation, Soyres et al. (2018) study the reduction of trade costs and shipment times through BRI transport infrastructure projects. Their research revealed that BRI can greatly reduce the trade cost and shipment time, with an average reduction range from 1.2 percent to 2.5 percent (Soyret et al., 2018). Later, Jiang et al. (2021) investigate trade efficiency of BRI, highlighting the need for improving trade efficiency by building more infrastructure cooperation within BRI countries.

From a environnemental perspective, Hahm et al. (2018) utilize a global trade analysis project model to show potential economic benefits of BRI corridors, emphasizing an

important precondition of managing social effects, environmental risks and project costs carefully. Zubedi et al. (2022) examine the effects of energy consumption and foreign direct investment (FDI) on environmental sustainability within the BRI in Pakistan. The study reveals that the BRI can substantially boost trade, FDI, and the living standards of citizens. However, it emphasizes that carbon emissions will certainly rise and are related to growing energy consumption, FDI, and economic growth in the long run (Zubedi et al., 2022). Finally, Zhang et al. (2023) investigate how the Silk Road Economic Belt helps to long-term economic growth in Central Asia, with an emphasis on Kazakhstan, emphasizing the importance of economic stability for long-term development. These studies collectively provide a comprehensive review of the BRI, covering various dimensions such as trade, environment, and economic growth.

The importance of environmental quality in the process of economic growth in any country has been a topic of interest in academic studies. Not only because environmental quality is the basis for our human beings for survival, but also a valuable source to generate economic interests. For example, Lechaudel et al. (2007) addressed how environmental factors influence mango fruit development and quality, emphasizing the significance of preharvest environmental conditions in agricultural outcomes. Lozano et al. (2008) created an environmental growth model for a tourism-focused economy, emphasizing the impact of environmental conditions on economic activity. However, there are lots of factors in social science that can adversely affect environmental quality. For instance, Shahbaz et al. (2020) revisited the nexus between financial development and environmental degradation in the context of the United Arab Emirates, incorporating economic growth and globalization in their analysis, emphasizing that financial development and economic growth is positively linked to environmental degradation.

Even though environmental quality is crucial, it is fragile to human economic activities. But there do exit some ways to protect the environmental quality as well as developing economies (Shafik,1994). For instance, Iorember et al. (2021) evaluated the influence

of renewable energy use, human capital, and trade on ecological footprint, emphasizing the role of renewable energy in promoting environmental sustainability. Li et al. (2021) studied the influence of green logistics on economic growth and environmental quality in BRI nations. They found that global green logistics could improve both green economic activities and environmental consequences. Overall, these studies highlight the need to address environmental quality alongside economic development.

2.5.2 Environmental Growth Nexus

Several theories have been proposed to explain the environmental growth nexus. The Ramsey model is extended to include natural resource inputs, pollution, and endogenous technical development as environmental constraints (Acemoglu et al., 2012; Barbier, 1999). It stated that sustainable growth can be achieved if taxes and subsidies encourage innovations towards clean inputs to replace traditional production inputs in economies (Acemoglu et al., 2012). Furthermore, the relationship between carbon dioxide emissions and economic growth has been studied, with distinct patterns observed in different countries based on their economic development levels. Developed countries are frequently aligned with N-shaped and M-shaped models, while developing countries are generally associated with inverted U-shaped, inverted N-shaped, and simply growing models (Yang et al., 2015).

Among all environmental growth nexus, the most famous one, the environmental Kuznets curve (EKC) hypothesis, has been extensively explored both theoretically and empirically, indicating a certain consensus of pollution-growth nexus. Simon Kuznets invented the Kuznets Curve in 1955, proposing that income disparity rises initially, then falls as economic progress continues (Kuznets, 2019). Then this theory is extended to environmental degradation and economic progress, being so called Environmental Kuznets Curve (EKC) hypothesis, which proposes an inverse U-shaped relationship between economic progress and environmental degradation. Initially, as countries' economies expand, environmental contamination worsens. However, after a specific

income level is reached, the trend reverses, resulting in higher environmental quality (Dinda, 2004).

The EKC hypothesis has sparked interest in several studies on BRI countries. Rauf et al. (2018) investigated the EKC hypothesis for BRI economies and discovered findings in consistent with EKC hypothesis in developed economies. Besides, Saud et al. (2018) analyzed the impact of financial development, economic growth, FDI, electricity consumption, and trade openness on environmental quality in BRI countries, concluding that financial development and trade openness can enhance environmental quality. Later, Saud et al. (2019) investigated the relationship between financial development, income level, and environmental quality in central and eastern European countries, and discovered evidence to support the EKC theory for the panel countries. Muhammad et al. (2020) found that urbanization and international commerce had a significant impact on CO2 emissions in BRI countries, supporting the EKC hypothesis in upper-middle and high-income groups. Tamazian and Bhaskara Rao (2010) used panel data from 24 transitional economies from 1993 to 2004 to investigate the link between economic, financial, and institutional developments and environmental degradation. Their findings give further support to the EKC theory. Gao and Fan (2023) investigate the impact of technological innovations and institutional quality on carbon dioxide emissions in BRI nations, reflecting the Environmental Kuznets Curve. Rahman et al. (2020) also evaluated the EKC hypothesis for nations in the Bangladesh-China-India-Myanmar economic corridor under the BRI, focusing on carbon dioxide emissions, GDP per capita, energy consumption, and trade openness. They identified that the theory is only valid in the short term and recommended ways to mitigate environmental degradation and achieve sustainable development.

The second well-known hypothesis is “Pollution Heaven hypothesis” (PHH) (Copeland & Taylor, 2017), which proposes that economic development cooperation might potentially move high-polluting businesses to poor countries through foreign investment, resulting in environmental degradation there. More specifically, this hypothesis asserts

that "*frequent economic exchanges and communications among economies could largely lead to pollution transformations from developed countries into developing ones*" (Liu et al., 2018, pp6-7). To verify this hypothesis, Liu et al. (2018) investigated environmental situation in the BRI countries from 1990 to 2016 and discovered evidence supporting the Pollution Havens Hypothesis.

The third hypothesis, known as "The Pollution Halo Hypothesis" (PHAH), proposes that with lower trade barriers and increased cooperation among multi-nations, multinational enterprises could transfer environmentally friendly technologies to host countries, such as pollution abatement technologies, renewable energy-related technologies, and energy-conserving technologies (Duan & Jiang, 2021). Thus, there is a good chance that international cooperation through businesses can strengthen host countries' green technology and raise environmental quality levels.

Regarding literature of PHH and PHAH hypothesis, Abid and Sekrafi (2021) investigated the direct and indirect effects of trade openness on environmental deterioration in 31 developed and 100 developing countries from 1980 to 2016. Their findings show that the PHH is generally connected with underdeveloped countries, whereas the PHAH is more commonly associated with developed countries (Abid and Sekrafi, 2021). But empirical findings do not support the EKC hypothesis in developing countries but do support it in developed countries (Abid & Sekrafi, 2021). This could imply that increased trade and foreign direct investment causes developed nations to move their polluting operations to developing countries, thereby resulting in emissions reductions in developed countries at the expense of developing countries (Abid & Sekrafi, 2021). Overall, these environmental growth nexuses offer useful insights on the correlation between economic development and environmental degradation in BRI countries.

2.6 Green BRI Investments Analysis

As a pivotal driver of BRI strategy implementation, China's Outward Foreign Direct Investment (OFDI) serve as a critical yet under-explored nexus for analyzing BRI investments. This part focuses on disentangling the two environmental pathways through which OFDI operate: conventional investment patterns that may perpetuate carbon-intensive industrial transfers (Pollution Haven hypothesis) versus emerging green OFDI practices that potentially facilitate low-carbon technology transfer and environmental governance enhancement (Pollution Halo hypothesis). The following analysis seeks to identify Chinese investment flows and trends by systematically analyzing these investment patterns and their diverse consequences on carbon emissions.

2.6.1 China' FDI General Landscape

Prior to the inception of BRI, Chinese companies had already engaged in overseas investments across numerous countries. It is essential to gain a preliminary understanding of China's overall FDI landscape before conducting an in-depth analysis. From 2003 to 2015, as indicated by figure 11, China's direct investment net figure (equal to outflow minus inflow) remained negative, indicating a sustained inflow of direct investment that exceeded the outflow over this 12-year period. Between 2015 and 2018, China's outward direct investment surged globally, turning the FDI net amount into a positive figure. China's FDI with net inflow and outflow trends can be found in the figure 12 and figure 13.

When looking at the inflow and outflow of direct investment, respectively, this study finds that the inflow of direct investment into China increased dramatically, from 58 billion dollars in 2003 to 290 billion dollars by 2013, a fivefold increase in figure 13. During this phase, China's economy grew rapidly, and foreign investment activities were particularly vibrant because China emerged as a crucial player in the global manufacturing sector and value chain. However, after 2013, as domestic industries were approaching maturity, the inflow of direct investment began to decline. During the

COVID-19 pandemic, probably due to effective containment measures and the continued operation of factories, the inflow of direct investment rose again, reaching a historical peak of 344 billion dollars in 2021. After that, because of the global geopolitical tensions, especially the US-China trade war, and the increased labor cost, increased policy uncertainty, and economic slowdown, FDI inflow into China plummeted to a very low level at 43 billion dollars (Investment Monitor, 2024).

Regarding China's global FDI outflow in figure 12, it grew rapidly from a negligible amount in 2003 to a historical peak of 216 billion dollars in 2016, marking an approximately 26-fold increase. Particularly after the BRI Initiative was proposed in 2013, the outflow of Chinese enterprises' direct investment surged to its peak in 2016. During the COVID-19 pandemic, there was a decline in the outflow, which recovered to pre-pandemic levels by 2022. After 2022, with the rapid decrease in inflow and the sustained high outflow of direct investment, China's net direct investment turned positive again, suggesting a continuous high level of outward investment in the foreseeable future.

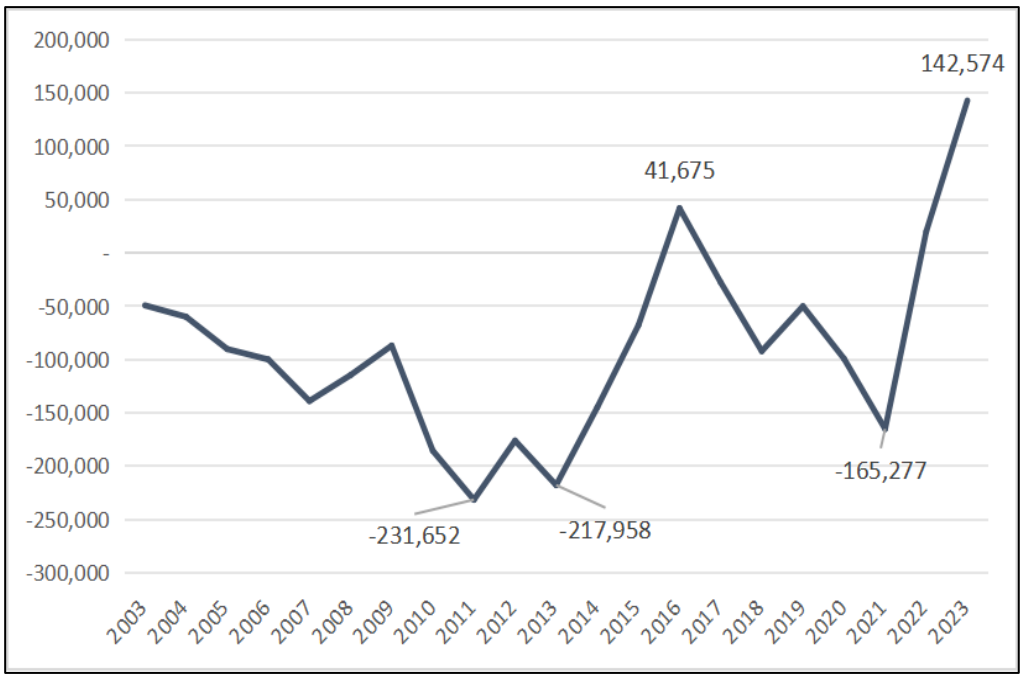


Figure 11. China's FDI Net Amount (Million US Dollars)

Source: World Bank, 2023.

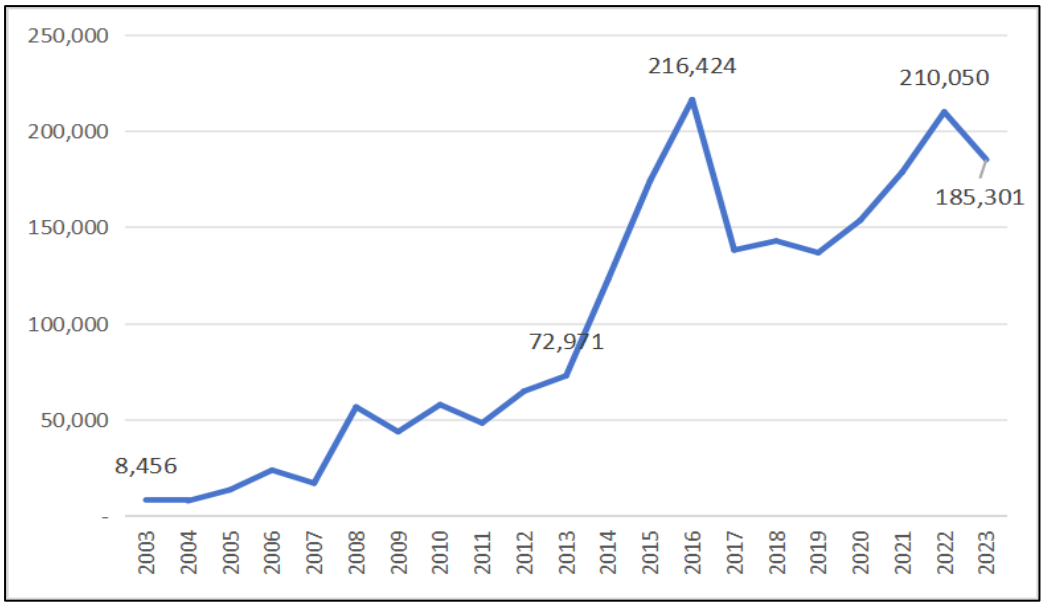


Figure 12. China's FDI Net Outflow Amount (Million US Dollars)

Source: World Bank, 2023.

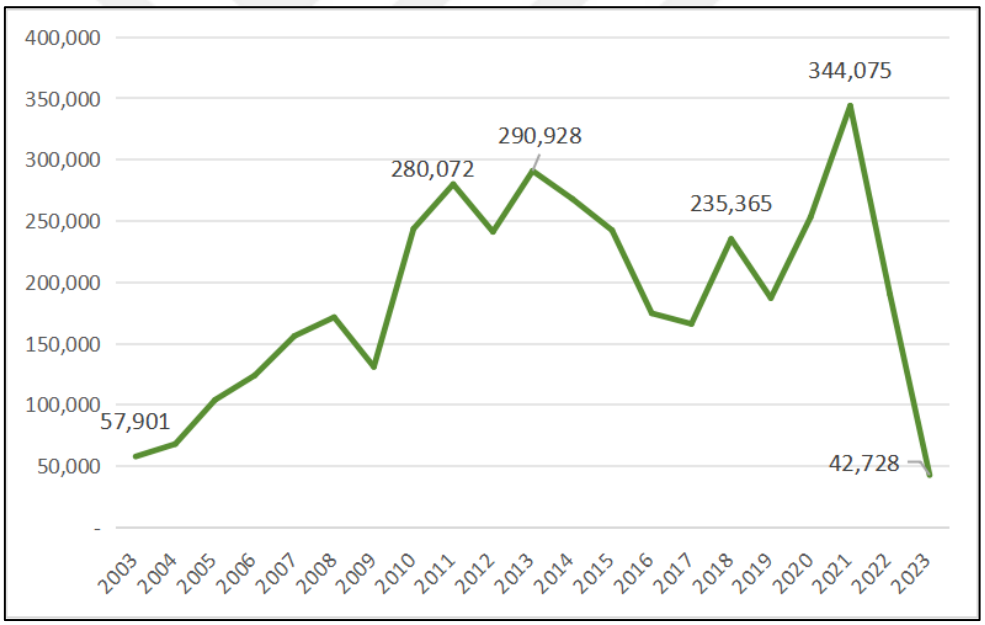


Figure 13. China's FDI Net Inflow Amount (Million US Dollars

Source: World Bank, 2023.

2.6.2 China's OFDI General Landscape

By breaking down the collected OFDI data, this study analyzes investment industries in figure 14 and destined countries in figure 15. As for invested industry shown in figure

14, in 2007, China's outward direct investment was predominantly allocated to wholesale and retail trade, leasing, and business services, with significant investments in transportation, mining, and manufacturing. After 16 years, in 2023, wholesale and retail trade, leasing, and business services are still dominating the leading position. But investment amounts in some sectors are increasing. For example, manufacturing has expanded to the third place of all industries. Scientific research, technical services and geological exploration also move up to the higher tank, followed by the financing industry (4th place), the mining industry (5th place), and transportation warehousing and postal services (6th place).

As for the investment-destined countries in figure 15, based on data of invested destinations from 2007 to 2021, a shifting pattern the changing trend can be uncovered. First of all, during 14 years, the top 3 countries have consistently been Hong Kong, China; the British Virgin Islands; and the Cayman Islands, all of which are known for international havens for tax, financing, and international trade. Apart from these countries, the other top 11 independent countries receiving the most Chinese OFDI are listed in the line figure 15. It is observed that in 2007, Canada, the United Kingdom, and Australia were the top 3 most popular destinations of China's OFDI, with Canada as the first place received 1.03 billion dollars. However, China's OFDI flowing to Singapore reached its peak in 2015 and remained the leading country in 2021. Later in 2016, China's OFDI flowing to the United States peaked and remained the top 2 destinations in 2021. This underscores Therefore, Singapore and the US play a significant role in China's global investment environment. Notably, it is evident that Indonesia experienced a remarkable increase in receiving Chinese OFDI, growing from 0.099 billion dollars in 2007 to 4.37 billion dollars in 2021, becoming the 3rd place of investing destinations. A similar situation also happened in Viet Nam with 5th place in China's OFDI. Conversely, Australia and the United Kingdom have witnessed a rapid decline of investments, only ranking 6th and 7th places. These dynamic changes highlight that China's OFDI destinations are experiencing notable shifts

towards Asian countries, with significant investment growth in Southeast Asia, particularly in Indonesia and Viet Nam.

