Using GTAP-POWER for Analysing Investment Heterogeneity: China's Energy Investment Impacts in the Belt and Road Countries

Abstract

China's Belt and Road Initiative (BRI) represents one of the most significant energy infrastructure investment schemes in the 21st century. Given its vast scope, pivoting towards a more environmentally-conscious strategy has the potential to significantly further the United Nations Sustainable Development Goals (SDGs), especially in the domains of energy (SDG 7) and climate action (SDG 13). Despite its importance, there remains a notable shortage of comprehensive studies integrating environmental and economic impacts for the BRI nations, especially regarding detailed energy types. This study uses the Multiregional Input-Output (MRIO) Table constructed by the Global Trade Analysis Project-Power (GTAP-Power) database to empirically analyse the impact of China's energy investments on the total output, value-added and carbon emissions across eight representative BRI nations (Kazakhstan, Russia, Indonesia, Italy, Chile, Peru, Malaysia, and Saudi Arabia). Using the GTAP-Power database enables a nuanced, empirical analysis of the sector-specific impacts of energy investments. Preliminary findings indicate these investments' positive economic implications regarding total output and value-added. Conversely, the environmental costs, specifically carbon emissions, demonstrate considerable regional heterogeneity. Thus, a comprehensive assessment of the investment impacts is essential, focusing on the balance between economic benefits and environmental consequences. By aligning its investment strategies with global sustainability targets, the BRI can enhance its contribution to sustainable development. This study provides a deeper understanding of the relationship between economic growth and ecological protection in the context of China's energy financial contributions in the BRI countries.

Key Words: The Belt and Road Initiative, Multiregional Input-Output (MRIO) Table, carbon emissions, energy investment, heterogeneity, GTAP Power

1. Introduction

The Belt and Road Initiative (BRI), launched in 2013, is China's national policy of opening up to the outside world, which aims to foster global prosperity by enhancing connectivity, policy coordination, trade, financial integration, and cultural exchange (OECD, 2018). The BRI agreements currently cover 151 countries across various projects across all BRI industries (Bega and Lin, 2023), whether completed, in progress or planned, are projected to total an estimated US$575 billion (Maliszewska & Van Der Mensbrugghe, 2019). Since the inception of the BRI, Chinese investment in participating countries has surged, reaching $20.3 billion across 57 nations by 2021, a 14% year-on-year increase (Ministry of Commerce, 2022), which has significantly bolstered cooperation between China and BRI nations (Zhao et al., 2019a; Zhou et al., 2018). Despite extensive research on the BRI's economic and social outcomes (Thürer et al., 2020; Torres, 2019; Yu, 2016; Clarke, 2018; Zhou & Esteban, 2018), its sustainability and decarbonisation impacts remain underexplored.

Energy infrastructure forms the backbone of the BRI's. China's energy investment in BRI nations, accounting for nearly 43% of the total BRI investments from 2014 to 2020, has substantial economic and environmental impacts (Wu et al., 2020; Zhao et al., 2019b). Although these investments support economic growth, particularly in developing countries, they pose environmental challenges (Zhao et al., 2019b; Lai, Lin & Sidaway, 2020; Basheer et al., 2023). Existing literature mainly focuses on the impacts of large-scale infrastructure projects under the BRI (Zhu & Gao, 2019; Qian et al., 2019; Chen & Li, 2021; Liu et al., 2020), often overlooking the integration of the economic and environmental effects of energy investments. Specifically, the literature lacks an in-depth exploration of investments by energy type in BRI countries. Consequently, a comprehensive analysis addressing the trade-offs between economic gains and environmental costs for different types of energy investment is notably absent.

This study uses the Multiregional Input-Output (MRIO) model to holistically assess the impacts of energy investments in BRI countries at national levels. Traditional methods, such as Life Cycle Assessment, usually focus on specific products and their environmental footprints, addressing individual goods or services (Mannan et al., 2018). Although Material Flow Analysis (MFA) can be used at the macro level, its reliance on physical data may limit its ability to capture the complex economic interactions central to analysing macro-scale investment impacts (Dunuwila, Rodrigo & Goto, 2018; Graedel, 2019). Given the study's unique context, we have opted for the MRIO model because of its proficiency in tracking trade flows and repercussions within international trade (Miller, 2022; Chen & Li, 2021), making it an ideal tool for analysing the economic and environmental effects of the BRI's energy investments. The MRIO provides a comprehensive mapping of product flows within the economic activities, effectively capturing the complex web of sectoral interdependencies (Steen-Olsen et al., 2014; Wiedmann et al., 2010; Zhang et al., 2016). For example, it can elucidate how renewable energy investment in one nation might influence manufacturing and utilities in another(Wang, Jiang & Li, 2022; Tian et al., 2019).

This study aims to provide a holistic evaluation of the economic and environmental impacts of China's energy investments under the BRI. The findings will offer empirical insights for policymakers, aiding the promotion of sustainable strategies within BRI investments and balancing economic growth with environmental responsibility. This research raises several pivotal questions:

(a) How do China's energy investments impact the environment in BRI countries, particularly concerning their industrial growth and natural environment?

(b) What economic benefits arise from these energy commitments, and how do they relate to their environmental ramifications?

(c) How do the economic advantages from these investments correlate with environmental concerns across distinct BRI nations?

2. Research Methodology

2.1 MRIO for Energy Investment Impact Assessment

Understanding shifts in total output, value-added, and CO_2 emissions through the lens of an MRIO table offers valuable insights into economic and environmental dynamics (Miller, 2022). Specifically, evaluating total output changes provides a nuanced understanding of sectoral performance and economic growth patterns, identifying sectors leading economic expansion or contraction (Miller, 2022). The assessment of value-added variations highlights the distributional issues behind economic growth or contraction and recognises sectoral contributions to the broader economic landscape (Bjelle et al., 2021). From an environmental perspective, tracking carbon emissions is paramount to understanding the environmental implications of economic activities and pinpointing sectors with high carbon intensity (Zhang et al., 2016; Wang, Jiang & Li, 2022) and aiding in forming emissions reduction strategies (Wiedmann et al., 2010). Consequently, this combined economic-environmental assessment offers a comprehensive framework to investigate economic performance alongside environmental stewardship.