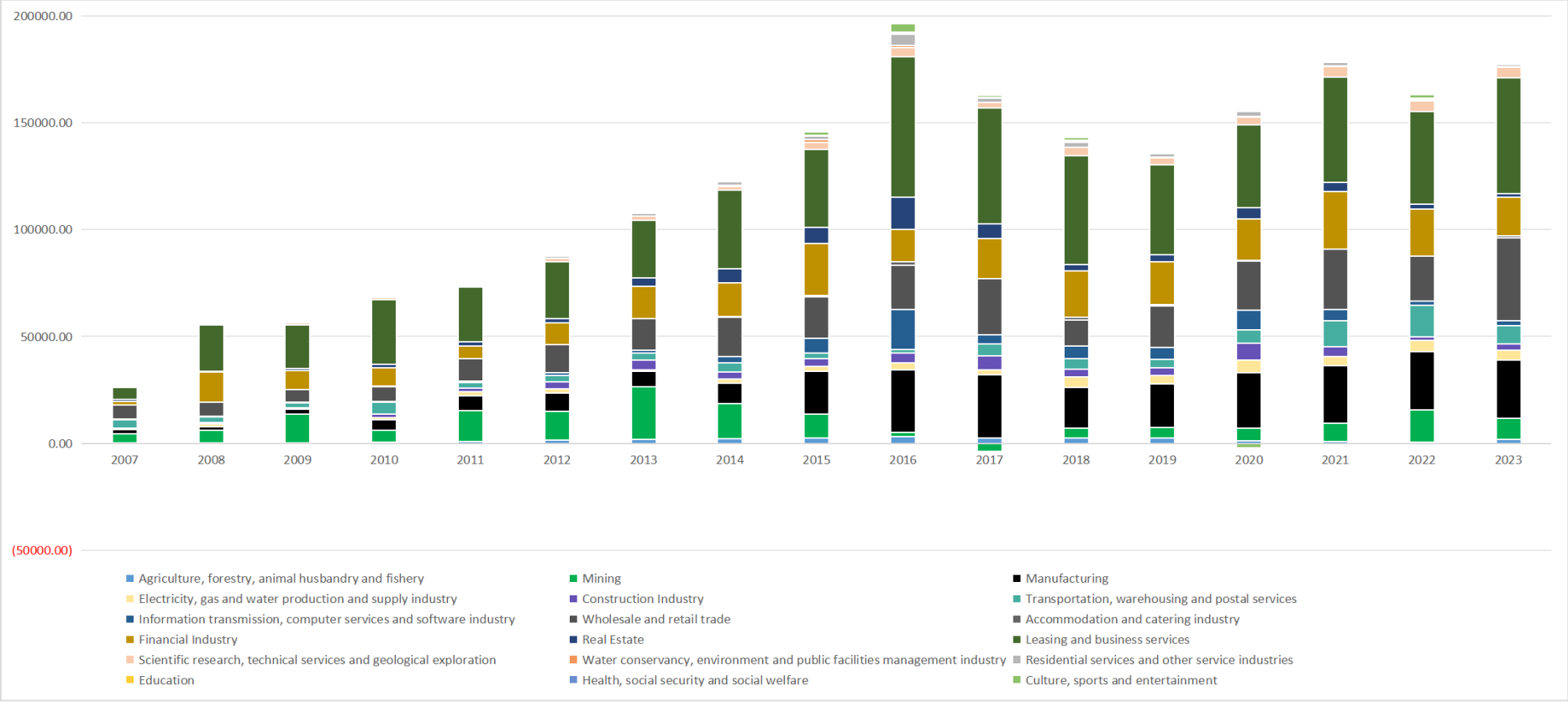


Figure 14. China's Outward FDI Flows by Industries

Source: National Bureau of Statistics of China, 2024

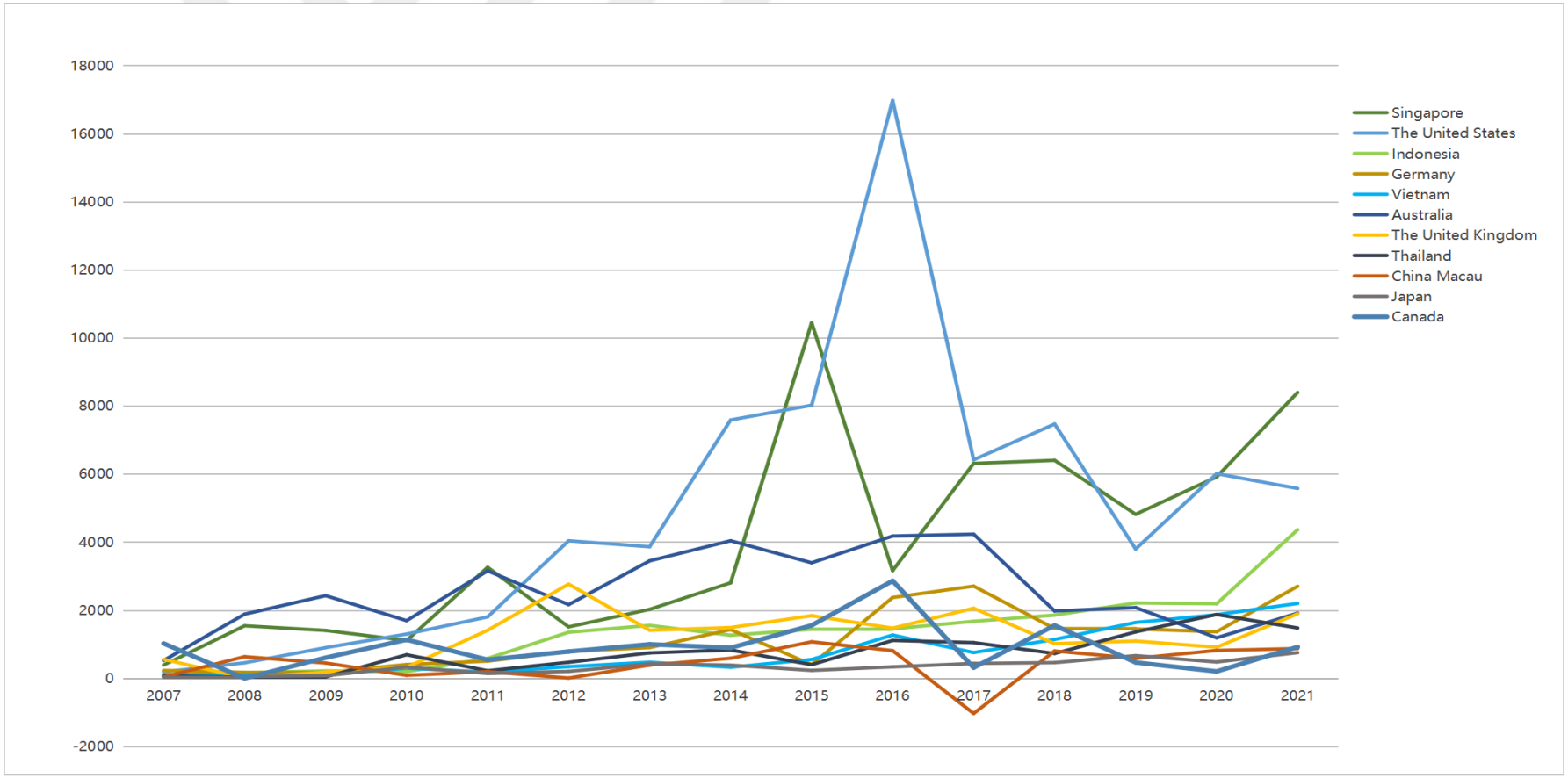


Figure 15. Destinations of China Outward FDI Flows

Source: National Bureau of Statistics of China, 2024

2.6.3 China's Green Investments in BRI Participant Countries

To further examine China's OFDI in BRI countries, detailed information on each individual investment project is required. Given the data availability, the database in the China Global Investment Tracker website is used, which records and aggregates data of large Chinese investment projects (more than $100 million USD), presenting their crucial elements such as the investing entities (Chinese enterprises), receiving nations, investment dates, sectors, and investment amounts. This database is meticulously compiled by the American Enterprise Institute and made accessible to the public, being the most comprehensive resource of Chinese global outward investments and frequently utilized in academic research (Shao, 2020). On this foundation, to ascertain whether each investment transaction is classified as green FDI, a thorough collation of sub-sector information using publicly available online news and data need to be conducted. Then the author manually appended the sub-sector information and classified them based on whether the investments align with the green attributes based on the six targets of the EU Taxonomy.

The analysis of these investment projects is confined to 45 developing countries participating in the BRI. Besides, aligned with the same time period of following empirical study, the time window of this green investment analysis spans from September 2013 to December 2023. However, it must be acknowledged that the database on the website does not represent all of China's overseas investment projects because lots of BRI projects less than 100 million dollars are not included in this dataset. Despite this, it can still substantially aid in understanding the trends and the degree of greenness of BRI investments.

First of all, regarding Chin's oversea investments portfolio, the figure 16 depicts the shifting sectoral allocation of China's total overseas investments (combining green and non-green together) from 2013 to 2023. The data reveals significant changes in China' BRI investment priorities over the decade.

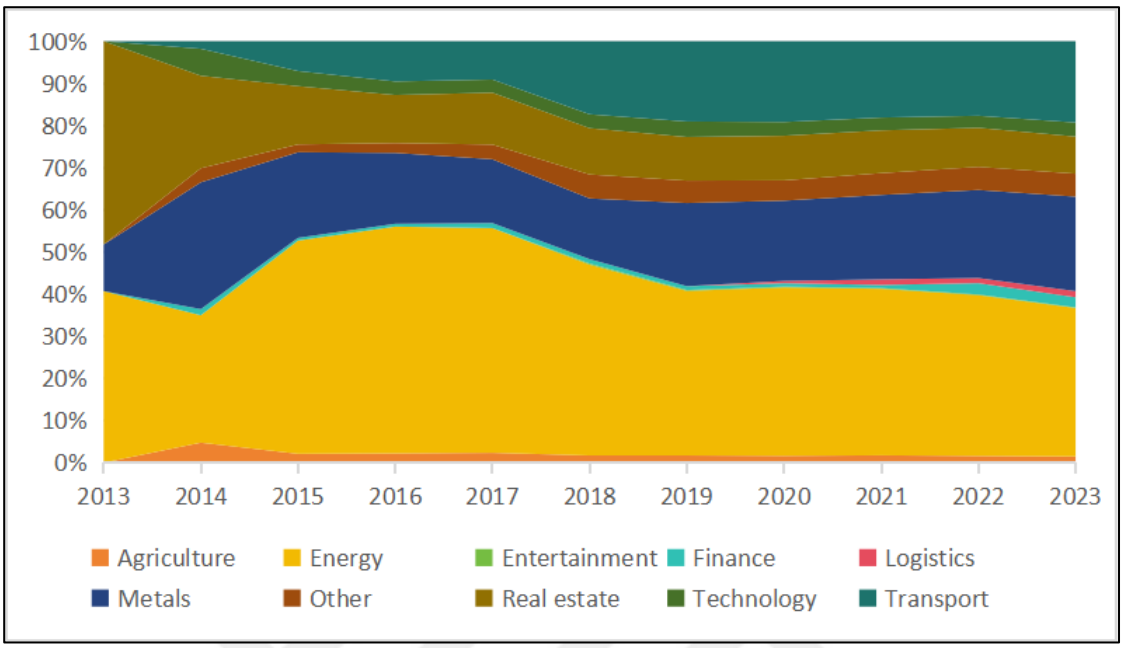


Figure 16. Stacked Percentage of BRI Investment Sectors

Source: China Global Investment Tracker.

From the above figure, it is observed that, in 2013, prominent sectors are real estate and energy, accounting for 33% and 28%, respectively. Later in the following decade, from 2013 to 2023, the percentage of real estate diminished to 9% at the end. However, the percentage of energy was dramatically increasing since 2014 and reached its peak in 2017, accounting for 53% of total investments. Then, though the absolute number of energy-related investments was still rising, its percentage of the total investment portfolio was decreasing, being 35% at the end of the year 2023. While declining from its peak, energy remained a substantial and top-largest sector throughout the period. Another dynamic, changing sector is the metal sector, which experienced significant growth through the period, from the beginning of the year, 8% of the investment portfolio, to 22% in 2023, becoming the second-largest sector. In addition, the transport sector has also undergone a rapid rise, from nearly 9% in 2017 to 19% in 2023, being

the top 3 largest sectors of investment portfolio. Other sectors, such as agriculture, finance, logistics, and entertainment, constantly constituted only minor fractions of the overall investment distribution. Overall, this figure shows the growing importance of investment portfolios in energy, metal, and transport.

As the second step, classifying investment projects into green and non-green categories based on limited information poses a challenge for numerous studies, and ours is no exception. After reviewing various environmental protection frameworks, including the Green Industry Catalogue and the Task Force on Climate-Related Financial Disclosures (TCFD). This study opts to use the EU Taxonomy framework, which is currently the most widely applied and influential classification standard of green and non-green investments (Murgolo et al., 2023). Since the classification within this framework is based on detailed information regarding industry, used technology, and certain emission standards. But this study's available information is limited to sector and sub-sector, so this classification is mainly focused on whether the industry aligns with the six objectives mentioned in the framework. These objectives encompass climate change mitigation, climate change adaptation, sustainable use and protection of water and marine resources, transition to a circular economy, pollution prevention and control, and protection and restoration of biodiversity and ecosystems (Lucarelli et al., 2020). The principle of classification is that if a sub-sector aligns with one of these six objectives and does not significantly harm the others, investments in that sub-sector can be categorized as green investments; otherwise, they are considered non-green investments. This study categorizes 400 significant investment projects directed towards 45 BRI countries into green and non-green investment projects.

From an analytical perspective based on *the number of* categorized projects, the table 2 is made. It is observable that since 2013, the quantity of significant investment projects, regardless of being green or non-green, has been increasing annually. Between 2013 and 2021, the proportion of green projects fluctuated between 10% and 30%. This

proportion experienced growth and stabilized around 40% from 2021 to 2023. Detailed data and specific information can be found on the table presented below.

Table 2. Number of BRI Investments by Greenness

Year	Non-Green Projects	Green Projects	Percent
2013	7	2	22%
2014	22	8	27%
2015	36	9	20%
2016	20	8	29%
2017	24	6	20%
2018	43	5	10%
2019	38	11	22%
2020	22	6	21%
2021	24	10	29%
2022	22	15	41%
2023	35	27	44%

Source: China Global Investment Tracker.

Further categorizing the investment projects on *the value basis*, figure 17 classifying green and non-green projects is made. Regarding the general trend of total investments, it is evident that from 2013 to 2016, there was a rapid increase in significant investment projects, rising from 4.52 billion dollars to 19.15 billion dollars. The total value of investments fluctuates, rising from 2013 to 2015 with highest value of 27.48 billion dollars. This amount then decreased to 8.37 billion in 2017, then rebounded to levels exceeding 25 billion in 2018 and 2019. After 2020, overseas BRI investment project amounts entered a phase of stable growth.

Besides, focusing solely on the trend of green investment amounts, it is observed that the monetary value of green investment projects reached its first peak at 41% in 2016. Despite the total investment amount that year being a decline from the previous year, this could signify a transition towards a green investment paradigm in 2016. Following 2016, the proportion of green investment amounts rapidly declined, hitting the bottom at 8% in 2018 before beginning a gradual annual increase, eventually returning to a high proportion of 46% by 2023. The gradual increase from 2018 to 2023 has witnessed a

growing importance of green BRI projects among investments portfolios. Thus, it can be speculated that China's investment pattern in these BRI developing countries has placed greater emphasis on the greenness and sustainable development of investments since 2018.

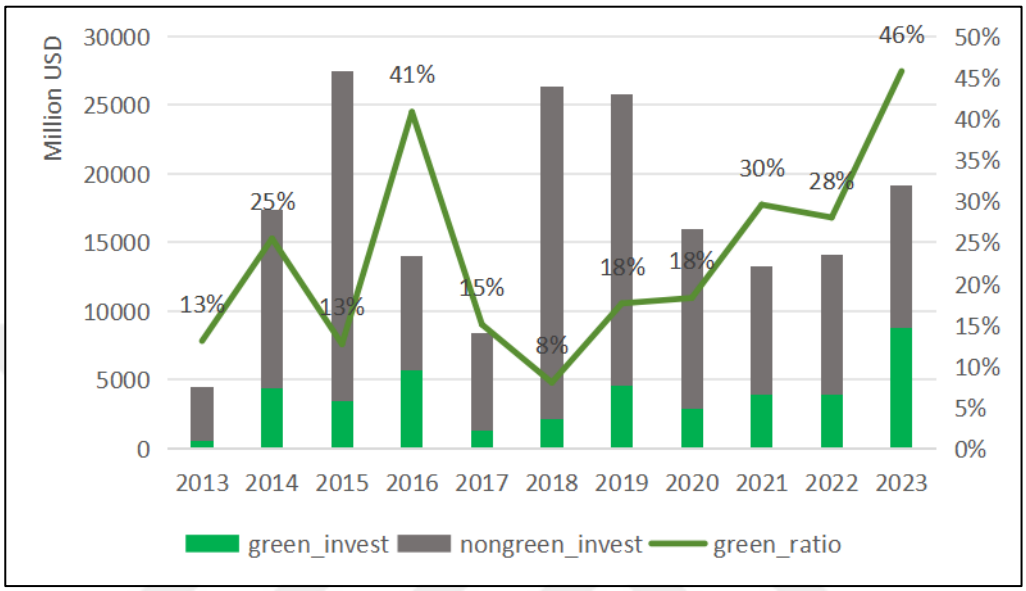


Figure 17. Value of BRI Investments by Greenness

Source: China Global Investment Tracker.

Utilizing the classification methodology, information on projects categorized as green investments is obtained. Based on the industry and sub-sector distribution of these green investment projects for the year 2023, the following figure 18 is constructed. This chart indicates the key areas where China's significant overseas green investments are concentrated. The data reveals a strategic focus of BRI investments in developing countries, being weighted towards securing metal resources and developing technologies. This strategy is crucial for the green transition, particularly electrification and energy storage. Among the large investment projects calculated by monetary value in 2023, investments are primarily directed towards four primary sectors: Metals (accounts for 54.5%), Transport (22.0%), Energy (18.4%), and Technology (5.1%). Then, this study further break down these sectors into sub-sectors, allowing us to

analyze the specific investments patterns. The below concentric circle presents the components of each sector and their corresponding shares.

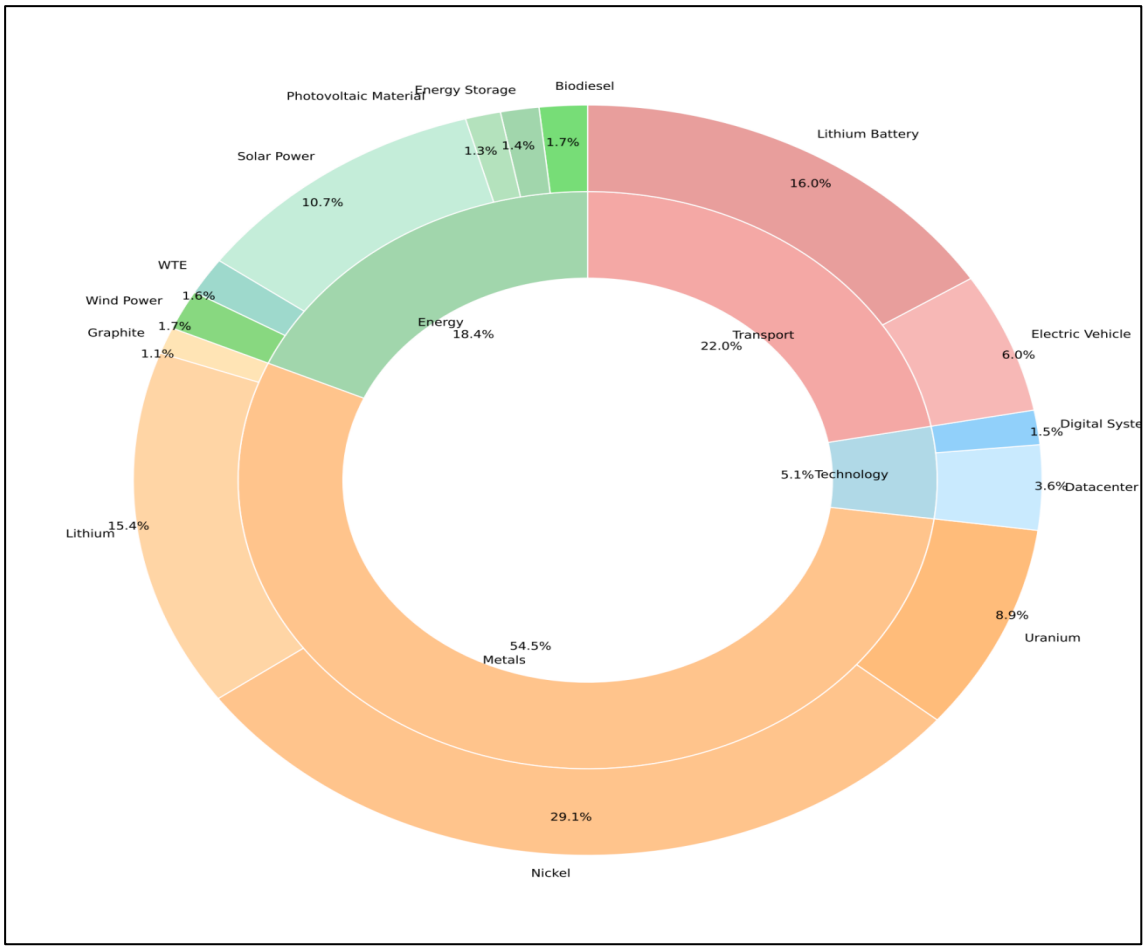


Figure 18. Sector and Sub-sector Distribution of BRI Investments

Source: China Global Investment Tracker.