2.1 Calculations of the MRIO model

The construction of the MRIO table uses the GTAP-power database (see e.g.Peters, Andrew & Lennox (2011) and Steen-Olsen et al (2014)). To streamline the analysis, the original segmentation of 64 sectors in this dataset has been aggregated into 24 categories, ensuring a more concise focus on diverse energy types; the detailed classification can be found in supplementary data.

2.1.1 Estimating Changes in Total Output

The foundation of the analysis lies in the Leontief demand-driven model, which is renowned for its application in discerning the change in total output in response to variations in final demand. The mathematical representation outlines the change in total output ΔX as:

$$\Delta X = L * \Delta F \tag{1}$$

Where:

$$L = (I - A)^{-1} \tag{2}$$

In this context, the change in total output hinges on the Leontief inverse matrix$(I - A)^{-1}$ and the adjustment in final demand ΔF. The matrix $L = (I - A)^{-1}$can be calculated from the intermediate input matrix of the MRIO tables of the eight countries, while F incorporates the alterations in energy investments. Given the linear relationship between the final demand F and total output in equation (1), the effect of augmented energy investment on the change in Total Output can be obtained. ΔX indicates the impact on the total output of the BRI investing country, and its value's magnitude denotes the variation (typically an augmentation) in the total output of the BRI Countries stemming from the energy investment.

2.1.2 The change in Value Added (GDP)

The study extends its analysis from total output to understanding the effects of energy investments on sectoral value-added, essentially GDP. To determine the GDP impact, the change in total output is integrated with the value-added coefficients (V):

$$V = \frac{Vi}{X_r^i} \tag{3}$$

$$\Delta GDP = V * \Delta X \tag{4}$$

Here, the matrix V denotes the value-added coefficient matrix, reflecting the ratio of value-added per unit of output for each sector. The Vi is the value added of I in region r, and the X_r^i is the total output of i in region r. A higher ΔGDP value infers a more significant GDP augmentation in a BRI nation after receiving energy investment.

2.1.3 Environmental footprint

As mentioned, the carbon footprint is selected as a footprint indicator that measures the impacts of critical energy investment on the BRI's environment. In this study, the carbon emission E is calculated by the EEMRIO approach (see e.g. (Miller, 2022; Peters, Andrew & Lennox, 2011)). Based on the linear relationship between final demand and total output in equation (1), the effect of increased energy investment on the amount of change in CO_2 emissions can be obtained. The influence of augmented energy investment on CO_2 emissions change can be calculated as follows:

$$S = \frac{Ci}{Xi} \tag{5}$$

$$\Delta E = S * \Delta X \tag{6}$$

Here, S represents the emission intensity matrix, signifying the volume of CO_2 emissions per unit of output for each economic sector. Using GTAP power, we can determine the aggregate carbon emissions for every sector, expressed in CO_2eq units. By dividing this emission vector by the total economic output vector, X_r^i, we can derive the vector for direct GHG emissions intensity, denoted as S, measured in Mtoe CO_2eq/USD. ΔE indicates the impact on the total CO_2 emissions of the BRI investing country, and the large value signifies that the energy investment has resulted in a more considerable increase in the CO_2 emissions of the BRI nations.

2.2 Research targets

The research focuses on eight countries: Kazakhstan, Russia, Indonesia, Italy, Chile, Peru, Malaysia, and Saudi Arabia, representing about 45% of all BRI energy investments. Their substantial share underscores their importance in illustrating the initiative's diverse economic impacts, distinct energy frameworks, and regional effects. Kazakhstan and Russia are notable energy exporters, characterising the BRI's strategic integration of geopolitics and energy security in Eurasia (Rezaeinejad, Zeraat Peyma & Zhen, 2023; Bennett, 2016). Indonesia and Malaysia, as emerging markets within the Indo-Pacific area, reflect the BRI's pursuit of sustainable energy and infrastructure development (Tritto, 2021; Dar & Seng, 2022; Hock & Gomez, 2022). Italy, a G7 nation, signifies the BRI's adaptability within mature economies, allowing it to scrutinise its adaptability to diverse regulatory environments (Men & Jiang, 2020). Chile and Peru, being South American countries rich in mineral and energy resources, underscore the BRI's transcontinental reach and its dedication to resource-driven growth (Li & Zhu, 2019). Saudi Arabia is a leading oil exporter, and manifests BRI's collaborations within the global oil matrix (Duan et al., 2018). Analysing these diverse nations ensures a comprehensive understanding of the BRI's energy strategy, reinforcing the study's broad applicability and validity.

2.3 Data source

The MRIO table used in this study is based on the Global Trade Analysis Project-Power (GTAP-Power) of 2014, which presents an in-depth overview of several technologies in the power sector, including renewable sources and fossil fuels (Peters, Andrew & Lennox, 2011). The GTAP-Power database facilitates a nuanced analysis of sector-specific energy investment impacts by providing a more detailed breakdown of the electricity sector (Thube, Delzeit & Henning, 2022).This database disaggregates the electricity sector into subcategories like transmission and multiple energy types such as coal, gas, oil, nuclear and renewables (Peters, 2016).

Information regarding the magnitude of energy investment and the nature of projects is gleaned from two databases. The first is the Investment Project Information Database, maintained by the

Ministry of Commerce of China. The second source is the China Global Investment Tracker, a resource curated by the American Enterprise Institute.