This distribution instantly demonstrates the metals sector's enormous dominance, accounting for more than half of all green overseas investments over this period. These metals are classified into green investments because these raw metal materials are usually used to make some essential parts of green technologies such as lithium battery and energy storage system for electric vehicles, solar panels, wind turbines and nuclear power energy. The emphasis of these metals reflects China's strategic investment priority in obtaining global raw materials that are essential for the supply chain of green technologies. Specifically, there are 3 kinds of metals gains the most importance, with nickel accounting for the largest share of 29.1%, followed by Lithium and Uranium

with share of 15.4% and 8.9% respectively. These metals are crucial components for manufacturing green technologies and low-carbon nuclear energy. Within the metals, although Graphite only has 1.1% share of total investments, it is still a strategic kind of metal for manufacturing batteries and other high-tech materials.

As for the transport sector, constituting 22% of the BRI green investments, it is apparently associated with the previously mentioned strategy of obtaining materials for green technologies. The largest share of transport sub-sector is the Lithium Batteries, with 16% of total green oversea investments, followed by the second largest share of electric vehicles accounting for 6% of green investments. This pattern indicates that transport investments mainly focus on the green transition of electrification of vehicles by production, manufacturing and supply of electric vehicles. In this way, it is observed China's ambitious investment strategy to build the whole value chain of electric mobility and capture its intrinsic value.

The following third sector is the energy sector, representing 18.4% of the total green investments. As mentioned before, the percentage of energy enjoys the largest share of total oversea investments with 33%. However, in terms of green oversea investments, its percentage become less dominant with only 18.4%. It suggests that non-green oversea investments still account for a large proportion in BRI participating countries. Within the energy sector, solar power led the position with large share of 10.7% of total green investments. This indicates the solar technology of China has reached some maturity and cost-effectiveness that allow solar-related products to gain the central position of renewable energy. The photovoltaic materials accounting for 1.3% of green investments also support manufacturing of equipment for solar power. Other kinds of renewable energies are quite fragmented with small share, specifically, wind power 1.7%, waste-to-energy 1.6%, energy storage 1.4%, biodiesel 1.7%. In general, this diversification demonstrates China' s attempt of its oversea investment pattern to invest in various energy power, though slightly concentrated in solar power.

Finally, the technology sector accounts for the smallest share, only at 5.1% green investments. This share can be divided between two sub-sectors, including Datacenters (3.6%) and Digital Systems (1.5%). While these investments represent a small proportion of total investment, they may reflect a rising realization of the need for digital infrastructure to manage increasingly complex and distributed green energy systems, as well as possible improvements in the energy efficiency of digital operations.

Overall, as shown in the concentric graphic, China's green overseas investment strategy in 2023 was strongly focused on acquiring essential metal resources and investing in their downstream applications, primarily lithium batteries and electric vehicles. It is observable that China's ambition to build the global supply chain of electrification of vehicles by investing in fundamental materials for batteries. As a direct renewable energy, China' heavily investments of solar power is another demonstration of its purpose to lead the green transition.

These findings are consistent with research conducted by Nedopil (2025) and his teams. They study Chinese BRI engagement in various sectors over 2013 to 2024 and found similar investment patterns. A significant portion of these investments is concentrated in electric vehicle batteries and manufacturing, as well as the substantial expansion of solar PV manufacturing. This research also studied investments distribution across various sectors in 2024, providing further information than above analysis of 2023 investment pattern. This research revealed that technology and manufacturing have emerged as key growth sectors in Chinese investment, exceeding $30 billion by 2024 (Nedopil, 2025). Furthermore, China's strategic participation in metals and mining has achieved a new high of 21.4 billion dollars in 2024, a 10% increase from 2023 (Nedopil, 2025). Notably, the metal and mining sectors are especially important due to the fact that certain minerals and metals are crucial for green transition and electric vehicle batteries, such as nickel and lithium. So far at the end of 2024, it is stated that, China already controls a major portion of global mining resources, including more than 80%

of global graphite resources, as well as material processing in lithium, nickel, cobalt, and graphite, where China owns more than 50% of global capacity (Nedopil, 2025).

Based on BRI participating countries, a further analysis of green BRI investments to explore their impact on carbon emissions per capita of participating countries is conducted. The total BRI green investments and the growth rate of carbon emissions for various BRI countries from 2013 to 2023 are calculated. The relationship between them is depicted in the scatter plot figure 19. In the sample BRI countries, there are 24 countries that have received green investments during 2013-2023. Amid these data, the case of Laos (with total green investment 3120 million USD and growth rate of carbon emission per capita 469%), the case of Cambodia (with total green investment 410 million USD and growth rate of carbon emission per capita 175%) and the case of Nepal (with total green investment 590 million USD and growth rate of carbon emission per capita 165%) are excluded because of its extremely high growth rate of carbon emission which significantly exceed the descriptive range of the vertical axis of the graph below. However, since these countries are parts of green investment sample countries, this study still includes their features in the following analysis for completeness and consistency.

The scatter plot figure 19 indicates that the impact of green BRI investment on the growth rate of carbon emissions varies greatly across each country. Although there is a trend line in the graph, the distribution of the scatter points indicates that there exists a non-linear relationship between the scale of green investments and changes in carbon emissions, which demonstrate a significant heterogeneity. For an overall picture, the mean value of the total green investments for all countries is 1956 million USD and the median value is 570 million USD, which denotes a large deviation. Therefore, it is reasonable to regard green investments with amount beyond 2000 million USD as high investments.

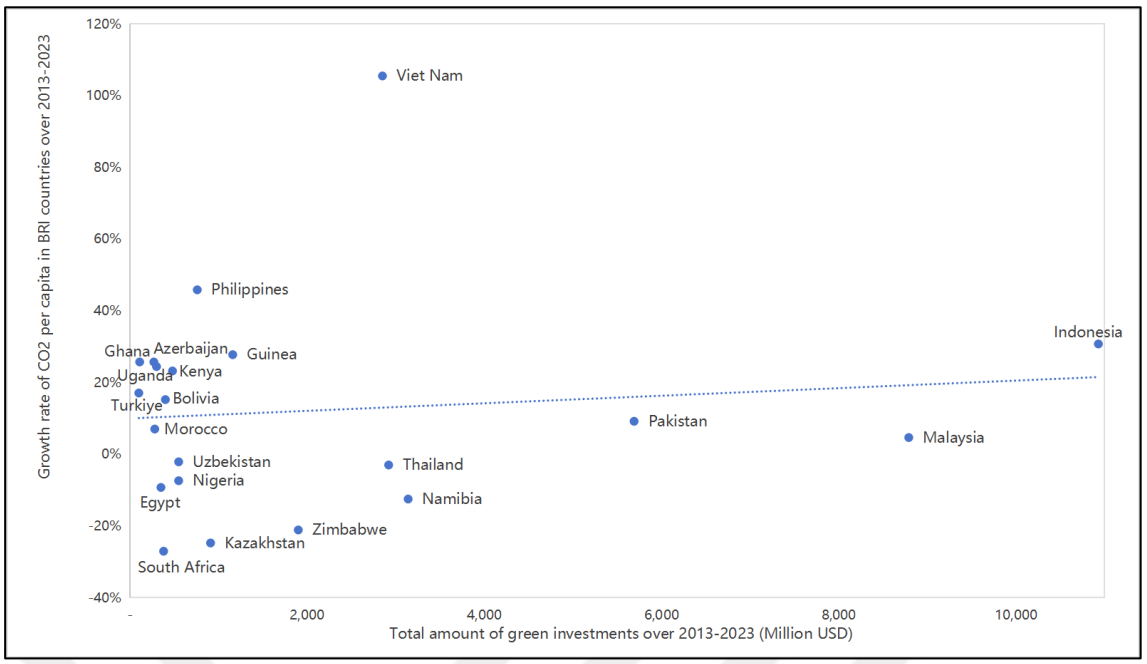


Figure 19. Green BRI Investments and Carbon Emission Growth 2013-2023

Source: World Bank, (2024) and China Global Investment Tracker (2024).

From the figure 19, it is easily noticed several prominent characteristics. Firstly, there are cases of high green investments coexisting with high emissions. Apart from the Viet Nam case with around 100% growth rate in the graph, Loas and Cambodia as early mentioned are also demonstrate this coexisting between high green investments and high carbon emission. Therefore, it is speculated that green investments primarily allocated to large-scale hydropower and infrastructure projects may lead to short-term carbon emissions rising alongside economic expansion due to long project cycles and the absence of complementary policies. For instance, the construction of hydroelectric dams may trigger deforestation or methane emissions, offsetting the long-term benefits of clean energy generation. Fundamentally, the country's rapid economic development has led to a sharp increase in energy demand in industries and transportation. Green investments might be insufficient to fully offset the growing use of traditional high-carbon energy and carbon emission from vibrant economic activities.

Second, the impact of green investments on local carbon emission is dependent on lots of other factors such as BRI countries' regulatory policy. For instance, the unexpectedly high efficiency of low green investments is observed in Kazakhstan which received

China’s investments of nuclear, wind and energy storage BRI projects. These green investments in renewable energy may only have supplemented effect, while the main carbon reduction is achieved by the policy of forcing the closure of inefficient coal-fired power plants. Therefore, to achieve a better low-carbon development, coordination with green investments and relevant policies are needed.

Thirdly, the type of green investment plays a key role in influencing carbon emissions. The impact of different green investment types, such as renewable energy, energy efficiency upgrades, and green infrastructure, varies significantly. In the renewable energy-dominated category, Ghana and Kenya serve as successful examples. Egypt, with an investment of 350 million USD in wind and solar power, leading to significant emission reduction by 9% carbon emission per capita. In contrast, Indonesia and Malaysia, despite investing in solar power and Photovoltaic materials, have seen an 5% increase in net emissions due to energy efficient and infrastructure upgrade projects in gas, Lithium battery, semiconductor and data center. Indonesia has the similar investment types with a major focus on battery and its metal raw materials.

So, the relationship between green investments and carbon emission is non-leaner and heterogeneous in various BRI countries. The impact of green investment on carbon emissions is highly dependent on investment type, national characteristics and policy coordination.

China is the largest carbon emission in the aggregate. According to the IEA, growth of emission in China is also the global largest increase of 565 Mt in 2023, probably due to its coal dominated energy consumption structure. However, recent years China continuously dominate global clean energy additions (International Energy Agency, 2024). Specifically, the year 2023 marked a historic milestone in clean energy deployment, with solar PV and wind capacity additions surging by 85% and 60%, respectively, and most of the additions come from China. Also, EV adoption has accelerated globally, with sales rising 35% to 14 million vehicles, and China led these transitions due to its one in three vehicles sold being electric (International Energy

Agency, 2024). This clean energy has remarkable influence on the carbon emission reduction. From 2019 to 2023, there are around 2.2 billion tons (Gt) of carbon emissions annually avoid thanks to the deployment of clean energy such as solar PV, nuclear power, wind power, heap pumps and electric cars. In the absence of them, the original predicted carbon emission amount would be three times larger (International Energy Agency, 2024).

3. RESEARCH HYPOTHESIS, METHODOLOGY AND DATA

3.1 Research Hypothesis

The purpose of the study is to explore the impact of joining the BRI on the environmental quality of BRI participating countries. Based on the preceding literature study, it is acknowledged that, according to the EKC theory, the majority of BRI participating nations are developing countries in the early stages of economic development, fast expansion of economic activity at this stage will result in environmental degradation. Besides, various studies show that many BRI developing nations' economic levels are still insufficient to boost environmental quality. As a result, the EKC turning point for improving environmental quality has not yet been reached. Furthermore, under the PHH, economic cooperation among countries can result in higher-developed countries moving polluting firms to less-developed countries. Similarly, these two ideas imply that because the majority of BRI participating nations are economically developing, joining the BRI may have a detrimental influence on the environmental quality of BRI participating countries.

However, PHAH expects that through international cooperation, higher-development countries will transfer green technology to less-developed countries, enhancing local environmental quality. In this case, joining BRI could have a positive influence on the environment in BRI participating nations, depending on whether BRI investments are green and environmental governance throughout project implementation. Currently, there is no consensus in the existing literature as to whether the BRI participation has a negative or positive impact on the participating countries' environmental quality.

Another complicated issue is about measuring environmental quality levels in multiple countries, which has always been a difficult task in the environmental assessment literature. Li et al. (2014) discussed the use of the Human Green Development Index (HGDI), to ensure comparability among countries in terms of combined environmental

quality and economic levels, focusing on indicators related to energy efficiency and climate change. Besides, Mustapha et al. (2016) proposed a new Green Index (GI) as a tool for assessing the greenness of facilities, addressing limitations of existing green assessment tools. Another indicator that measures the green performance of countries is the Green Total Factor Productivity (GTFP). Being different from traditional total factor productivity that considers only labor and capital, it is a measure of productive efficiency that considers energy consumption and environmental undesirable outputs (Chen & Golley, 2014). For instance, research conducted by Li, Zhou and Cheng (2022) has assessed the green total productivity (GTFP) of 121 countries over the period from 2007 to 2017. The findings indicate that the level of green economic development in the BRI countries is generally on the rise, although it remains notably below the global average, with variations in driving force observed across different time periods (Zhou and Cheng, 2022).

In this research, to measure environmental quality across different BRI participating countries, Carbon dioxide (CO2) emissions per capita have been adopted to assess every single country's environmental quality and sustainability situation. It provides a clear metric that allows the comparison of environmental impact of BRI across different nations, regardless of their population size. Moreover, the lower per CO2 capita emissions always reflect healthier ecosystems and more sustainable lifestyles, serving as an important sign of a country's commitment to addressing climate change (Nordhaus, 2018). Besides, tracking the change of CO2 emissions per capita over time can help gauge the effectiveness of national or international policies aimed at sustainable development and green growth, making the CO2 emissions per capita a valuable tool for environmental governance (Pachauri et al., 2014).

It is fully acknowledged there is a considerable gap in the current literature review about examining the BRI's overall impact on BRI member countries using real-world data. Considering the strong momentum and rapid increase in green BRI investments in recent years, this study proposes the hypothesis:

The BRI participation has an overall positive impact on the reduction of carbon emission per capita in BRI participant countries.

3.2 Methodology

Difference-in-Difference (DiD)

This research aims to explore the environmental implications of BRI participation for the countries involved in the initiative. Given that China's influence on BRI participant nations is similar to the treatment effect of particular policy intervention studied in many social science works, this study opts for a research methodology that employs the Difference-in-Differences (DiD) approach in a quasi-experimental statistical scenario, which is widely used to investigate BRI effects in many researches (Shao, 2020; Zhou, Wang & Luo,2023; Li, Zhou & Cheng; 2022). The DiD technique is particularly suitable for measuring the causal effects in observational settings when randomized controlled trials are infeasible. It compares the difference in outcomes between the two groups - treatment group and control group - before and after the intervention, thereby isolating the effect of inference from other confounding factors.

Initially, the idea of DiD was first used in the field of medicine and disease studies of cholera outbreaks in London as an experiment (Snow, 1855). Then there was a cornerstone paper written by Campbell (1969) who powerfully illustrates the logic behind DiD in the context of evaluating the effectiveness of social reforms as interventions. He proposed that the evaluation requires a comparison group to isolate reform's effect from other confounding factors and time-invariant factors to achieve a more robust and causal inference (Campbell, 1969). Later, the DiD method gained widespread popularity in economics and other social sciences, largely due to the prominent work of economists like Ashenfelter and Card in the realm of labor economics, who used it to evaluate the impacts of social training program on earnings level (Ashenfelter and Card, 1985). Likewise, Card and Krueger (2000) made famous research about the effect of minimum wage increase on the employment rate in New

Jersey using the DiD method by compassion with Pennsylvania. This study showed the method's ability to mimic experimental conditions in observational data, making it particularly attractive for evaluating large-scale interventions, such as education reforms (Duflo, 2001), healthcare policies (Baicker et al., 2013), and environmental regulations (Greenstone & Hanna, 2014). Subsequently, the DiD was developed into a systematic econometric approach, which is used to estimate the causal effect of a specific intervention or treatment by comparing the changes in outcomes over time between a treatment group and a control group (Abadie, 2005).

The core assumption of the DiD is the "parallel trends", which depicts that, absent treatment, the outcome trajectories of both groups would have evolved similarly (Angrist & Pischke, 2009). This design effectively controls for time-invariant unobservables factors and secular time trends, addressing confounding biases common in observational data (Angrist & Pischke, 2009). The time-invariant unobservable trends are some long-lasting inherent features of units that will not change in short-term period but will potentially affect outcome variables, for example, the culture and religious characteristics of a country are usually invariant in a certain time. Secular time trends are surrounding factors that affect all observational units such as economic cycles and technological progress. Then how DiD is able to control them? Firstly, to control both inherent features of units, DiD calculates the mean change in the *treatment group* before and after the intervention. Secondly, to control secular time trend, DiD further calculate the mean change in the *control group* over researching time. As a result, the difference between above two mentioned mean changes allows to isolate the pure effect of intervention without confounding bias.

DiD Evolution

The foundational DiD design assumes two periods (pre- and post-treatment) and two groups (treatment and control). This method is effective for binary time period and single time point treatment. Gradually, it is developed into a multi-period time with an extended post-treatment observational time window. The parameter estimator is still

valid if the parallel assumption holds itself. Later, empirical applications impel DiD to keep evolving. Because sometimes units get treated at multiple time periods, DiD involved the staggered treatment adoption (for treatment at different times). But in this case, the traditional DiD framework becomes untenable owing to the violation of the parallel trend assumption. With multiple time periods of treatment, the effect may vary by different timing, and the obtained estimation may be biased (Goodman-Bacon, 2021). Then DiD applications at this stage faced criticism of oversimplification. To address these issues, scholars introduced the Two-Way Fixed Effects (TWFE) Models in the DiD framework, which incorporate unit and time fixed effects to control for unobserved heterogeneity (Bertrand, Duflo & Mullainathan, 2004). However, TWFE is found to be not robust to the treatment effect heterogeneity because some of the comparisons could be made between newly treated units versus already treated units, making it hard to have a clear interpretation (Goodman-Bacon, 2021). Then, Callaway & Sant'Anna (2021) proposed group-time average treatment effects (ATT) to address TWFE limitations. Their estimator aggregates group-specific ATTs using inverse probability weights, ensuring robustness to staggered timing and heterogeneous treatment effects.Based on the above evolution of the DiD method, this research firstly uses the TWFE DiD method with unit and time fixed effects and then uses the Goodman-Bacon Decomposition to analyze the accuracy of the result and interpret the decomposition. To further verify the result and explore the dynamic treatment effect, this study applies the recent advancement of the DiD-ATT method (Callaway & Sant'Anna, 2021) to see the average treatment effect.

3.3 Variables and Data

Dependent Variables

Aligned with research objectives, this study chooses to examine the BRI's environmental effect through the indicator of carbon emission per capital over the period from 2011 to 2023. As mentioned before, the indicator of CO2 emission per

capita is selected to represent environmental quality because it directly reflects the pressure of human activities on the global climate system. Its accumulation will cause climate warming, which will trigger extreme weather, sea level rise and ecosystem damage, thereby indirectly worsening environmental quality. Also, it is usually used in cross-national comparative studies due to its high availability and standardization. The data of the CO2 emission per capita is sourced from the world bank database. This time window is selected considering the data availability, the time of BRI proposal and the change of global climate policies.

Independent Variables

This study is primarily focused on examining the impact of the BRI; hence the key dependent variable is BRI participation. The BRI is a binary variable in the DiD methodology. This implies that, from a cross-national perspective, the BRI variable is assigned a value of 1 if it signs the BRI cooperative document with China, and 0 otherwise. Another dummy variable is the same as "Post", from a longitudinal timeline, is assigned a value of 1 for time after joining the BRI, and 0 for those not yet join the BRI or never joined BRI.

Control Variables

Control variables can reduce omitted variable bias and increase the internal validity of the study by isolating the effect of the BRI from other influences on CO2 emission, thus improving the precision of the estimated treatment effect.

Several economic variables are necessary to include as controls. First, considering different economic development levels among countries, GDP per capita is selected for control variables. Data are present in constant current US dollars. To compress the variance scale and deal with non-leaner issues, this research uses the logarithm form of GDP per capita for regression. The second economic control variable is merchandise trade as a measure of trade openness. It is the sum of merchandise exports and imports divided by the value of GDP, all in current US dollars. It reflects a country's

engagement in global markets and international trade (Daude and Stein, 2007). The third is the FDI net inflow, which is the flow of direct investment equity in the reporting economy, covering equity capital, earnings reinvestment, and other capital. It indicates to what extent a country is attracting foreign investments and foreign business operations existed in the reporting economy.

Beyond economic factors, political stability is also essential for long-term political relation and actively involved in the BRI, as political instability can deter foreign investment due to increased uncertainty (Aizenman and Marion, 2004). It is to measure political stability and the absence of violence or terrorism. This control variable provides a composite score for a nation on an aggregate metric, normalized to a standard distribution, which typically ranges from approximately -2.5 to 2.5 (World Bank, 2023). Besides, demographic factors such as the level of urbanization as a share of the total population can exert pressure on environmental resources and should be considered as controls (York et al., 2003).

Furthermore, variables that can directly affect environmental quality need to be considered. For example, energy intensity, measured as energy consumption per unit of GDP, is a crucial indicator of resource efficiency and its environmental impact (Stern, 2007). In addition, renewable energy consumption is measured as the share of renewable energy in final total energy consumption, acting as a key determinant of a country's environmental footprint (Apergis and Payne, 2010).

To summarize all dependent and control variables, the table 3 is made to understand the detailed information of each variable used in this paper.

Table 3. Summary of Variables

Abbreviation	Indicator Name	Data source
GPC	GDP per capita (current US$)	World Bank Databse
REC	Renewable energy consumption (% of total final energy consumption)	World Bank Databse
UP	Urban population (% of total population)	World Bank Databse
MT	Merchandise trade (% of GDP)	World Bank Databse
PS	Estimated Political Stability	World Bank Databse
FDINI	Foreign direct investment, net inflows (BoP, current US$)	World Bank Databse
EI	Energy intensity level of primary energy (MJ/$2017 PPP GDP)	World Bank Databse
COP	Carbon dioxide (CO2) emissions excluding LULUCF per capita (t CO2e/capita)	World Bank Databse

Note: "BoP" means FDI net inflows recorded in a country's Balance of Payments. "MJ/$2017 PPP GDP" means how many megajoules of primary energy are required to produce 1 international dollar of Gross Domestic Product (GDP) measured in 2017 international dollars after adjusting Purchasing Power Parity (PPP). "LULUCF" means "Land Use, Land-Use Change, and Forestry". "tCO2e/capita" means tonnes of CO_2 emitted per person in a country.

3.4 Treatment and Control Group Construction

In accordance with the prerequisites of quasi-natural experiments and DiD approach, it is imperative to establish a treatment group and a control group to isolate the impact of the BRI. For the treatment group, countries that signed Memorandas of Understanding (MoUs) with China during the period of 2013-2018 are selected and designated as BRI-countries. This time witnesses the most active worldwide countries' engagement with the BRI, providing strong representativeness for BRI countries. Subsequently, for the control group, this study defines the scope to include countries that DiD not sign MoUs with China during 2013-2018, classifying them as non-BRI nations. It is acknowledged that there exist substantial disparities in the economic development levels of nations worldwide, so the BRI is likely to exert varying influences on economic fundamentals. To ensure the congruence in trends between the treatment and control groups, this study narrows the sample to include only developing countries, specifically those classified as low-income and middle-income nations by the United Nations. These

countries are predominantly located in Asia, Pacific, Middle East and Africa. Moreover, since European countries are mostly developed countries, it is hard to find a developing countries' pairs in Europe for comparison. So, BRI member countries located in Europe are excluded. Eventually, there are 62 BRI countries selected to treatment group and 40 countries selected to control group, as shown in the table 4.

Table 4. List of Countries in Treatment Group and Control Group

Countries in treatment group	Algeria, Angola, Armenia, Azerbaijan, Benin, Bolivia, Burundi, Cabo Verde, Cambodia, Cameroon, Comoros, Costa Rica, Djibouti, Dominica, Ecuador, Egypt Arab Rep., El Salvador, Ethiopia, Gabon, Gambia The, Ghana, Grenada, Guinea, Indonesia, Iran Islamic Rep., Iraq, Kazakhstan, Kenya, Kyrgyz Republic, Lao PDR, Lebanon, Madagascar, Malaysia, Maldives, Mauritania, Mongolia, Morocco, Mozambique, Myanmar, Namibia, Nepal, Nigeria, Pakistan, Papua New Guinea, Philippines, Rwanda, Senegal, Sierra Leone, South Africa, Sri Lanka, Sudan, Tajikistan, Tanzania, Thailand, Togo, Tunisia, Turkiye, Uganda, Uzbekistan, Viet Nam, Zambia, Zimbabwe.
Countries in control group	Argentina, Bangladesh, Belize, Bhutan, Botswana, Brazil, Burkina Faso, Colombia, Congo Dem. Rep., Congo Rep., Cote d'Ivoire, Dominican Republic, Equatorial Guinea, Eswatini, Fiji, Guatemala, Guinea-Bissau, Haiti, Honduras, India, Jamaica, Jordan, Kiribati, Lesotho, Liberia, Malawi, Mali, Mauritius, Mexico, Nicaragua, Niger, Paraguay, Peru, Samoa, Sao Tome and Principe, Solomon Islands, Suriname, Timor-Leste, Tonga, Vanuatu.

Admittedly, it is impractical to construct two perfectly homogenous national groups due to the inherent differences among countries in terms of their historical, cultural, and developmental trajectories. The aim is to identify the most similar groups possible to bolster the credibility of the DiD assumptions. To verify the assumption of parallel trends between the two groups, this study conducts a regression with pre-treatment year dummies, which are essential to affirm the validity and accuracy of this research (Angrist & Pischke, 2009). In the regression, the distant period away from the treatment year and generate several year dummies for years before the treatment and years after the treatment are calculated. Then, the regression estimates the parameters of interactions between year dummies and the treatment group dummies. As indicated in the table 5, the non-significant coefficients for the pre-treatment year apparently support the parallel trends assumption (Angrist & Pischke, 2009). The coefficient figure 20

clearly shows an upward increase around the treatment happening year, which further buttresses the assumption of parallel trend.

Table 5. Parallel Trend Test Result and Coefficient Graph

	FCOP
pre_4	0.013
	(0.34)
pre_3	0.015
	(0.35)
pre_2	0.008
	(0.20)
current	0.023
	(0.69)
post_1	0.120***
	(2.79)
post_2	0.097**
	(2.53)
post_3	0.106***
	(2.71)
post_4	0.128***
	(2.66)

Note: The label "*" represent the result is significant at what kinds of level. The label of "*" means 10% confidence level. The label of "**" means 5% confidence level. The label of *** means 1% confidence level.

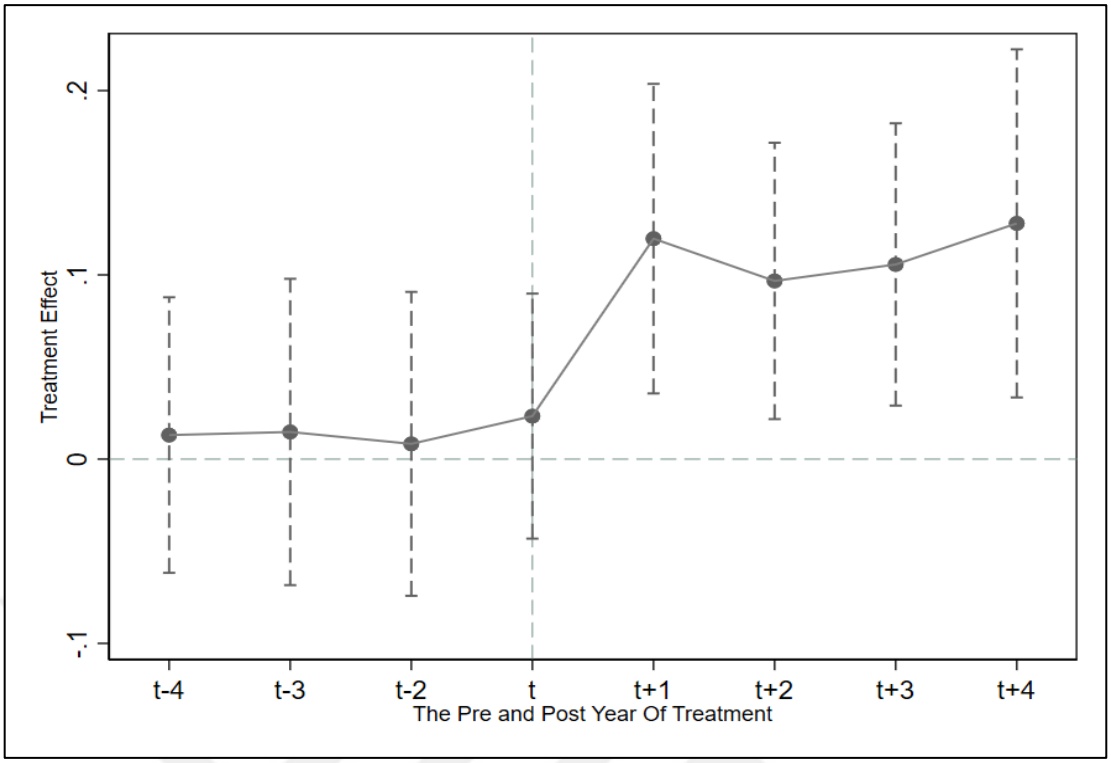


Figure 20. Parallel Trend Test Graph

Note: The horizontal axis is time before and after the treatment time. "t" means the treatment time and the t is different for countries. The vertical is the value of coefficient.

3.5 Data Description

Collectively, 102 sample countries are included in this research. To evaluate the pre-existing trends between the treatment and control groups prior to the inception of the BRI, the dataset incorporates observational time window starting from 2011. Due to data availability, this time window of post-treatment effect is end up in 2023.

However, as an econometric technique, the dependent variable (carbon emission per capita) is lagged by one period (using from period t+1), which is a common method to deal with endogeneity problems, especially in empirical analysis of the impact of policies or economic behaviors on the environment (Arellano & Bond, 1991). For example, Greenstone and Hanna (2014) employed lagged environmental pollution data as the dependent variable to mitigate the reverse causality between policy implementation and environmental pollution. Grossman and Krueger (1995) utilized

lagged carbon emissions as the dependent variable to control for the dynamic relationship between economic growth and environmental quality. In this setting, the endogeneity problem typically comes from reverse causation, omitted variables and measurement errors. The reverse causation may arise if countries with high carbon emissions may seek to join BRI for the support and green technology. Further, the omitted variable may emerge when certain unobserved factors (e.g., technological progress, changes in energy structure) may affect both carbon emissions and the decision to participate in the BRI. By doing one-period lagged operation for dependent variable, it can ensure that the independent variable can precede the dependent variable in time, thus reducing the reverse impact and partially eliminating the effect of omitted variable. In this paper, the one-period lagged CO2 emission per capita is denoted as "FCOP" in the regression.

After lagging one period of dependent variable, the year 2023 observations of CO2 per capita are rolled out from regression. The effective observational time of the panel data is from 2011 to 2022. Therefore, this study now have a 1224 observational panel dataset (102 multiple by 12) for further DiD analysis. The data description of all involved variables is presented in table 6 below.

Table 6. Descriptive Statistics of Variables

Variable	N	Mean	SD	Min	p25	p50	p75	Max
FCOP	1224	1.73	1.86	0.04	0.44	1.01	2.39	8.68
DiD	1224	0.31	0.46	0	0	0	1	1
lnGPC	1224	7.85	0.91	5.84	7.14	7.9	8.63	9.46
MT	1224	56.99	26.93	19.28	38.45	50.56	68.45	154.97
PS	1224	-0.39	0.8	-2.4	-0.87	-0.36	0.08	1.16
REC	1224	42.27	29.36	0.5	13.15	39.15	71	93.6
UP	1224	49.35	20.3	13.03	33.29	48.69	66.19	91.25
lnFDII	1224	18.63	5.71	0	18.32	20.17	21.46	24.65
EI	1224	4.98	2.59	1.76	3.24	4.29	5.89	14.35

Note: "N" represents sample size. "SD" represents standard deviations. "Min" represents the minimum value of each variable. "p25, p50, p75" represent the variables at the 25%, 50%, 75% quantile respectively. "Max" represent the maximum value of each variable.

The above descriptive statistics reveal significant variation in carbon dioxide emissions per capita (FCOP), merchandised trade (MT), political stability (PS), renewable energy consumption (REC), urbanization percentage (UP), the natural logarithm of foreign direct investment (lnFDII), energy intensity (EI) across the sample. The gap between mean value and max value indicates that most variables except for natural logarithm of GDP per capita (lnGPC) suggests substantial distinction among BRI participating countries and control group countries. lnGPC has a mean of 7.85 and a standard deviation of 0.91, with a relatively concentrated manner. This is probably due to the fact that all of selected countries are developing countries.

To assess the relationship between variables and identify possible multicollinearity issues, a correlation table of variables is made in table 7. It helps to screen out independent variables that have a greater impact on the dependent variable.

Table 7. Correlation Table of Variables

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1)FCOP	1								
(2)DiD	0.152***	1							
(3)lnGPC	0.679***	0.006	1						
(4)MT	0.228***	0.016	0.197***	1					
(5)PS	0.104***	-0.132***	0.356***	0.264***	1				
(6)REC	-0.683***	-0.112***	0.729***	-0.201***	-0.249***	1			
(7)UP	0.515***	0.005	0.631***	0.150***	0.074***	-0.507***	1		
(8)lnFDII	0.088***	-0.044	0.045	-0.063**	-0.097***	-0.04	0.058**	1	
(9)EI	-0.104***	-0.013	0.490***	-0.003	-0.206***	0.510***	-0.267***	-0.038	1

Note: The "*" label represent at which level result is significant. The label of * means 10% confidence level. The label ** means 5% confidence level. The label *** means 1% confidence level.

The primary purpose of the correlation coefficient table is to demonstrate the strength and direction of the linear relationships between variables, identify potential multicollinearity issues, and select appropriate variables for inclusion in the model. From the above result, it is seen that CO_2 emissions per capita have a positive and significant correlation with GDP per capita (0.679***), indicating a higher economic level is related to increased carbon emissions. Similarly, the positive and significant

correlation between CO_2 emission and urbanization percentage (0.515***) suggests that a higher urbanization level is associated with increased carbon emission. In contrast, there is a negative and significant correlation between renewable energy consumption and CO_2 emission (-0.683***), implying that the higher level of renewable energy consumption usually relates to the lower carbon emission. Regarding other notable correlations between variables, GDP per capita is positively and significantly correlated with renewable energy consumption and urbanization percentage, with correlations of 0.729*** and 0.631***, respectively. This means that economic development level is usually reflected by high consumption of renewable energy and urbanization. Therefore, it can be preliminarily inferred that economic development, urbanization, and renewable energy usage are critical factors influencing carbon emissions per capita. Furthermore, the correlation between the BRI (DiD) and FCOP is 0.152***, indicating that BRI participating countries may face increased carbon emissions in the post-treatment period. However, this finding requires further validation through regression analysis to control for the influence of other variables.

With respect to multicollinearity issues, the above correlation table doesn't show a relative problem because all the correlation numbers are under the value of 0.8, which is usually regarded as the threshold to be alarmed about multicollinearity problems. This problem can also be detected by VIF analysis. The correlation table 8 suggests that there is no severe correlation problem. The table below is about the variance inflation factor (VIF) of all variables is presented to examine whether multicollinearity exists in the model. Normally, the VIF has a reasonable range of 1-10, and it means it is highly probable that multicollinearity exists if the VIF is higher than 10 (O'Brien, 2007). In this VIF test, the VIF of all variables is far below 10, meaning there is no multicollinearity problem in this research.

Table 8. VIF Test Result of Variables

Variable	VIF	1/VIF
lnGPC	3.1	0.322901
REC	2.4	0.416118
UP	1.77	0.564558
EI	1.45	0.689402
PS	1.31	0.763202
MT	1.13	0.883712
DiD	1.05	0.948229
lnFDII	1.02	0.97644
Mean VIF	**1.66**	

4. EMPIRICAL RESULTS

To assess the impact of the BRI on the participating countries' environmental quality, considering the advancement of DiD method and the research setting with multiple treatment period, this study first employ the TWFE DiD estimation equation with unit and year fixed effect, then apply the Bacon Decomposition method to analyze for more accurate interpretation. Later, the ATT regression proposed by Callaway and Sant'anna (2021) is used to see the group-time average treatment effect. These three methods in the framework of DiD can make sure that the obtained estimation result are accurate and robust.