3. Results and discussions

3.1 The BRI Energy investments

Figure 1 shows the number of energy investments made by the Chinese BRICS Initiative in the target countries studied over the past almost ten years. This investment encompasses both conventional (coal, gas, and oil) and renewable energies, with the latter including hydropower, wind, solar, and nuclear sources. Wind, solar and nuclear power are all included in the alternative sector. Of the eight countries studied, Russia, Peru, Kazakhstan and Saudi Arabia are the countries with the largest energy investments in the BRI. Except for Russia's fractured total energy investments (15480 million USD), the other seven countries' total energy investments average 6000 million USD to 8000 million USD, which helps examine the differences in economic and environmental impacts due to different types of energy sources for similar total investment amounts. The graph shows that traditional energy investments remain predominant. Specifically, oil and natural gas projects constitute approximately 70% of the total investments, with Indonesia leading in the carbon-intensive coal sector investments.

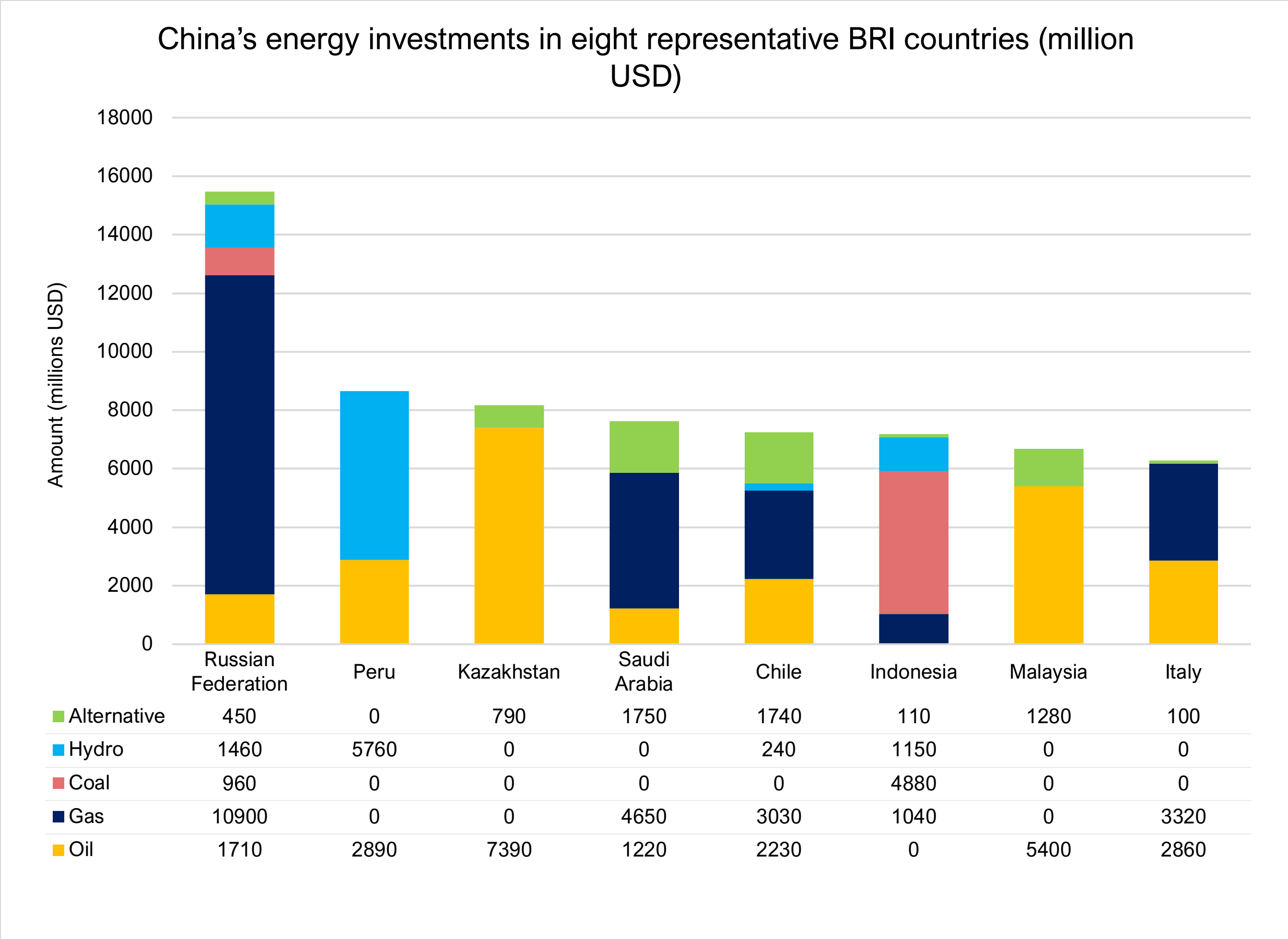
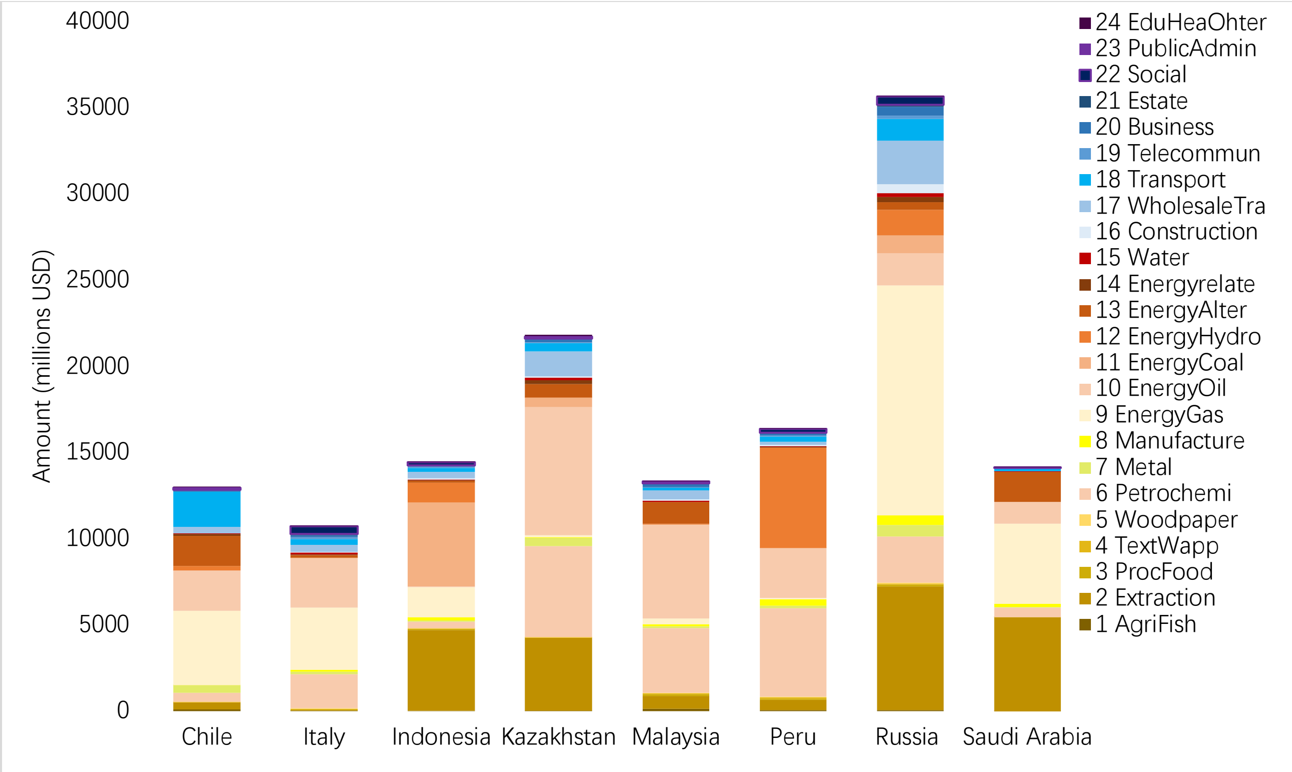