To begin with, the DiD model is expressed in the below equation:

$$COP_{it+1} = \alpha_i + \alpha_t + \alpha_0 + \beta_1 \mathrm{DID}_{it} + X_{it} + \varepsilon_{it}$$

Where i represents country unit, t represent year, α_i is country fixed effect, α_t is the year effect effect, α_0 acts for the interception term, ε_{it} acts for error term, X_{it} represents vector of a series of control variables. DiD is the interactive term of treatment group and post-treatment period (treatment group * post-treatment year). In specific, the country unit is denoted as 1 if it is in the treatment group (join the BRI in this case) and denoted as 0 if it is in the control group. The year is denoted as 1 if it is the post-treatment year, otherwise it is denoted as 0. For example, the country "Türkiye" joined BRI in 2015, so the treatment current year is the 2015, the pre-treatment year (2011-2014) is assigned as 0 and the post-treatment year (2016-2023) is denoted as 1. DiD is the most important regressor in the equation and the primary focus is on its coefficient β_1, as it captures the differential effect of BRI on the CO2 emission per capita after countries join BRI compared to countries that have not joined to BRI.

After getting the coefficient estimator of DiD, this study further do the decomposed analysis of result using Bacon decomposition technique. Since multiple treatment times are staggered and treatment effects are dynamic, Goodman-Bacon (2021) demonstrated that TWFE estimates are weighted averages of all possible 2*2 DiD comparisons

between treatment cohorts, possibly leading to biased estimated by negative weights. So, this Bacon decomposition technique helps to highlight how late-treated units contribute negatively to estimates.

Next step is to use the ATT method to verify the validation of estimates. Proposed by Callaway and Sant'Anna (2021), the central idea is to extend the traditional DiD approach by defining and estimating the average treatment effect at different time points for the treatment and control groups then add up all these blocks with weighted average. This method is particularly useful in dealing with staggered treatment adoption scenarios and enhance credibility of DiD estimates. The definition equation of ATT is given below. This measures the average causal effect of the treatment for units in group *g* at time *t*, comparing their treatment outcomes to what would have happened had they not been treated.

$$ATT(g,t) = E[Y_t(g) - Y_t(0)|G = g] \quad (1)$$

Where $\mathrm{Yt(g)}$ represents the observed outcome for group g at time t, $\mathrm{Yt(0)}$ represents the counterfactual outcome for for group g at time t. This equation means that when the defined group is g (G=g), the average difference between $\mathrm{Yt(g)}$ and $\mathrm{Yt(0)}$. Usually, when processing ATT analysis, there are two options based on different comparing foundation of parallel trend assumption, specifically to compare with "never-treated" units or "not-yet-treated" units. When using "never-treated" units as comparisons for the parallel trend assumption, the definition equation is presented in the equation (2). But when using "not-yet-treated" units as comparisons for the parallel trend assumption, the definition equation is presented in the equation (3).

$$ATT(g,t) = E[Y_t - Y_{g-1}|G = g] - E[Y_t - Y_{g-1}|C = 1] \quad (2)$$

$$ATT(g,t) = E[Y_t - Y_{g-1}|G = g] - E[Y_t - Y_{g-1}|D_t = 0, G \neq g] \quad (3)$$

In the equation (2). $C = 1$ denotes the control group that never receives treatment. In the equation (3), $D_t = 0$ indicates units not yet treated by time t, $G \neq g$ excludes the group treated at time g. Here is an example to illustrate the scenario of equation (3). The unit "Türkiye" joined BRI in 2015. So, it belongs to the group "2015" that constitutes all units joined BRI in 2015. Another unit "Uganda" joined BRI at 2018, so it belongs to the group "2018" that constitutes all units joined BRI at 2018. When calculating the treatment effect of BRI on Türkiye's (as one unit of "2015" group) CO2 emission per capita in 2015, Uganda (as one unit of "2018 group") is taken as the "not-yet-treated" unit for comparison, though Uganda is also a unit of treatment group and will eventually receive treatment in 2018. In this research, to be consistent with TWEF DiD regression whose comparison target is control group, this study only applies the equation (2) as a further validation to DiD regression result.

4.1 DiD Regression

The result of the TWFE DiD regression with unit and year fixed effects is presented in the table 9. In the table 9, column (1) displays the relationship between CO_2 emissions per capita, and the interactive term DiD without the inclusion of control variables. Column (2) shows the outcomes after incorporating control variables into the regression model. To investigate the specific impact of BRI on carbon emissions in various industries, this study separately regressed the absolute carbon emissions from industry, energy, and transportation sectors as the dependent variables in the columns (3), (4), and (5).

As indicated by the column (1) and (2), the overall impact of BRI on participating countries' CO2 emission per capita is significantly positive at 1% confidence level, with coefficients of 0.071 and 0.080 respectively. Though the effect is modest, it does imply that BRI participating countries have experienced a significant increase in carbon emissions, on average, 0.08 metric tons of carbon emissions per capita since the countries joined the BRI. This treatment effect could be attributed to the BRI's primary

focus on promoting infrastructure development, which usually leads to increased economic activities as well as energy consumption, resulting in higher carbon emissions per capita. For control variables, the GDP per capita is strongly positive and significant with 0.468, which buttresses the positive association between economic growth and environmental degradation in the EKC in the early stage.

Table 9. Results of DiD Regression

	(1)	(2)	(3)	(4)	(5)
	FCOP	**FCOP**	**FCOIND**	**FCOENE**	**FCOTRANS**
DiD	0.071***	0.080***	0.549***	6.981***	1.467***
	-2.67	-3.29	-2.76	-6.12	-3.94
LnGPC		0.468***	0.706	8.527***	0.025
		-5.93	-1.62	-2.68	-0.04
MT		0.004***	0.025***	0.087**	0.001
		-3.32	-3.38	-2.33	-0.08
PS		0.103***	0.067	-2.324	1.199***
		-2.77	-0.33	(-1.56)	-3.2
REC		-0.008**	-0.016	-0.247*	-0.023
		(-2.42)	(-1.21)	(-1.94)	(-1.06)
UP		0.009	0.223***	1.610***	0.282***
		-1.12	-4.02	-4.15	-3.34
LnFDII		-0.003	-0.001	0.062	0.016
		(-1.49)	(-0.07)	-1.23	-1.52
EI		0.060**	-0.012	3.584***	-0.043
		-2.32	(-0.15)	-4.55	(-0.33)
_cons	1.708***	-2.527***	-11.261**	-115.805***	4.143
	-150.82	(-3.14)	(-2.08)	(-3.07)	-0.75
ID	Yes	Yes	Yes	Yes	Yes
YEAR	Yes	Yes	Yes	Yes	Yes
N	1,224	1,224	1,224	1,224	1,224
Adj R^2	0.98	0.983	0.98	0.988	0.993

Note: The "FCOP" represents the final carbon emission per capita. "FCOIND" means the final carbon emission form industry sectors. "FCOENE" means the final carbon emission from energy sectors. FCOTRANS means the final carbon emission from transportation sectors.

In column (3), the result indicates that the BRI positively impacts the carbon emissions from the industrial processes with a coefficient of 0.549 at a 1% significance level. This suggests that the BRI has substantially increased carbon emissions in the industrial sector of participant countries. This may be caused by the BRI's promotion of numerous industrial projects, such as various industrial parks, steel, cement, and manufacturing. Additionally, the significant positive correlation with merchandise trade

and urbanization percentage, with 0.025*** and 0.223***, respectively, implies that the higher rate of urbanization and foreign trade openness leads to higher carbon emissions in BRI participating countries. As for the carbon emission from industrial processes, no other significant effect is detected under this sample and model specification.

In column (4), as indicated by the DiD estimator, BRI has a significantly positive impact on carbon emissions from energy sectors in participating countries, with a coefficient of 6.981 at a 1% confidence level. This finding suggests that the BRI has notably increased carbon emissions from the energy sector of participant countries. This energy-related carbon emission has a broader scope that primarily includes the building sector, industrial combustion, electricity generation, and energy fugitive emission. The data is sourced from the World Bank database. Not only do the BRI infrastructure projects stimulate the growing energy demand, but also numerous energy-related BRI projects, such as coal-fired power, thermal power, and petroleum- and gas-driven power plants, directly boost local carbon emissions. In this case, some control variables—GDP per capita, merchandise trade, urbanization rate, and energy intensity—are also positively related to energy-related carbon emissions. Renewable energy consumption with less fossil fuel is found to have a significant negative correlation with carbon emission.

In column (5), it uncovers that, as represented by the DiD coefficient, the BRI has significantly and positively impacted the amount of carbon emissions from the transportation sector in BRI participating countries, with a coefficient of 1.467 at a 1% confidence level. This indicates that, after joining the BRI, countries have experienced significantly increased carbon emissions in the transportation sector. Transportation-related carbon emissions primarily originate from energy consumption in various modes of transportation, such as road, rail, air, and maritime transport. This effect is understandable due to BRI's projects being associated with highways, railways, high-speed railways, ports, airports, metros, and various vehicles. These infrastructures undoubtedly increase trade and logistical activity in BRI-participating nations, raising

carbon emissions. Furthermore, the regression shows significant and positive correlations with control variables such as political stability and urbanization percentage, indicating the importance of a stable political environment and a sizable urban population in driving transportation-related carbon emissions.

4.2 Bacon Decomposition

The Bacon decomposition analysis provides a detailed breakdown of the DiD estimates for the above model (2) regression, offering insights into the potential biases and the composition of the overall treatment effect. The overall DiD estimate is 0.0795, as indicated in the figure 21, which is consistent with the above coefficient result of 0.08. The decomposition table 10 reveals three key components for further analysis: the timing groups, the never-treated versus timing groups, and the within-group variation.

Firstly, the timing groups component has a beta coefficient of -0.0186 and a total weight of 0.2426, indicating that the comparisons among treatment groups treated at different times contribute negatively to the overall estimate, albeit with a relatively small weight. Secondly, the never-treated versus timing groups component shows a positive beta coefficient of 0.1065 and a substantial weight of 0.7211, suggesting that the comparison between never-treated groups and those treated at various times is a significant driver of the positive treatment effect. This comparison type likely captured 72% of the treatment effect. Thirdly, the within-group component, with a beta coefficient of 0.2004 and a weight of 0.0362, indicates that the variation within the treated groups over time also contributes positively to the overall estimate; however, its weight is extremely small. In general, based on the overall result, it is safe to speculate that 72% of the treatment effect is generated from the comparison between treated units and never-treated units, which is favorable for inference and sound for methodology. Nevertheless, the remaining 24% of the treatment effect generated from comparisons between treated units at different time points could be a potential bias for the DiD estimation. This concern will be examined by using the ATT technique in the following part.

Table 10. Result of Bacon-Decomposition

	Beta	TotalWeight
Timing groups	-0.0186	0.2426
Never_vs_timing	0.1065	0.7211
Within	0.2004	0.0362

Note: "Beta" represents to which direction that the targeted comparison group contributes to the overall treatment effect (positive or negative). "Total Weight" represents to which extent different comparison groups constitute the treatment effects. "Timing groups" group means two units of comparison both come from treatment groups. "Never vs timing" group means two units of comparison come from never-treated group (control group) and treatment group respectively. "Within" group refers to the variation within the treatment groups over time.

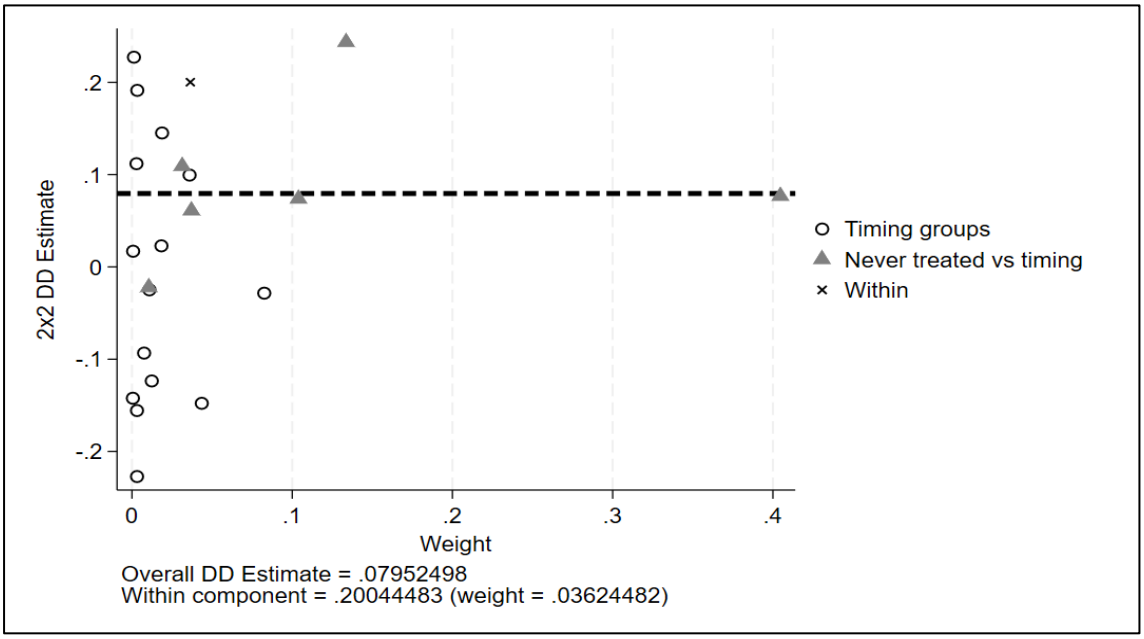


Figure 21. Bacon-Decomposition Graph

Note: The graph has the same estimation value as the above table. Thus, the explanation of each group can be found in the above note.

4.3 Group-Time Average Treatment Effect

The summary of Group-Time Average Treatment Effect for the Treated (ATT) results is listed in the table 11. It is noticed that the overall coefficient of BRI participation (DiD) is 0.134, being a bit higher than previous coefficient 0.08. The corresponding p-value is 0.0159, indicating that the significance level is around 1%, supporting the credibility of

estimation result. The 0.134 coefficient indicates that the BRI has a statistically significant and positive effect on carbon emissions per capita in participating countries.

Table 11. Result of ATT Regression

Overall	Coefficient	Std. Error	z-Statistic	Prob.
DiD	0.134	0.0554	2.411	0.0159

Note: The z-statistic indicates the size of the coefficient relative to its standard error. It equals to the coefficient divided by standard errors. A larger value indicates that the coefficient is more significant relative to its uncertainty. For example, if $|z|>1.96$, it means the significant level is at 5%.

The summary table provides a weighted average treatment effect of the BRI participation on CO_2 emission per capita in BRI participating countries. Since the result is a summary of the weighted average value of all comparison groups, this result is the aggregate treatment effect. Notably, the ATT regression is conducted totally based on the never-treated groups, the previous concern of potential biases is effectively excluded.

When further breaking down the treatment effect into different groups, this study can analyze the dynamic treatment effects. In the following analysis, this study presents the result of dynamic treatment effect variance among groups, which are classified by two criteria. In the table 12, the sample units are classified into six groups based on the year of joining BRI, reflecting the changes in treatment effect for country groups that joined BRI at different time points.

Table 12. Group Effect of Treatment

Group	Coefficient	Std. Error	z-Statistic	Prob.
2013	0.202785	0.097251	2.085177	0.0371
2014	0.080608	0.127377	0.632826	0.5268
2015	0.312794	0.176994	1.767262	0.0772
2016	0.086198	0.122184	0.705475	0.4805
2017	0.159036	0.120154	1.323599	0.1856
2018	0.032402	0.035869	0.903357	0.3663

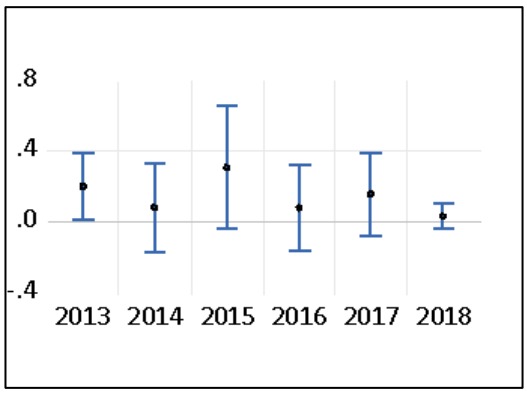


Figure 22. Group Effect of Treatment Graph

Note: The vertical axis means the value of the coefficient. The horizontal axis means countries groups that together joined the BRI at a specific year.

The coefficients table 12 and figure 22 above display the treatment effects across different groups, which are categorized based on the timing of their participation in the BRI. There is considerable variation in the coefficients and their significance. Specifically, the group of countries that joined BRI in 2015 has the strongest positive effect on carbon emissions per capita, with a coefficient of 0.3128, at the 10% significance level. Following that, the group that participated in BRI in 2013 has a similar effect on per capita carbon emissions, albeit with a smaller impact, with a coefficient of 0.2029 at the 5% significance level. The other groups, including those from 2014, 2016, 2017, and 2018, do not exhibit statistically significant treatment effects in the sample and model. This reveals that the year of a country's participation in BRI can influence the treatment effect to varying degrees. The countries in the 2013 and 2015 groups may take part in more BRI projects or project types that greatly promote carbon emissions, such as high-carbon energy projects. Countries that joined BRI after 2015 may have engaged in fewer BRI projects or engaged in more clean energy projects.

The table 13 demonstrates the chronic treatment effect over the 10 years, showing how the impact evolves in each single year during 2013 to 2022.

Table 13. Date Effect of Treatment

Date	Coefficient	Std. Error	z-Statistic	Prob.
2013	-0.047279	0.090132	-0.524553	0.5999
2014	-9.77E-05	0.150336	-0.00065	0.9995
2015	-0.03228	0.052047	-0.620212	0.5351
2016	0.125044	0.078045	1.602209	0.1091
2017	0.215154	0.08615	2.497435	0.0125
2018	0.191724	0.049735	3.854886	0.0001
2019	0.21951	0.054815	4.004526	0.0001
2020	0.167323	0.067029	2.496275	0.0126
2021	0.131943	0.072137	1.829064	0.0674
2022	0.213442	0.091129	2.342202	0.0192

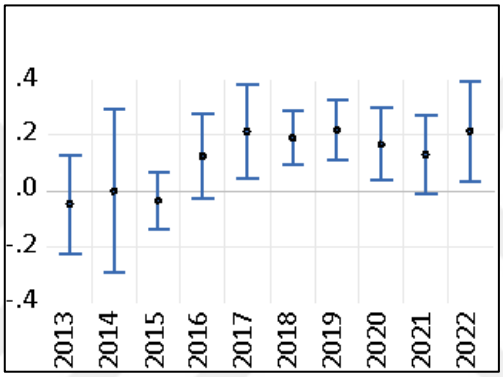


Figure 23. Date Effect of Treatment Graph

Note: Vertical axis means the value of coefficients. Horizontal axis means time point of different years.

Based on the above coefficient table 13 and figure 23, it is observed that coefficients are generally positive and increase over time since 2016, with a growing confidence level since 2017. This indicates that the impact of BRI on the carbon emission per capita is becoming significantly observable after 2017, and this effect keeps going on in the later years. Besides, the growing coefficients over time may represent increased infrastructure or energy-intensive BRI projects that relate to the higher level and long-term carbon emissions with a cumulative effect.

Building upon the yearly treatment effect, it is curious to examine the duration effect, which shows the dynamic change of treatment effect as the duration of exposure to the BRI.

Table 14. Duration Effect of Treatment

Duration	Coefficient	Std. Error	z-Statistic	Prob.
0	0.026248	0.021359	1.228895	0.2191
1	0.103576	0.039314	2.634594	0.0084
2	0.110067	0.049045	2.244207	0.0248
3	0.113464	0.051832	2.189053	0.0286
4	0.124194	0.057157	2.172862	0.0298
5	0.269379	0.12511	2.153141	0.0313
6	0.293408	0.171853	1.707325	0.0878
7	0.328289	0.251273	1.306503	0.1914
8	0.182121	0.130388	1.396758	0.1625
9	0.613548	0.373423	1.643038	0.1004

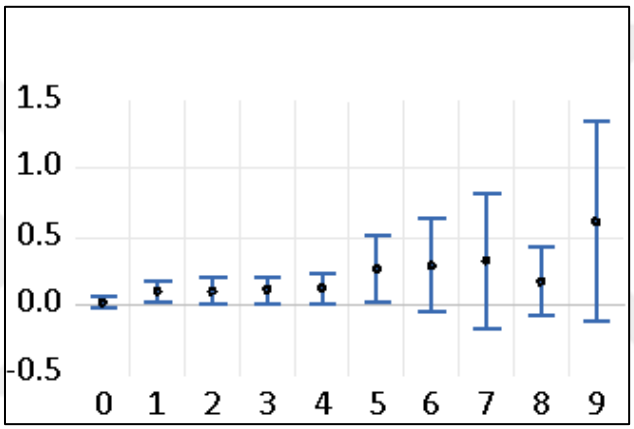


Figure 24. Duration Effect of Treatment Graph

Note: The vertical axis means the value of coefficients. The horizontal axis means the duration of years.

The table 14 and figure 24 of duration effects shows how the treatment effect changes as the duration of exposure to the BRI increases. In general, the coefficients rise with increasing length, from 0.0262 at duration 0 to 0.6135 at duration 9. From duration 1 to duration 9, the significance level of these coefficients is essentially within 10%, indicating that the general trend is valid and statistically significant. As a result, the increasing coefficients reflect the BRI's long-term and likely escalating environmental impact. It basically implies that the longer a country is exposed to BRI, the larger the influence on its carbon emissions will be detected.

To sum up, the ATT analysis reveals that participation in BRI has an average treatment effect on the CO_2 emission per capita with a significant and positive coefficient of 0.134 in BRI-participating countries. The group effect shows that countries that joined BRI in 2013 and 2015 have a positive effect on carbon emissions per capita in their countries. Later, the yearly effect uncovered that the treatment effect of the BRI on carbon emission has appeared in a significantly upward trend since 2017. Finally, the duration effect analysis found that the longer a country is exposed to BRI, the larger the influence on its carbon emissions.

4.4 Heterogeneity Analysis

To further examine the BRI's impact on the CO_2 emission across various regions, the heterogeneity analysis based on the geographical distribution of the BRI participating countries is made. While the overall treatment effect of BRI is positive, its significance and magnitude vary across regions. Countries in the sample are categorized into 6 regions, specifically, Central Asia, East Asia & Pacific, Latin America & Caribbean, Middle East & North Africa, South Asia, and Sub-Saharan Africa.

The result is given in the table 15. Overall, the DiD coefficients in "East Asia & Pacific" and "Middle East & North Africa" are significant at the 5% significance level, with coefficients of 0.145** and 0.234**, respectively. It means that BRI participation in these areas has a positive and statistically significant effect on the countries' CO_2 emissions per capita.For each region, apart from the influence of BRI, the driving factors of carbon emission are greatly distinct. In East Asia & the Pacific, GDP per capita, merchandise trade, and energy intensity are detected to have a positive effect on carbon emissions. Similarly, in Central Asia, the result suggests that economic growth, urbanization expansion, and merchandise trade are also major drivers of emissions in this region. The REC demonstrates its effect on carbon reduction in many regions. In Latin America & the Caribbean, the LNGPC and PS are significantly positive factors, suggesting that economic growth and political stability contribute to carbon emissions

in this region. In the Middle East & North Africa, the result means that international trade engagement and renewable energy usage can slightly mitigate carbon emissions. In South Asia, urbanization is detected as the only positive driver of carbon emission per capita, reflecting that rapid urban growth can lead to environmental pressure. In sub-Saharan Africa, the LNGPC and PS are significant positive factors, the same as in Latin America & the Caribbean, indicating the role of political stability and economic development on carbon emissions.

Table 15. Result of Heterogeneity Based on Regions

	Central Asia	East Asia & Pacific	Latin America & Caribbean	Middle East & North Africa	South Asia	Sub-Saharan Africa
	FCOP	FCOP	FCOP	FCOP	FCOP	FCOP
DiD	0.054	0.145**	0.053	0.234**	0.154	0.004
	-0.69	-2.13	-1.29	-2.37	-1.19	-0.1
lnGPC	0.491***	0.439*	0.530***	0.326	-0.035	0.432***
	-2.9	-1.79	-3.52	-1.32	(-0.12)	-5.2
MT	0.009***	0.014***	0.005	-0.006**	0.011	0.004***
	-2.76	-4.79	-1.21	(-2.46)	-1.32	-2.7
PS	-0.209	0.153	0.194***	-0.014	0.177	0.115**
	(-1.60)	-1.31	-3.68	(-0.11)	-1.09	-2.57
REC	-0.027***	0	-0.008**	-0.077**	0.013	-0.006*
	(-4.09)	-0.03	(-2.07)	(-2.61)	-0.64	(-1.91)
UP	0.138***	0.031	0.020*	0.044	0.093**	0.006
	-3.4	-1.3	-1.88	-1.12	-2.04	-0.62
lnFDII	-0.007	0.004	-0.009	-0.005	-0.005	-0.006
	(-1.27)	-1.07	(-1.05)	(-1.38)	(-0.40)	(-1.63)
EI	0.036	0.246***	0.277***	0.149	-0.177	-0.015
	-0.87	-3.64	-3.89	-1.37	(-1.21)	(-0.47)
_cons	-7.950***	-4.859***	-4.852***	-2.257	-1.247	-2.101**
	(-2.68)	(-2.66)	(-3.02)	(-0.50)	(-0.38)	(-2.48)
ID	Yes	Yes	Yes	Yes	Yes	Yes
YEAR	Yes	Yes	Yes	Yes	Yes	Yes
N	84	204	240	108	84	504
Adj R^2	0.996	0.986	0.981	0.987	0.968	0.975

Note: The "*" label represents the result is significant at what kinds of level. The label of * means 10% confidence level. The label ** means 5% confidence level. The label *** means 1% confidence level.

4.5 Robustness Test

A commonly used robustness test to validate the reliability of the treatment effect of DiD estimations is the placebo test (Eggers et al., 2023). It represents the estimated

treatment effect when the treatment is artificially assigned to periods before the actual treatment occurred. In an ideal scenario, if the treatment effect is genuine, the placebo effect should be close to zero and statistically insignificant for these fake treatment periods. This is because no actual treatment was administered during these periods, and any significant effect would suggest the presence of biases or unobserved confounding factors.

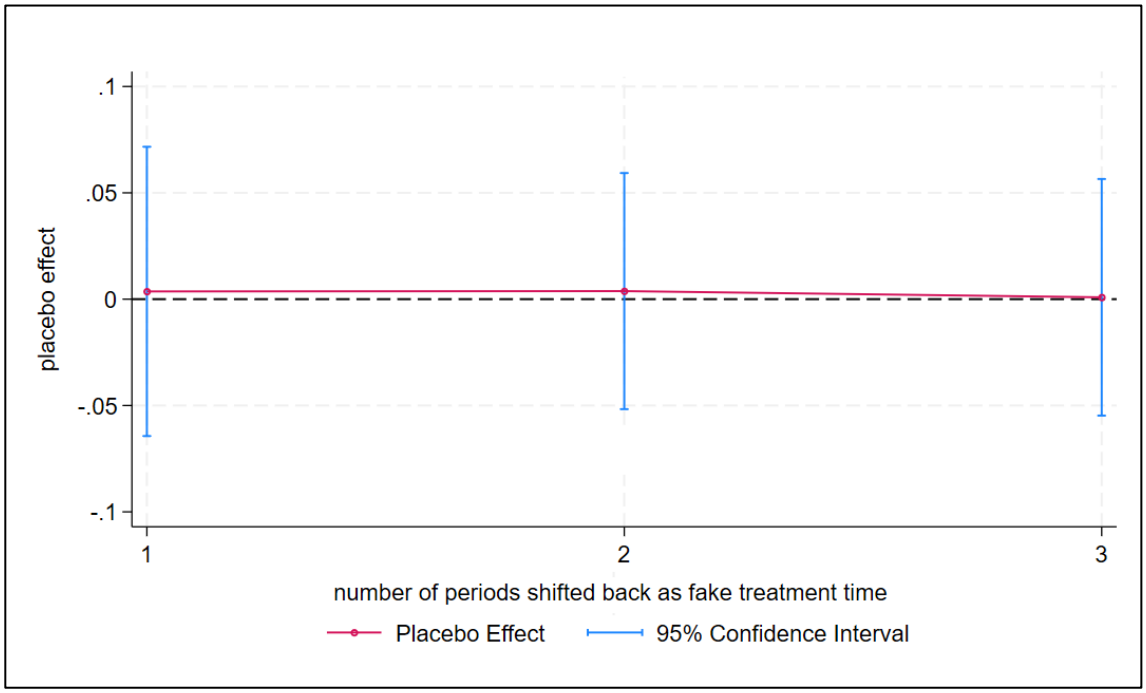


Figure 25. Result of In-Time Placebo Test

Note：The number of periods shifted back includes 3 years to test whether treatment effects exist earlier than the study time window.

This study randomly advances the policy time by 1 to 3 years, and the result of the placebo test is present in figure 25. It plots the placebo effect against the number of periods forwarded as fake treatment times, along with a 95% confidence interval. The graph shows the placebo effect fluctuating around zero within the confidence interval including zero for the periods. This suggests that the estimated treatment effects during fake treatment periods are not significantly different from zero, reinforcing credibility and robustness of the previous DiD estimation.

5. DISCUSSIONS

From the green BRI investments analysis, a changing development of China' foreign investments inflow, outflow and net amount are firstly noticed. They clearly depict an obvious shift from focusing inflow investments to outflow investments and now become a capital out-flowing country with tons of overseas investments, especially driven by the BRI framework. Then regarding Chin's outward FDI, these investments are dominantly allocated to wholesale and retail trade, leasing and business services, with significant investments in transportation, mining, and manufacturing. Further, the investing destination analysis implies that China' largest invested destination in recent years are Singapore, The United States, Indonesia, German and Vetnam. And it highlights a notable shifting geographical focus towards Asian countries. As for the investment portfolio evolution, a shifting sector allocation illustrates a dynamic change of China's overseas investment strategy, characterized by the dominance of the energy sector, fluctuating yet sustained significance of metals, a decline in traditional sectors such as real estate, and a clear rise in the prominence of transport and technology investments in recent years.

Among these investments, this study classifies them into green investment and non-green investments based on the alignment of six objectives in the EU Taxonomy. Afterwards, the comparative analysis of green and non-green investments in terms of numbers and values of these investments are made to see their patterns in these BRI developing countries. It is found that China has placed greater emphasis on the greenness and sustainable development of investments since 2018 and reached a high proportion of 46% of green investments in 2023, supporting the hypothesis 2 that green BRI investments are increasing. Furthermore, the breakdown of subsectors give sounding evident that China' green investments are heavily concentrated in securing critical minerals such as Nickel and Lithium, investing in the downstream application of these materials, primarily Lithium Batteries and Electric Vehicles. The green investments in renewable energy generation, led by Solar Power, were also substantial.

Based on this analysis, this study proposes a research hypothesis that whether participating in BRI has brought a better environmental quality in terms of carbon reduction in BRI participant countries. From empirical analysis, this research makes valuable founding that BRI participating countries are experiencing a significant increase in their carbon emission per capita after joining the BRI initiative, validating hypothesis 1. More specifically, carbon emission from different sectors such as industry, energy-based and transport all experienced a significant increase affected by the BRI, though the diving activities are slightly varied for each sector. Geographically, the treatment effect of BRI is particularly significant and positive for the carbon emission in "East Asia & Pacific" and "Middle East & North Africa", probably due to their rapid industrialization within the decade. The accuracy and validation of these empirical results are ensured by the combined method of TWFE DiD, Bacon Decomposition and ATT regression and tested by the placebo test.

5.1 Results Explanation for EKC, PHH, PHAH Hypothesis

The above green BRI investment analysis and empirical research findings provide valuable perspectives illustrating the complex environmental impacts of BRI within its participating countries, especially in developing countries. This section, these findings under the framework of the Environmental Kuznets Curve (EKC), the Pollution Haven Hypothesis (PHH), and the Pollution Halo Hypothesis (PHAH) are analyzed again to contribute more insights about interwoven dynamics that shape the BRI' environmental trajectory and implications of participating countries.

As explained in the literature review, The EKC hypothesis illustrates an inverted U-shaped relationship between environmental degradation and economic development that is usually measured by per capita income. The model describes that, in the early stages of development, environmental degradation worsens as industrialization rapidly soars up due to business scale effects and neglect of environmental protection. Beyond a certain income threshold, as national economies shift towards services rather than heavy

industries, in-house green technology improves, environmental awareness grows, and stricter environmental regulations are enacted, environmental degradation theoretically begins to decline. At a result, the environmental quality should increase even the economic development continues.

The essential finding that BRI has a significant and negative treatment effect on the developing participating countries is strongly consistent with EKC hypothesis. In fact, lots of these BRI participating countries are in the rapid developing and industrializing stage, positioned on the ascending slope of the EKC and associated with rising environmental degradation. Another important economic growth, spurred by large-scale infrastructure investments characteristic of BRI in sectors of transport, energy, industry, is tightly coupled with rising environmental degradation. Therefore, the BRI, by accelerating industrialization and energy consumption, appears to be pushing these countries further and faster up this initial slope, leading to the observed increase in carbon emissions per capita in these developing member countries.

According to the EKC hypothesis, environmental degradation is highly related to economic status in a country. It is necessary to discuss how BRI affects differently in developing countries and developed countries. It is recognized that BRI impact on developing countries often on the ascending slope of the EKC, just as the result of this research. Whereas BRI impact on the developed countries are more often near or past the turning point, which means a growing economy would lead to a less environmental degradation (Benzerrouk et al., 2021). So how does this effect come differently for developing countries and developed countries?

As for the developing countries, BRI investments, particularly in heavy infrastructure (roads, ports, energy plants, industrial zones), can significantly accelerate their GDP growth. According to the EKC logic, this rapid, infrastructure-led growth could *accelerate the climb* up the curve, potentially leading to a faster increase in environmental degradation in the short term. Also, there are some BRI investments involving carbon-intensive activities, if they are operated in a country with weak local

environmental regulations, they could potentially lead to a *higher peak* on the EKC for certain pollutants. Conversely, the "Green BRI" argue that it could help developing countries flatten the EKC curve. If BRI facilitates the transfer of cleaner technologies, renewable energy infrastructure, and best practices in environmental management earlier in the development process than would otherwise occur, it could theoretically allow these economies to grow without experiencing the same peak levels of environmental degradation that have been seen historically by currently developed nations. Though this study shows that green investment under the BRI framework is increasing in recent years, empirical results still don't manifest any sign of it effect of "flatten the curve".

As for the developed countries, they typically have matured regulatory frameworks and a high degree of public awareness for environmental quality. BRI projects in these countries must adhere to stringent domestic environmental standards while implementing (Coenen et al., 2021). Therefore, direct BRI investments are unlikely to reverse the trend or cause a significant increase of pollution that degrades the environment. BRI investments in developed countries might focus on high-tech or green sectors, for example, battery technology and smart grids. Such collaborations could potentially reinforce or accelerate the move towards an economy with less environmental pressure, aligning with the theoretical downward slope of the EKC.

The PHH suggests that polluting industries and companies may incline to move to the jurisdictions with less stringent environmental regulations. While this study doesn't examine regulatory stringency of BRI participating countries, the observed increase in carbon emissions from industrial and energy sectors following BRI participation is consistent with outcomes predicted by the PHH. China's shift to becoming a major capital exporter, with a significant amount of OFDI flowing to potentially pollution-intensive sectors like mining, manufacturing, and constructing traditional energy infrastructure, for instance, the coal-fired power plant was especially prominent before the 2021 prohibition. This reflects that, in part, companies seeking locations

where environmental compliance costs are lower, contributing to increased emissions in host countries.

However, the environmental effect of BRI projects is complicated by considering the evidence of a remarkable shift towards green investments since 2018, reaching 46% of the total in 2023. This recent trend introduces the hypothesis of PHAH, which depicts that foreign direct investment can bring cleaner technologies, superior environmental management practices, and potentially higher standards than locally available, thus creating a positive environmental spillover or "halo". In the case of BRI projects, the notable surge in Chinese investments in renewable energy such as solar power, critical metals for electrification such as Nickel and Lithium, and downstream applications, including batteries and electric vehicles, clearly aligns with the potential for a PHAH effect. It is observable that China is actively investing in the building blocks of the green transition globally. But its long effects on improvement of environmental quality are not able to be detected so far.

Despite the significant and growing share of green investments, the net observed empirical effect of BRI projects in this study has been an *increase* in overall per capita emissions, rather than mitigating carbon emissions. This might imply several possibilities. First, the negative impact of BRI-driven non-green investments on local environment still outweighs the positive impact of the green portfolio. Additionally, the PHAH effect is currently incipient, and its positive impact may take longer to manifest in aggregate emission reductions. Second, even "green" investments, particularly the extraction of critical minerals such as Nickel and Lithium, have embedded carbon themselves that contribute to overall emissions, making a purely positive PHAH hypothesis more complicated.

In a nutshell, BRI appears to accelerate developing BRI participating countries along the EKC's early development phase with environmental degradation, with outcomes consistent with potential PHH dynamics driving increased emissions. However, the recent, substantial trend towards green investments signals a potential shift aligned with

the PHAH. The empirical findings revealed that this green shift, while significant in proportion and strategic focus on securing supply chains of green technologies, has not yet demonstrably changed the overall trend of simulating carbon emission per capita in developing BRI participating countries. Looking forward, the future environmental implication of BRI projects will depend crucially on whether the scale and effectiveness of these green investments can eventually outweigh the environmental pressures generated by economic expansion.

5.2 BRI Environmental Governance

At the inception of the BRI, the framework did not incorporate the concept of environmental governance, which led to extensive criticism from the international community regarding the lack of proper environmental assessments, inadequate environmental mitigation measures, and an emphasis on economic pace at the expense of environmental consequences (Coenen et al., 2021). Early investments, particularly in the energy sector, heavily favored coal-fired power plants, exacerbating concerns about climate change impacts and air quality in host countries (Gallagher et al., 2019). Subsequently, due to dual pressures from both domestic and international spheres, the notion of environmental governance within the BRI framework began to evolve rapidly. Especially when the concept of "ecological civilization" is introduced in the legislation and greatly advocated in China, the policy of BRI initiative has shifted to promote the greening of the BRI and proposed a new upgraded vision of "Green BRI". This shift reflects a growing awareness that environmental sustainability is crucial for the long-term success and legitimacy of the BRI initiative.