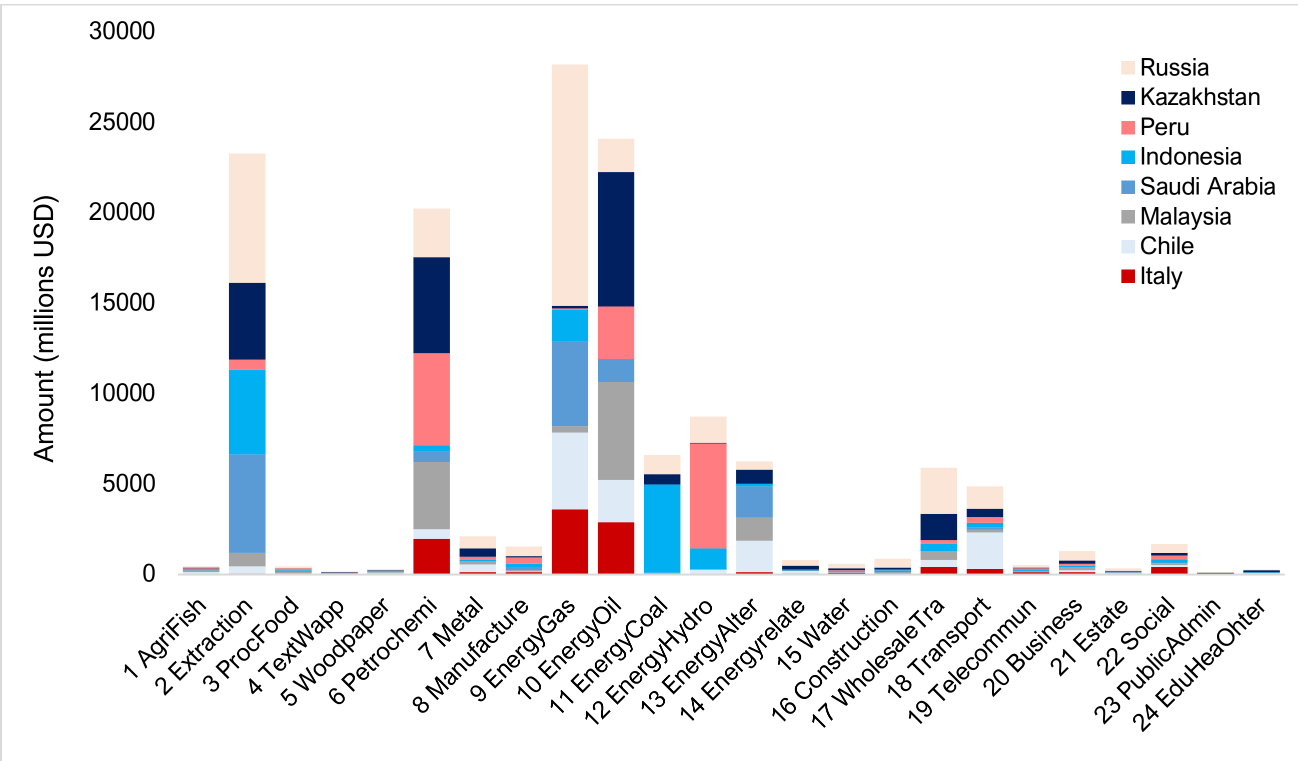
Figure 1. China's energy investments amount in eight representative BRI countries (unit: million USD)

3.2 Economic Impact of China's energy investments in the BRI Countries

This study quantifies the sectoral impacts of China's energy investments within the BRI framework, focusing on eight representative countries. Empirical results illustrate sector-specific variations in the total output and value-added induced by China's BRI energy investments across the eight nations.


Amount (millions USD)
40000
35000
30000
25000
20000
15000
10000
5000
0
Chile
Italy
Indonesia
Kazakhstan
Malaysia
Peru
Russia
Saudi Arabia
24 EduHeaOhter
23 PublicAdmin
22 Social
21 Estate
20 Business
19 Telecommun
18 Transport
17 WholesaleTra
16 Construction
15 Water
14 Energyrelate
13 EnergyAlter
12 EnergyHydro
11 EnergyCoal
10 EnergyOil
9 EnergyGas
8 Manufacture
7 Metal
6 Petrochemi
5 Woodpaper
4 TextWapp
3 ProcFood
2 Extraction
1 AgriFish

(a)


Amount (millions USD)
30000
25000
20000
15000
10000
5000
0
Russia
Kazakhstan
Peru
Indonesia
Saudi Arabia
Malaysia
Chile
Italy
1 AgriFish
2 Extraction
3 ProcFood
4 TextWapp
5 Woodpaper
6 Petrochemi
7 Metal
8 Manufacture
9 EnergyGas
10 EnergyOil
11 EnergyCoal
12 EnergyHydro
13 EnergyAlter
14 Energyrelate
15 Water
16 Construction
17 WholesaleTra
18 Transport
19 Telecommun
20 Business
21 Estate
22 Social
23 PublicAdmin
24 EduHeaOhter

(b)

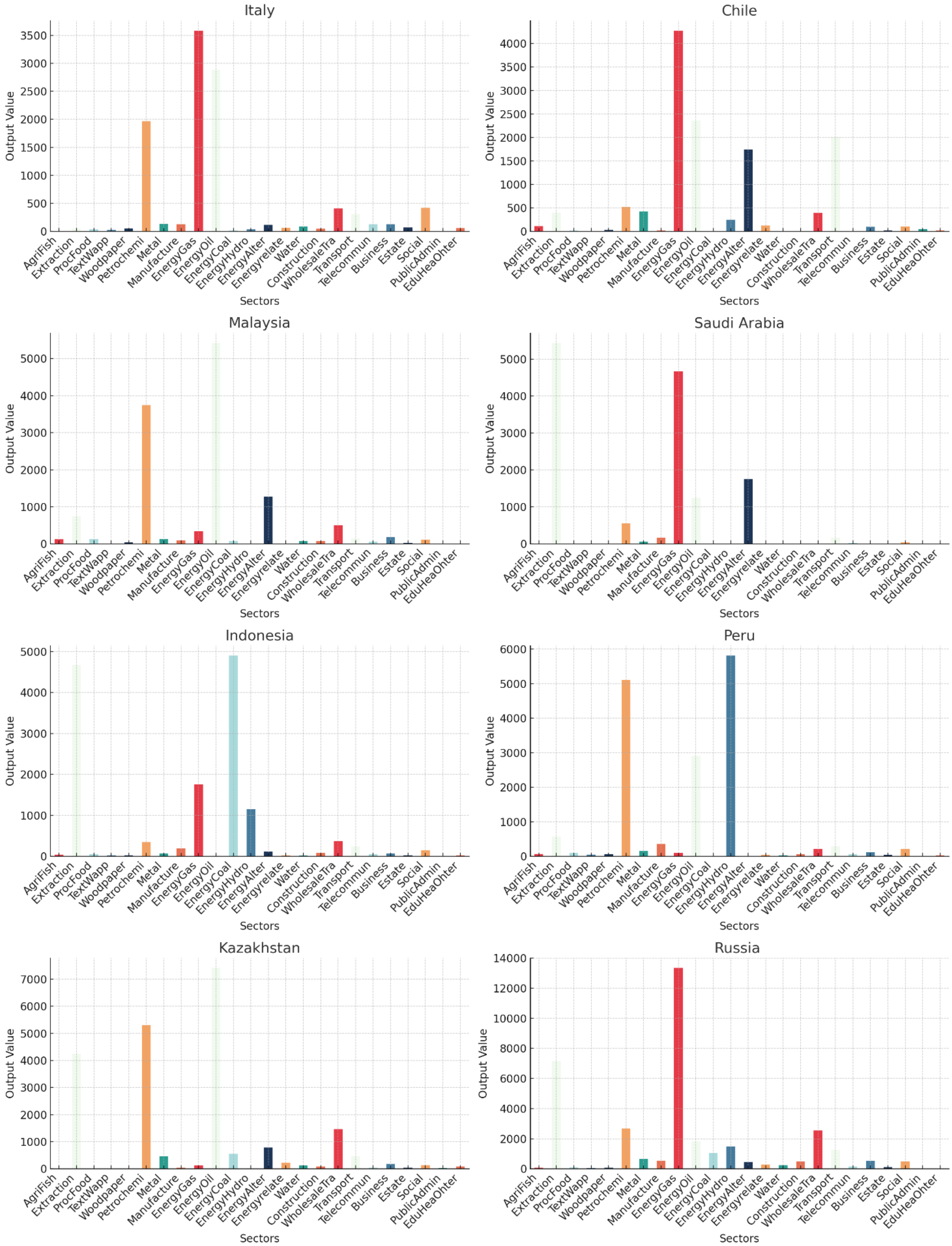
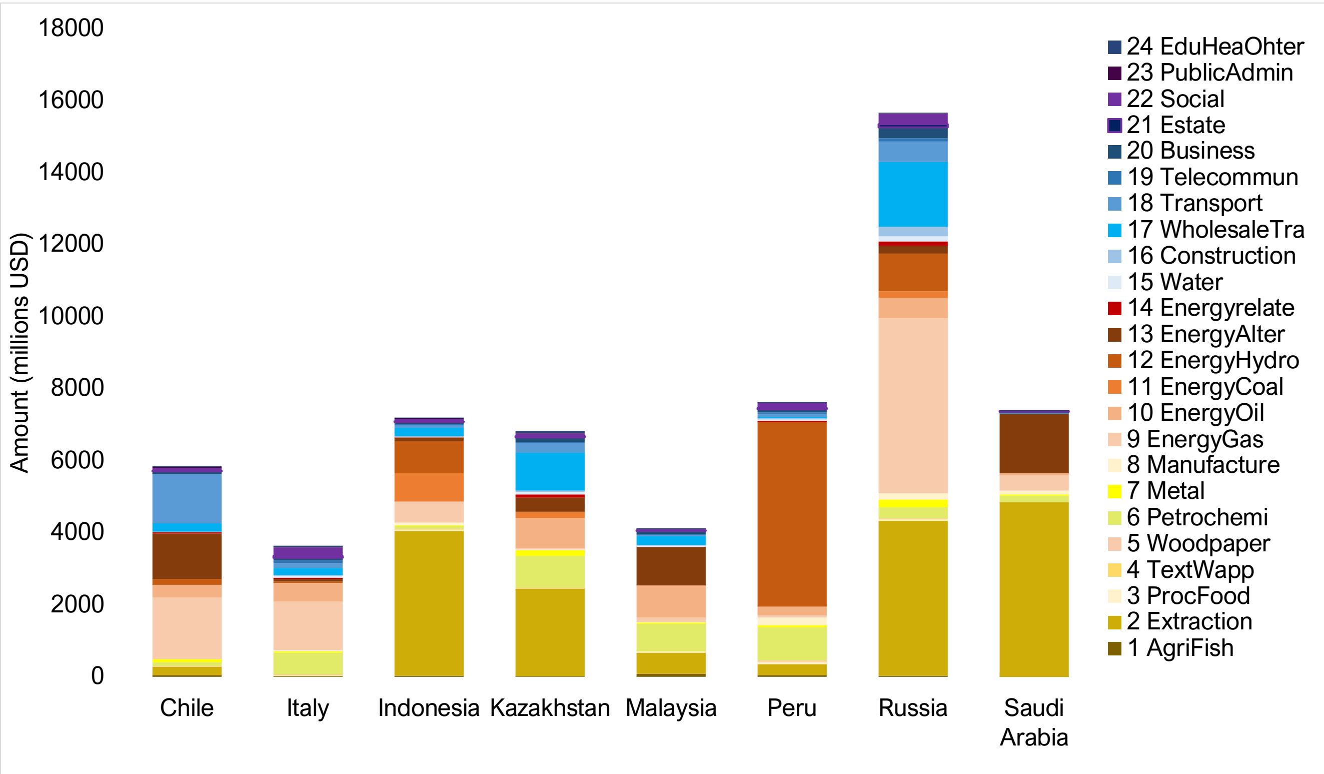