Several key guidance, principles and documents shape the formal environmental governance architecture of the BRI. At early stage in 2017, *"Guidance on Promoting Green Development of the Belt and Road Initiative"* issued by four government ministries proposes to integrate the green principle to the BRI, promoting the concept of Green BRI and outlining overall objectives. Then in the same year, *"One Belt One Road*

Ecological and Environmental Protection Cooperation Plan" was issued to specify tasks of greening BRI, establishing international platforms and encourage companies to sign the green BRI agreement. In the financing area, the *"BRI Green Investment Principle"* document was introduced in 2018 to encourage firms incorporate environmental and social risk management into BRI investments. Later in 2019, *"Green Bond Support Catalogue"* was come up with aim to clearly define the scope of "green BRI project" to avoid green washing and make financing support more feasible. In 2021, President Xi Jinping made commitment to not build any new coal-fired power plant aboard in his 2021 UNGA Pledge marked a significant policy shift. Later in 2022, four governmental ministries again issued a document named *"Green Development Guidance for Belt and Road Initiative Projects",* which explicitly give instructions in 15 specific domains, being the the most comprehensive framework to date. Moreover, a series of *"Guidelines for Green Development of Belt and Road Initiative (BRI) Project"* published by BRI Green Development Institute during 2019 and 2023 introduces a traffic light system for classifying projects based on environmental impact, for instance, red, yellow and green projects, encourages adherence to international or stricter standards when implementing BRI projects.

Though China has issued lots of top-down guidance and principles to promote the environmental protection and safeguards within the BRI projects, the current status quo of the environmental governance of BRI framework is still insufficient and fragmented, largely due to these policies' non-bonding natures, multi-layer engagement players, and variance of the host countries. Firstly, the key issue of current environmental governance deficient is undeniably relevant to voluntary-based policies, which serves as an excuse of circumventing environmental issues in the design and execution of BRI projects. Second, in the reality, BRI project planning and execution involve a complex and interweaving web of actors, including relevant governance departments (e.g. Commerce Ministry), Chinese policy banks (e.g., CDB, China Exim Bank), state-owned enterprises (SOEs), private companies, and host country governments, leading to

variable adherence to central guidelines. Third, when implementation, BRI projects are legally bound by the environmental laws and regulations of the host countries, the stringency and enforcement capacity of these countries vary widely. For instance, The Bar-Boljare highway project in Montenegro has a very lenient Environmental Impact Assessment conducted by the local environmental agency prior to the project, but the loose and rushed assessment reflects an ineffective and week enforcement of impact evaluation in host countries (Coenen, Newig & Meyfroidt, 2022). The existing factors have significantly impeded the development of environmental governance within the BRI framework.

The environmental governance of BRI is transnational in essence, making it difficult to implement and generate effects. A study about transnational environmental governance of green BRI through case studies reveals that, China's green BRI strategy is focused on applying advanced green technologies and environmental protection in BRI investments, but it may not enough to stimulate the green transformation in BRI participating countries (Geng, 2024). It points out that China's way of BRI environmental governance is the "shallow-green" approach, which means adding and patching up incremental improvements on existing social-economic system, rather than "red-green" approach that calls for a fundamental radical reconstruction of ecological social-economic system (Huan, 2016). This demonstrates that the BRI's greenness is mild and lacks deep engagement in host countries' environmental problems. While researching case studies, the author found deficiencies of BRI environmental governance -being fragmented and lacking a well-functional backing network of Chinese government, corporations and NGOs (Geng, 2024). The usually top-down and state-centric approach from central government to corporations is commonly seen, but support from government and corporations to NGO is too limited to work for local community with environmental issues (Geng, 2024). It is suggested that Chinese NGOs could play a more significant role in environmental governance of oversea BRI projects.

It is realized that the core challenge of the BRI lies in reconciling the BRI's primary goal of promoting economic development with the imperative of environmental sustainability. This reconciliation is difficult due to extra efforts, management and technologies are required. However, some BRI projects already demonstrate considerable efforts to align economic development objectives with environmental protection, climate mitigation, and resource efficiency. For instance, the Tsingshan Industrial Park in Indonesia build clean energy base including solar and wind power to provide energy for the manufacturing of steel, nickel and batteries. Also, by using advanced technology, carbon dioxide emissions per ton of nickel production are reduced by 60% (Office of the Leading Group for the Belt and Road Initiative, 2023). So, this reconciliation is difficult but achievable by making strategic sector choices, applying green technologies, and adhering to both environmental standards of China and host countries. Besides, accelerating renewable energy deployment can be a good endeavor of this reconciliation, directly substituting fossil fuel generation and reducing carbon emission. For example, the Zhanatas Wind Farm in Kazakhstan as a renewable energy related BRI project, not only it helps Kazakhstan meet its renewable energy targets while emitting less CO2, but also it diversifies its energy mix away from coal and supports local economic activity.

A well-designed and effective environmental governance of BRI projects can play a significant role in promoting further development of the BRI toward global benefits. Regarding sustainable transportation, green investments in this area can help transport evolve away from inefficient or highly polluting modes. For example, electric vehicles can reduce exhaust emissions while improving urban air quality. Chinese manufacturers such as BYD and Yutong are important global suppliers of electric buses. There are some cities in BRI-participating nations like Latin America and Southeast Asia have purchased these buses (Strategic Energy, 2024). This procurement is probably supported by some BRI financial mechanisms or bilateral cooperation. In this case, BRI projects

can mitigate climate change by using electric public transportation with reduced carbon emission.

Moreover, green finance is an important branch of environmental governance, because green BRI investments can channel capital towards projects with positive environmental outcomes, encourages adherence to higher environmental standards. As advocated by the documents of "BRI Green Investment Principle" and "Green Bond Support Catalogue", transparency of green investments through the BRI framework is crucial, which potentially bring about financing favorable terms. For instance, financial institutions such as the Bank of China and the Industrial and Commercial Bank of China have issued green bonds explicitly related to financing eligible green assets under the BRI framework, which earmarks funds for environmentally beneficial activities.

These above examples illustrate the current situation of BRI environmental governance, existing complicated problems, and the significance of placing a sound environmental governance for reconciling economic development with green transition. It also reflects that BRI green investments is not just a theoretical possibility but an ongoing effort that has already happened in previously mentioned tangible projects and would continue in the future.

5.3 Cases of Green BRI Projects

Certainly, some green BRI projects have been conducive in promoting green development in participating countries. For instance, the Zhanatas Wind Power Project has not only alleviated power shortages in southern Kazakhstan but also established a precedent for the adoption of green energy systems. In Sri Lanka, the Colombo Port City has innovatively integrated green technologies to protect and foster the environment of coral communities. The China-Papua New Guinea Friendship School, which is committed to modernizing education in Papua New Guinea, is a proactive initiative for the use of green prefabricated construction methods. Additionally, the Greenwood International Trade Center is another example of green development,

aiming to establish a novel platform for trade between China and Russia. However, it is important to acknowledge that some non-green BRI projects, at the same time, are posing threats to local environment quality during their implementation phase. In this section, four BRI cases are categorized as either green or non-green BRI projects and their environmental effects and analyzed. Furthermore, some valuable enlightenment and suggestions are provided to better promote the BRI's green development.

The Renewable Energy Projects in Pakistan

As for Chinese oversea investments in renewable energy, Pakistan, as an important BRI member country in the China-Pakistan Economic Corridor, have received lots of financing investments to construct wind, solar and hydro-power stations (Li et al., 2022). This case study will introduce two renewable energy projects: the Karot Hydropower Station, and CAREC Corridor 1000 MW Wind Power Project.

It is universally known that an adequate electricity supply is a foundation to sustain economic growth and social progress. But for a long time, Pakistan has faced a chronic energy deficit, resulting in the frequent power outages and hindering the growth of national wealth (Baloch, Kaloi & Memon, 2016). In the rural area, nearly 1/3 of Pakistan residence are lack of electricity access because of insufficient electricity and grid connection (Baloch, Kaloi & Memon, 2016). Even in the urban area, load shedding is a common thing. The unstable voltage can also cause some damage of house applications.

Meanwhile, with the increase of Pakistan population in the recent decades, there is a growing demand of electricity with 8%-10% annual rate, highly surpassing the growth rate of electricity supply (Kanwal et al., 2020). As indicated by figure 25, this results in an expanding gap between electricity demand and supply, which will greatly restrict Pakistan's overall development. As shown in figure 25, Pakistan energy supplies by

sources in 2017-2018, Pakistan's energy consumption is severely unbalanced and heavily depend on the conventional resources, with oil, gas, coal, LNG (Liquefied Natural Gas) import LPG (Liquefied Petroleum Gas) together accounting for 88% of all energy sources (Global Village Space, 2024). To satisfy national growing demand, Pakistan must import approximately 80% of crude and refined petroleum products along with increasing amount of LNG, leading to a high dependence on imported energy resources (Global Village Space, 2024). Since the crisis of global supply chain caused by COVID-19 pandemic and subsequent outbreak of Russia-Ukraine War, the oil prices in the international market have been soaring and the cost of Pakistan's importing conventional resources has been increasing.

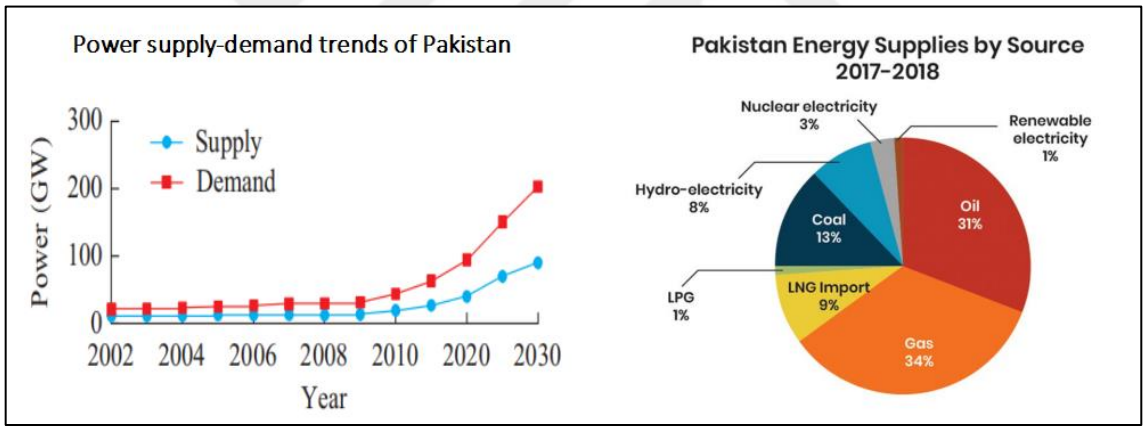


Figure 25: Energy Situation in Pakistan

Source: Kanwal et al., (2020) and Minhas, (2020).

Besides, over-reliance on traditional energy sources can lead to excessive carbon dioxide emissions and air pollution. Fundamentally, this situation is not caused by inadequate energy resources for power generation. In contrast, Pakistan has abundant renewable energy resources such as wind, solar and biomass that are greatly underdeveloped. According to Kanwal et al., (2020), Pakistan has sufficient solar radiation with 5.5 Wh/m2 per day and enough wind speed with 5-7 m/s in the shoreline provinces such as Sindh. provinces. In this case, the government has recognized the

need for diversification towards renewable energy sources to ensure energy security and mitigate environmental challenges. Thus, Pakistan government introduced foreign direct investments and signed the Momentum of Understanding in the BRI framework from China in terms of constructing power plant to utilize renewable energies.

The Karot Hydropower Station in Pakistan is an excellent example of how BRI projects can satisfy local energy needs as the same time prioritizing environmental sustainability and social responsibility. The Karot Hydropower Station is in Punjab where there are severe power shortages. This project undoubtedly promotes energy power generation in a clean way. As for its financing manner, this project was funded by Chinese investment from Silk Road Fund (BRI International Green Development Coalition, 2020). This project is operated based on a joint development model - the Build-Own-Operate-Transfer, which means the project construction started from 2016 and putted into operation in 2021, being able to collect revenue for a contracted period of 30 years then transfer to Pakistan government in a free manner (BRI International Green Development Coalition, 2020).

During the project implementation, it is worth noting that the project has taken several green initiatives to promote the renewable energy generation, biodiversity protection and sustainable construction. By harnessing the Jhelum River's hydropower potential, this hydropower station can generate 3.2 TWh of clean electricity annually, meeting the needs of over 2 million households and significantly reducing CO2 emissions (BRI International Green Development Coalition, 2020). Since the station is closely located to the Jhelum River, some precious endangered fish species in the project area have appeared and identified. To protect these fish, a comprehensive biodiversity management plan was implemented, including maintaining minimum downstream flow rates, establishing "No Fishing" zones, and incorporating ecological flow release structures ensure the preservation of aquatic life. To reduce transportation cost and its related carbon emission, project construction procures materials such as sand and gravel locally in a closed distance to fill the dam. Besides, the project adopted an advanced

wastewater treatment system, allowing 90% wastewater recycled to minimize the environmental influence. As for social benefit, this project not only offer 70% jobs to local employees but also starting a training program to learn other useful skills.

Another case is the CAREC (Central Asia Regional Economic Cooperation) Corridor 1000 MW Wind Power Projects in Pakistan, which is a landmark initiative aimed at addressing the country's energy crisis while promoting sustainable development. There are several key projects in CAREC program. At the conception of early 2010s, the project was taken under the CAREC program, a regional initiative promoting economic cooperation and infrastructure development. Investment in a 1,000 MW wind power project in Pakistan is underway according to the advocate of Energy Security. Chinese companies proposed to involve the construction of multiple wind farms since 2016 in the Gharo-Jhimpir wind corridor, located in Sindh province (CleanTech Law, 2017). For example, the Dawood Wind Farm constructed by Chinese company is now well-operational (Green Finance & Development Center, 2023). Then in 2021, the wind farms were able to operate functionally. It was also contributing to Pakistan's energy grid. The cooperation model is that Chinese partners providing only expertise, working together with local employees in wind turbine manufacturing, installation, and operation. As a result, this project significantly reduces Pakistan's reliance on fossil fuels and increase the availability of electric supply, contributing to carbon emission reduction and climate change mitigation.

The Sino-Singapore Tianjin Eco-City

The Sino-Singapore Tianjin Eco-City is a collaborative project between China and Singapore, primarily aimed at integrating Singapore's cutting-edge experience in green urban development into the construction of Tianjin city. As is widely recognized, Singapore is a highly environmentally sustainable nation, particularly evident in its urban planning and construction. Over 55% of its buildings possess green certifications (Green Building Masterplans, 2022). These structures are capable of significantly

enhancing energy and water resource efficiency while reducing carbon emissions. Besides, the governance's "Green Mark Scheme" started in 2005 also incentivizes developers of real estate to prioritize sustainability of buildings (Building and Construction Authority Green Mark Scheme, 2005). Due to its numerous environmentally sustainable practices, Singapore is frequently ranked as the country with the highest Environmental Performance Index in Asia (Environmental Performance Index, 2022).

Another city, as one of China's major port cities and a growing economic center, Tianjin faced challenges related to industrial pollution, resource depletion, and environmental degradation, including water scarcity, disposal of municipal and industrial waste and air pollution (Sining & Jun, 2021). The city sought sustainable solutions to support its continued economic growth while addressing environmental concerns. Therefore, this project has an obvious purpose to draw Singopera's sustainable city management experience to improve the ecological level of Tianjin city.

In 2007, the project was conceived as a bilateral collaboration between China and Singapore, aiming to develop a model eco-city that showcases sustainable urban planning principles. During 2008-2010, a comprehensive master plan was developed, making the city's layout, infrastructure, and sustainability targets, for instance, developing and marketing high-quality environmentally friendly residential, industrial, and commercial properties, transferring land plots within the Eco-City, leasing industrial projects, constructing infrastructure, and managing and maintaining green buildings (Sino-Singapore Tianjin Eco-City, n.d.). Since 2010, the project has been implemented in phases, with ongoing construction of residential areas, commercial zones, ecological features, and infrastructure. This project involves substantial investments from both China and Singapore, with estimates exceeding billions of dollars and total assets amounted to USD 2.72 billion (Zhan & de Jong, 2017). The cooperation model includes a joint venture company named "Sino Singapore Tianjin Eco-City" established by both governments, which is in charge of overseeing the

project's development and implementation, as well as facilitating knowledge sharing, technology transfer, and best practice exchange between the two countries.

This project has yielded positive environmental impacts, enhancing Tianjin's capacity for constructing green buildings, efficient water conservation, and urban waste management and so on. During the project's implementation, several green technologies, standards for green construction, and utilization of renewable energy were noteworthy. For instance, the Tianjin Green Building Park utilized solar energy, rainwater harvesting systems, and green roofs (Sino-Singapore Tianjin Eco-City, n.d.). The rainwater harvesting system achieved the recycling of water resources. The project also included objectives such as creating more green spaces and restoring wetlands (Low et al., 2009).

The Sino-Singapore Tianjin Eco-City project is a flagship initiative of the Chinese government, demonstrating the government's commitment to fostering ecological civilization construction. So, this project has garnered substantial governmental funding and support. The project has also pioneered an innovative model created by Singapore for urban development that integrates environmental protection, resource utilization, and economic growth into a cohesive development paradigm.

5.4 Cases of Non-green BRI Projects

The Myitsone Dam in Myanmar

The Myitsone Dam project is a hydroelectric power station dam constructed on the headwaters of Irrawaddy River, located in Kachin State, Myanmar. This project was halted now due to its various risks. It is a good example of failing BRI project caused by both environmental concerns and political instability. The project was designed to build in Myanmar, which is a country rich in natural resources and has the potential for developing hydropower stations. However, the country has long faced a range of developmental issues related to poverty, energy access, and environmental degradation. 24.8% of the population live below the national poverty line (World Bank 2017). More

than 60% of the population in the rural area has no access to proper electricity (Peralta, 2018).

The idea of building a hydropower dam was first conceived by Myanmar's Ministry of Electric Power (MOEP) in 2002, and a field survey was conducted. In 2006, a Chinese company—the State Power Investment Corporation—and MOEP signed an MOU to build two dams in Kachin State, Myanmar (Tha, 2019). Later In 2009, the Myanmar government and Chinese companies reached an agreement to build six more hydropower dams to improve the country's power supply. The Myitsone Dam project is worth about 3.6 billion USD, with most of the money invested by Chinese companies (Reuters, 2011). The Myitsone Dam project began construction in 2010, but Myanmar and Chinese companies did not inform the relevant residents in time during the survey and drilling, which caused some protest organizations to criticize the dam design for human rights issues, environmental damage, river diversion, biodiversity reduction, and other issues (Reuters, 2011). In 2011, Myanmar experienced a political change, and the new president preferred to use thermal power and natural gas power generation. So in 2011, the Myanmar government unilaterally announced a suspension of the construction of the hydropower station. Until now, the project is still suspended, and there is considerable uncertainty whether it can be resumed and rebuilt in the future.

While hydropower offers a potential solution for increasing energy generation and fostering economic development, concerns persist about the environmental and social consequences of large-scale dam projects. Considering its environmental impact and potential threats, Myitsone dam project could greatly alter river system and its hydrologic and sediment transport, leading to deforestation and habitat loss (Fawthrop, 2020). The construction of this dam and reservoir may inundate a large part of the forest and biological habitat, leading to desertification and the reduction of river and riverside animals. At the same time, there are articles saying that this hydropower station dam is very close to the earthquake fault zone, and the possible earthquake and dam collapse will bring greater disasters to the country, such as floods (Tha, 2019). In addition, if the

dam is built, the local people will need to migrate to other villages and face the risk of losing their land and lacking sufficient compensation (Reuters, 2011).



Figure 26. Suspended Myitsone Dam in Myanmar
Source: (Fawthrop, 2019)

For the above reasons, the Myitsone Dam project has attracted a lot of public criticism and opposition. After facing strong protests from local community residents, social groups, and environmentalists, the Myanmar government decided to suspend the project. The current suspended Myitsone Dam is shown in figure 26. This project has also attracted a lot of attention internationally, reflecting the many shortcomings faced by China's BRI projects in the specific implementation process, such as lacking sufficient communication with residents in the early phase, lacking the conduct and publication of project environmental assessments, lacking a transparent information disclosure mechanism, and so on.

The Emba Hunutlu Thermal Power Plant in Türkiye

The Emba Hunutlu Thermal Power Plant is a coal-fired power station located in Türkiye, serving as a classic BRI coal power project that has sparked extensive discussions about the environmental impact of coal-fired power stations on host countries. As the recipient country of the project, Türkiye is a rapidly developing economy with growing energy demands, yet it is heavily reliant on imported energy. In 2022, Türkiye remained to

import roughly all-natural gas, 91% oil products, and 77% coal from other countries (Kardaş, 2024). While the country has made attempts to diversify its energy mix and invest in renewables, fossil fuels continue to play an important role in electricity generation, accounting for 84% of total production in 2021 (Siccardi, 2024). In an effort to reduce dependence on foreign energy sources, Türkiye decided to construct coal-fired power stations.

The project has a brief conception and planning in the 2000s and it was conceived as part of Türkiye's efforts to increase domestic energy production and reduce dependence on imported energy sources. Then a consortium led by China's Shanghai Electric Power Company won the bid in 2013 to jointly develop and operate the power plant (Iha, 2017). The construction was agreed to be initiated in 2014 but delayed due to financing challenges and local opposition, but later projects commenced construction with financing problem solved (Ns Energy, 2019.). After several years of construction, the power plant started operations in 2019, contributing a significant capacity to national electricity grid in Turkiye. The plant has the capacity to supply the country's national grid with up to 11.5 billion kilowatt-hours (kWh) of electricity each year (Ns Energy, 2019). As for its cooperation model, the Emba Hunutlu project involved an investment of approximately $1.7 billion, primarily financed by Chinese banks and companies (Iha, 2017).

Though offering more energy power, it cannot circumvent the typical issue of environment influence for local community. As a coal-fired power plant, Emba Hunutlu contributes to air pollution by releasing pollutants such as sulfur dioxide, nitrogen oxides, and particulate matter, impacting air quality and posing a threat to public health in surrounding communities (Geybullayeva & Gülsün, 2021). Apart from air pollution, coal-fired thermal power plants demand considerable amounts of water to the cooling process. So, the large amount of water withdrawal from local sources undeniably affects aquatic ecosystems and competes with residential water users. Meantime, the wastewater discharge from thermal power plants to the local environment easily

pollutes local water circulation system. Furthermore, coal combustion generates large quantities of ash, which worsens the local air quality and environmental contamination (Health and Environment Alliance, 2021).

As a typical coal-fired power station, the Emba Hunutlu project has brought about an increase in electricity supply while also posing numerous environmental and health risks. The project, located in the local city of Adana, faced strong opposition from the community and environmentalists. However, due to the support from the host government and control over dissenting voices, such projects were widely distributed globally before 2021. For instance, the Turkish government, although acknowledging environmental concerns, maintains that the project is crucial for meeting the country's growing energy demands and reducing reliance on imported energy sources (Geybullayeva & Gülsün, 2021). These projects commonly face social criticism due to issues stemming from environmental pollution, improper use of water resources, and lack of project transparency.

5.5 Enlightenment and Suggestions to Greening BRI

By analyzing above cases, the complicated backgrounds, implementations and potential influences of each single project can be seen. Green projects can reduce carbon emissions, mainly focus on renewable energy generation. Non-green projects are recognized as controversial projects that either trigger lots of social and environmental problems or are suspended due to political instability and social opposition. From the case studies of green and non-green BRI projects, it is learned that green BRI projects, especially renewable energy and green city investments, greatly facilitate the sustainable and green development of local countries while solving growing energy demand problems. However, many existing non-green BRI projects have triggered severe environmental and social problems, typically in coal-fired power plant projects. Due to insufficient environmental governance in BRI project implementation, lots of projects are vulnerable to local political instability and social protests from local

communities. To enhance the resilience and reputation of BRI projects, some enlightenment of better BRI environmental governance is given in the last part.

The first enlightenment is about conducting the project environmental impact assessments (EIAs) and making it public before the approval and implement of BRI projects. By doing this, not only are some potential environmental risks identified on an early basis to apply better mitigation measures, but also the local communities are well-informed about what projects' environmental impact are and how it relates to their daily lives. BRI projects such as Myitsone Dam in Myanmar and the Emba Hunutlu Thermal Power Plant lacked doing such EIAs and faced fierce criticism from social groups with respect to projects' environmental consequence and inefficient social care. If the EIAs are properly used, projects can take robust mitigation measures to minimize ecological damage, pollution, and greenhouse gas emissions.

The second enlightenment is associated with BRI projects' engagement in the local community, respect local culture, and communicate with them in their best interest. Lots of BRI projects are criticized for lacking sufficient social care and culture sensitivity. When projects involve displacing residents and culture heritage sites, more attention should be paid to careful management, for instance, making an agreed relation plan and fair compensation to ensure residents interests. The Myitsone Dam project's suspension is a case that reflects the importance of public participation and respecting cultural values in project implementation.

The third enlightenment is related to labor rights and fair working conditions. Concerns have been raised about some degree of labor rights violations in particular BRI projects. For instance, the privatization of major the Port of Piraeus in Greece and the International Container Terminal in Colombo, Sri Lanka, has been associated with an increase concerns in labor rights (CISL, 2022). This is mainly because of the practice of combining direct hiring with subcontracting, which has resulted in a decrease in the number of direct hiring workforce, lower wages and diminished labor rights for

subcontracted workforce (Neilson, 2019). Therefore, fair salaries, healthy working conditions, and conformity with international labor norms are critical to the projects' social sustainability (Neilson, 2019). BRI projects should offer labor rights training programs and establish grievance systems that can help protect workers' rights and enhance reputation.

The fourth enlightenment is related to building up a communication channel and monitoring process to enhance projects' transparency and accountability. Lacking enough information and discussing channels, not mention independent monitoring bodies are constantly facing criticism for BRI projects in the international community. Though adding these aspects require BRI projects to make a great effort to manage, it is beneficial to build trust and reputation. Currently, many BRI projects, whether funded by Chinese investors or receiving nations, fail to provide enough information regarding project site, schedule, effect assessment on local environment and community, and lack an open forum for all stakeholders to communicate (CISL, 2022). For instance, the port's construction and COSCO's activities in Piraeus have not been discussed with the affected communities (CISL, 2022). Therefore, if these procedures are in place, BRI projects' international recognition, transparency, accountability and social responsibility for local participating countries would be greatly improved.

Other enlightenment from other BRI projects includes debt sustainability, technology transfer and local capacity building, as well as fair regional coordination. Before the decision-making of a BRI project, a careful assessment of host countries' debt sustainability, especially the situation of overburdening, should be conducted to avoid host countries' excessive debt burdens and projects' potential debt fraud. Besides, when using operate-and-transfer models for a BRI project, necessary technology transfer and training to equip local employees with operation capacity in host countries are highly suggested to enhance long-term sustainability of projects. In addition, currently existing trans-boundary environmental issues require cross-national cooperation, which is

another suggested non-commercial BRI projects could focus on to build the BRI's green image and global green transition initiative.

To deeply embed environmental sustainability into the planning, financing, implementing and monitoring process of BRI projects, a more applicable and effective green BRI framework needs to be established which require concerted efforts of multi-stakeholders. Building upon existing frameworks and acknowledging persistent challenges, the following suggestions aim to strengthen the environmental performance of the BRI projects.

First, the current ambiguity of green BRI projects classification makes possible research and environmental management difficult to conduct. So, developing and harmonizing a systematic "Green Taxonomies" is important to establish a clear and science-based criteria defining what constitutes a "green" BRI investment. Though the "Green Bond Support Catalogue" is already in place with general sector classification, it is not as clear and specific as other internationally recognized taxonomies. It could be potentially aligned with other international taxonomies such as the EU Taxonomy to enhance credibility and avoid greenwashing. This should cover not just climate mitigation but also biodiversity, pollution control, circular economy, and water resources. Based on a clear taxonomy of green BRI, lots of incentives and governance regarding green BRI projects are possible to be built on. Therefore, developing and harmonizing a systematic "Green Taxonomies" can lay a solid foundation for any other measures of green development of BRI projects.

Secondly, strengthening regulatory bindingness from voluntary principle to legislative obligation is equally important to improve enforcement of current and future issued environmental regulations. This is an inevitable next step of moving beyond voluntary guidelines and producing effective and immediate results. For example, after the coal-power plant prohibition, there is a rapid reduction of relevant oversea investments, though other coal related such as coal mining is still operating (Tritto, 2021). Therefore,

other feasible bounding measures could be included in the future regulation for BRI projects, for example, incorporating specific environmental clauses and requirements for comprehensive Environmental and Social Impact Assessments (ESIAs) into bilateral agreements, loan contracts, and project contacts related to BRI.

Thirdly, as BRI projects are backed by some international financing institutions such as Silk Road Fund, Asian Infrastructure Bank, enhancing green finance mechanisms and ESG integration into the funding decision-making process are feasible ways to improve the green level of BRI and inventive more BRI projects. Specifically, Chinese policy banks such as China Development Bank, and China Exim Bank and commercial banks involved in BRI should systematically integrate mandatory ESG risk assessments into all lending decisions, not just for projects explicitly labelled “green”. At the meantime, these ESG assessment reports pertaining to every single green BRI project should be transparent and publicly available on the websites. Apart from assessment, financing institutions are suggested to offer preferential financing terms such as lower interest rates for BRI projects that demonstrate superior environmental performance, exceed minimum standards, or deploy cutting-edge green technologies. To better fund green BRI projects, the issuance and use of dedicated green bonds and green loans are encouraged in financing institutions.

Fourthly, for the reputation and credibility of BRI initiative, government should continuously work on improving transparency, monitoring and accountability of BRI. For instance, relevant government department could establish a centralized and publicly accessible BRI project database that details all BRI projects including project developers, approval institutions, financiers, locations, amounts, environmental assessment reports, environmental management plans and so on. To better monitor implementing process, it should be required independent third-party monitoring of environmental compliance during project construction and operation, particularly for high-risk projects, with findings made publicly available. Also, collecting feedback from host countries and communities is inevitable part of dealing with public

environmental concerns, allowing relevant stakeholders' concerns to be raised and addressed promptly.

Fifthly, the opportunity of BRI platform serving as international cooperation should be fully utilized to promote knowledge sharing and technological innovation. For knowledge sharing, it is suggested to actively use platforms like the BRI International Green Development Coalition to share data, best practices, innovative green technologies, and policy experiences among participating countries and international partners. For technology innovation and transferring, it is prompted to encourage and finance the transfer and deployment of advanced green technologies within BRI projects, such as high-efficiency renewables, energy storage, smart grids, pollution control tech, sustainable transport solutions and so on.

CONCLUSION

In this study, the background of the BRI, encompassing the ancient silk road, the global economy, China's motivations, the BRI framework, and the development of BRI over the past decade are initially outlined. Subsequently, the concept of "Green BRI", its proposing background, and related policy guidance and principles are introduced. To depict the current state of green BRI development, the basic environmental conditions of BRI participant countries and potential significant role of BRI in the global environmental governance are explained.

To have a better understanding of green BRI investment, an overall descriptive statistical analysis of BRI projects and categorizing them into green and non-green projects are made. This analysis starts with exploring the evolution of China's investment portfolio over decades that illustrates a strategic reorientation in its overseas investment approach. This is marked by a high in investment in the mid-2010s, followed by a slight reduction in percentage of energy sector's dominance, but increase in the absolute amount of energy and mining sectors. There is also a noticeable decline in investments in traditional sectors like real estate. Further, the analysis of FDI and OFDI reveals a transition that shifts from a focus on inbound to outbound investments, leading to China now emerging as a significant exporter of capital propelled by BRI and shifts geographical focus towards Asian countries such as Viet Nam and Indonesia.

Within China's outward investments to BRI participant countries, a classification of 400 significant investment projects flowing to 45 BRI developing countries from September 2013 to December 2023 is made. These BRI investments are divided into green category and non-green category based on alignment with the six objectives outlined in the EU Taxonomy. A comparative analysis of these investments in terms of quantity and value reveals a similar pattern within BRI developing countries. It is observed that since 2018, China has increasingly prioritized the green and sustainable aspects of its investments, achieving a notable 46% of investments classified as green in 2023. A

detailed breakdown of sub-sectors reveals a significant concentration of China's green investments in securing critical minerals such as Nickel and Lithium, with investments in their downstream applications, notably Lithium Batteries and Electric Vehicles. Also, substantial green investments are made in renewable energy generation, with solar power leading the way. Based on this strong momentum of green BRI investments, this research desires to evaluate whether this green momentum has resulted in an improved environmental quality of participant countries.

To examine environmental impact of the BRI participation on BRI countries, a literature review on BRI and environmental quality is conducted, identifying three potential theoretical hypotheses that may emerge within the BRI, namely EKC, PHH, and PHAH hypothesis. Subsequently, aligned with the objectives of this research, this study proposes the hypothesis that participation in BRI will lead to a decrease in per capita carbon emissions in BRI participating countries. To test this research hypothesis, this study employs Difference-in-Differences, a Becon-composition analysis that verifies unbiased results, and more advanced and dynamic empirical method of the Average Treatment Effect on the Treated for analysis, with results as follows.

Based on the empirical analysis of the treatment effect of the BRI on carbon emissions per capita in developing member countries, it is found that BRI participating countries have experienced a significant *increase* in carbon emissions per capita following their participation in the initiative. Specifically, emissions from various sectors, including industry, energy, and transportation, have all seen a substantial increase caused by BRI participation, although the driving factors vary slightly across sectors. Geographically, the treatment effect of BRI is particularly significant and positive for carbon emissions in the regions of "East Asia & Pacific" and "Middle East & North Africa", likely due to their rapid industrialization over the past decade and large amount of BRI projects. Then, after investigate the treatment effect, it is uncovered that BRI's effects on the carbon emission have appeared significant upward trends since 2017. Furthermore, BRI participant countries that joined BRI in 2013 and 2015 have the strongest positive effect

on carbon emissions per capita. And the longer a country is exposed to BRI, the larger the influence on its carbon emissions can be detected, reflecting BRI's large-scale long-term and accumulating environmental impact.

These findings are consistent with the initial ascending slope of EKC hypothesis associated with rapid industrialization and rising environmental degradation. Further, results are adhered PHH pattern that companies relocate to places where environmental compliance costs are lower, contributing to increased emissions in host countries. This research identifies China's active investments and deployments in global renewable energy supply chain, but the expected PHAH effect is not yet realized and green BRI investments' impacts on environmental improvement for participant countries are not able to be detected so far.

Limitations

In this research, the carbon emission per capita is adopted to measure the climate change of environmental effect caused by BRI participation. Carbon emission is calculated based on various sources from all aspects of economic activities. Sometimes, high carbon emissions do not necessarily equate to poor local air quality, water pollution, or soil contamination, which are often the most immediate environmental consequences affected by BRI infrastructure projects. But, carbon emission per capita provides no information on these critical local environmental burdens. For instance, other kinds of air pollutants such as SO2, NOx, PM2.5, ozone precursors, water pollutants such as chemical runoffs and heavy metals, solid wastes, land use, biodiversity effects, deforestation, habitat fragmentation, soil erosion and so on.

In the part of the green BRI investments analysis, the classification of investments used according to EU taxonomy objectives is not a perfect clear-cut way. The EU Taxonomy was designed for the specific economic, regulatory, and environmental context of the European Union, which may not be directly relevant or appropriate to other countries. Due to a limited BRI project information, properly applying the EU Taxonomy using

detailed, verifiable technical data on project performance such as CO2e/kWh is impossible for this research. That's why the classification in this study based on whether a project subsector information aligns with its six objectives. This may lead to oversimplification in the classifying process into only two subsets of "green" or "non-green". In fact, many projects have mixed environmental impacts, for example, hydropower plants providing low-carbon energy but impacting river ecosystems. This oversimplified category might make overlook potential non-green factors in some investments.

Regarding research methodology, while combining TWFE DiD with diagnostic tools like Bacon Decomposition and robust estimators of group-time Average Treatment Effects (ATT) (Callaway & Sant'Anna, 2021) represents a significant advancement over naive DiD, several limitations remain, especially in the complex situation of BRI. First, BRI participation is not a single event but a complicated, evolving process with multiple periods for different participating countries. Defining the exact "treatment" time solely by the year of signing MoUs has a possibility of being ambiguous and misleading because it is not the exact time receiving BRI projects that substantially generate environmental effects. Secondly, although there is no perfect construction of treatment and control group, this research uses the best practice to show evident that parallel trend assumptions are highly possible to be held by regression results and relevant graph. Thirdly, another inherent assumption of DiD - "the stable unit treatment value assumption" implies no interference between units and treatment consistency. However, this is highly questionable for the complicated BRI scenario. Infrastructure projects such as roads, rails and ports inherently create connectivity, meaning economic activity and pollution in one BRI country could easily spill over into neighboring countries, violating the assumption of independent units. The year and unit fixed effect used in the method design, already give a reasonable safeguard, but cannot totally exclude above immeasurable spillover effect.

Further research suggestion

This research solves the problem of whether the BRI initiative has a positive or negative effect on the carbon emission per capita for BRI participant countries. But not how this effect is generated and changed. Future research should aim to disentangle the pathways through which types of BRI projects influence the change of carbon emissions. The following research questions could be explored. Do the negative effects primarily caused by increasing trade volumes and associated transport emissions shift the host country's industrial structure towards more polluting sectors? Does it include a positive power of transferring specific green cleaner technologies? How do these two contradicting powers play off each other and change dynamically?

The research focuses on CO_2 per capita as a prominent aspect of environmental issues. However, as explained in the limitation part, the other aspects of environmental outcomes are overlooked. Future research could consider other important indicators of the environment, including not only climate change but also water, soil, land use, waste disposal, biodiversity, and so on. Specifically, quantifying the effect of a particular BRI project or a category of BRI projects, such as industrial zones, power plants, transport infrastructure, and mining, on local air quality, water quality, biodiversity loss, and land use change in surrounding areas.

This research has noted the challenge of classification for all BRI investments and the aggregate negative effect of BRI despite green investment growth. Future work could take a sample of projects that this research explicitly classified as "green" vs. "non-green" within the same country or sector and compare their localized environmental impacts. Their specific environmental impact could be obtained using satellite data and local monitoring. This more in-depth research can help understand if designated "green" projects genuinely perform better environmentally, despite classification limitations. Furthermore, aggregate country-level studies like this research usually mask significant heterogeneity. So in-depth, mixed-methods case studies of specific, large-scale BRI projects are needed, for instance, studying a specific port,

railway, dam, or industrial zone. These could combine quantitative local environmental monitoring with qualitative analysis of decision-making processes, stakeholder engagement, implementation of environmental assessment, and community impacts. It can provide some context-specific insights to understand BRI projects' complicated environmental impacts.

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