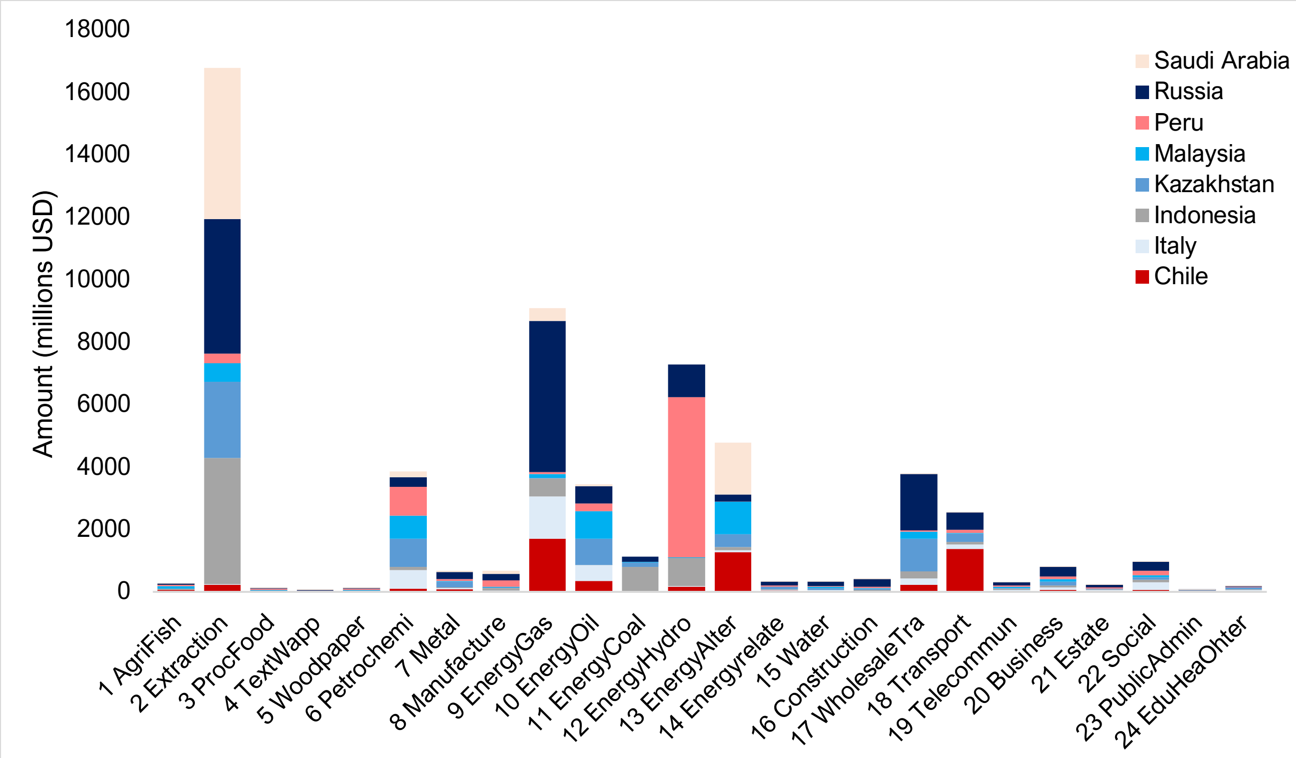
Figure 2. Impact of energy investments on total output by sector and by country in the eight countries along the BRI (unit: million USD). (a) Impact assessment of energy investments on the total output of

each sector (unit: million USD). (b) Impact assessment of energy investments on the total output of all countries (unit: million USD). (c) Impact assessment of energy investments on the total output of each country (unit: million USD).

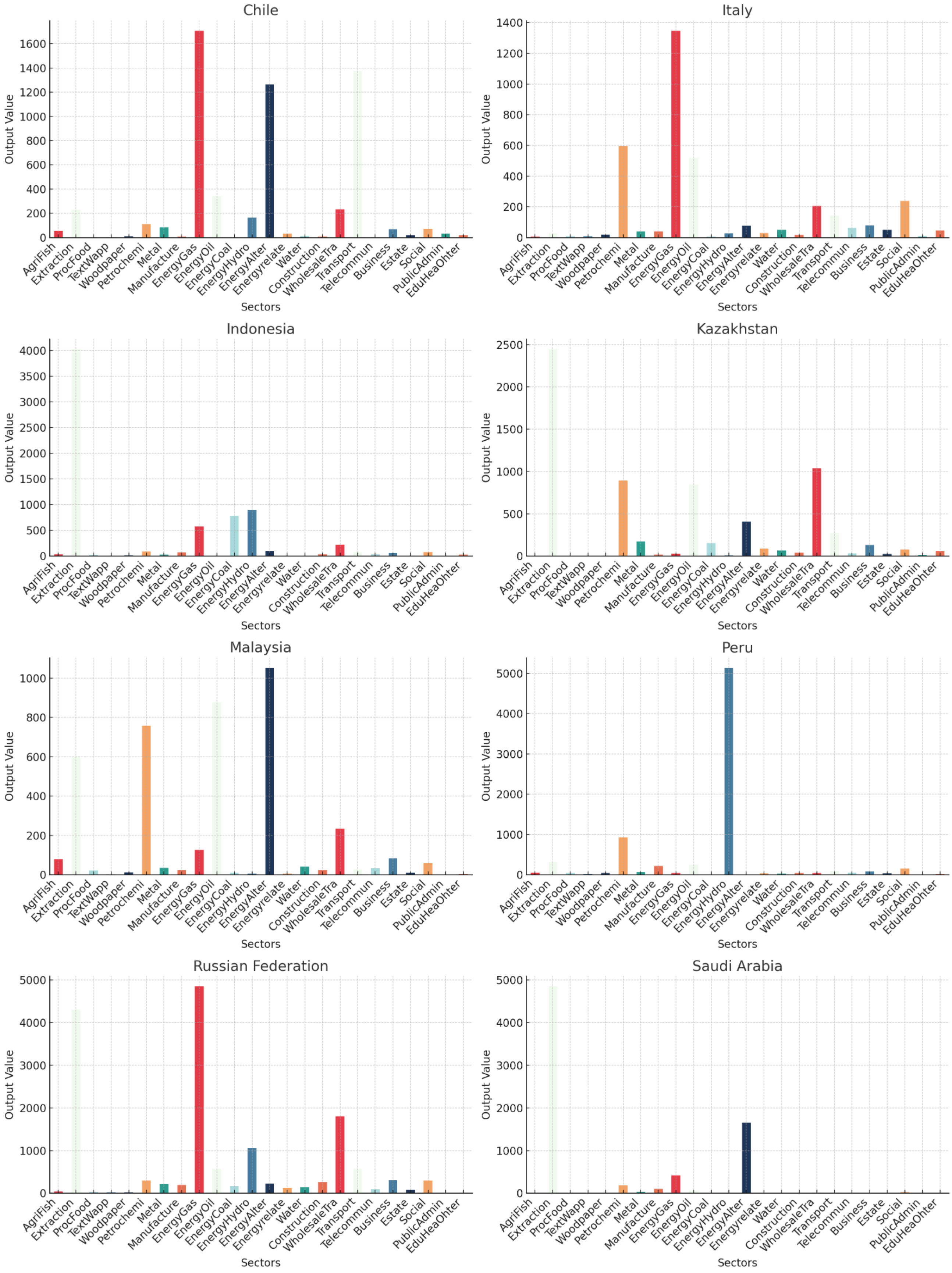
Figure 2 indicates the total output change by nation and by sector. Russia is the top contender in output augmentation, with Kazakhstan, Peru, and Indonesia trailing. While each country registers significant shifts in total output, the intensity varies. For instance, while Kazakhstan and Peru follow Russia regarding total output increase, other nations like Italy and Chile have comparatively lower output changes. While Kazakhstan's output growth surpasses Peru's, the latter receives a larger share of energy investment. A potential reason for this disparity might be attributed to the distinct energy investment landscapes: hydroelectric predominance in Peru versus Kazakhstan's fossil fuel reliance. Such differences might highlight the short-term profitability of fossil fuel assets, while investments in clean energy, such as hydroelectricity, often demand significant upfront capital. These variations emphasise the heterogeneous responses of different economies to China's BRI energy investments, influenced by factors like the nature of their industries and existing infrastructure.



(a)


Amount (millions USD)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Saudi Arabia
Russia
Peru
Malaysia
Kazakhstan
Indonesia
Italy
Chile
1 AgriFish
2 Extraction
3 ProcFood
4 TextWapp
5 Woodpaper
6 Petrochemi
7 Metal
8 Manufacture
9 EnergyGas
10 EnergyOil
11 EnergyCoal
12 EnergyHydro
13 EnergyAlter
14 Energyrelate
15 Water
16 Construction
17 WholesaleTra
18 Transport
19 Telecommun
20 Business
21 Estate
22 Social
23 PublicAdmin
24 EduHeaOhter

(b)


Chile
Italy
Indonesia
Kazakhstan
Malaysia
Peru
Russian Federation
Saudi Arabia
Output Value
Sectors
AgriFish
Extraction
ProcFood
TextWapp
Woodpaper
Petrochemi
Metal
Manufacture
EnergyGas
EnergyOil
EnergyCoal
EnergyHydro
EnergyAlter
Energyrelate
Water
Construction
WholesaleTra
Transport
Telecommun
Business
Estate
Social
PublicAdmin
EduHeaOhter

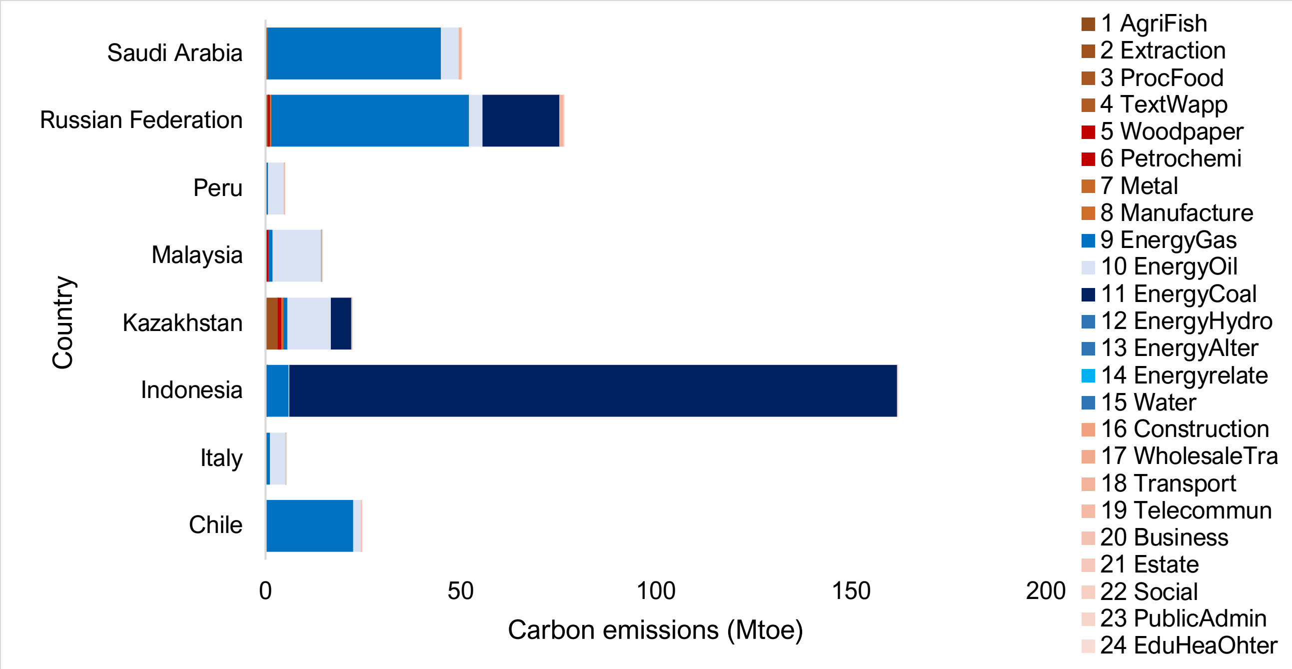
(c)

Figure 3. Impact of energy investments on value added by sectors in the eight countries along the BRI (unit: million USD). (a) Impact assessment of energy investments on value added of each sector (unit: million USD). (b) Impact assessment of energy investments on value added of all countries (unit: million USD). (c) Impact assessment of energy investments on value added of each country (unit: million USD).

As a critical measure of economic performance, value-added offers insights into the impact of energy investments. The analysis reveals the Russian Federation as the foremost beneficiary of China's energy investments, with significant value-added impacts, especially in the energy and extraction sectors. This trend is echoed in other energy-rich nations like Indonesia, Saudi Arabia, and Kazakhstan, emphasising extraction's pivotal role. Beyond the energy-focused sectors, there's an evident ripple effect in the service industry. The wholesale trade and post and telecommunications sectors emerge as significant recipients of this value-added impact across nations, hinting at an intertwined economic web. This trend may indicate an increase in service demand due to expanded output in the energy sector, implying a more widespread and integrated economic impact of China's energy investments.

3.3 Carbon emissions impact of China's energy investments in the BRI Countries

China's energy investments in BRI countries have catalysed shifts in environmental emissions, as depicted in Figure 4. Indonesia has the highest CO_2 emissions, followed by Russia and Saudi Arabia. Conversely, Italy and Peru have lower-level emissions. To further understand the sector-specific influence of China's BRI energy investments, we delve into the CO_2 emissions within the top three countries (Indonesia, Russia, and Saudi Arabia) and identify which sectors are the main contributors. In Indonesia, the EnergyCoal sector dominates CO_2 emissions, significantly surpassing the other sectors. For Russia, the EnergyGas and EnergyCoal sectors are the primary contributors. In Saudi Arabia, the EnergyGas sector leads, followed by EnergyOil. Comparing the change in CO_2 emissions associated with each type of energy investment, energy investments in the coal industry lead to a discontinuous increase in CO_2 emissions for the same inputs. On the contrary, both sectors of clean energy (EnergyAlternative and EnergyHydro) have extremely low CO_2 emissions. This divergence underlines the varying environmental implications of China's energy investments across the BRI countries.


Saudi Arabia
Russian Federation
Peru
Malaysia
Kazakhstan
Indonesia
Italy
Chile
Country
0
50
100
150
200
Carbon emissions (Mtoe)
1 AgriFish
2 Extraction
3 ProcFood
4 TextWapp
5 Woodpaper
6 Petrochemi
7 Metal
8 Manufacture
9 EnergyGas
10 EnergyOil
11 EnergyCoal
12 EnergyHydro
13 EnergyAlter
14 Energyrelate
15 Water
16 Construction
17 WholesaleTra
18 Transport
19 Telecommun
20 Business
21 Estate
22 Social
23 PublicAdmin
24 EduHeaOhter

(a)


Heatmap of CO2 Emissions by Country and Sector
Chile 0.00 0.02 0.00 0.00 0.01 0.20 0.07 0.01 22.19 1.90 0.04 0.00 0.00 0.00 0.00 0.00 0.00 0.15 0.00 0.00 0.00 0.00 0.00 0.00
Italy 0.00 0.00 0.00 0.00 0.00 0.06 0.00 0.00 1.11 3.93 0.00 0.00 0.00 0.01 0.00 0.00 0.00 0.07 0.00 0.00 0.00 0.00 0.00 0.00
Indonesia 0.00 0.28 0.00 0.00 0.00 0.06 0.02 0.01 5.61 0.05 155.74 0.00 0.00 0.02 0.00 0.00 0.00 0.10 0.00 0.00 0.00 0.00 0.00 0.00
Kazakhstan 0.00 3.10 0.00 0.00 0.00 1.01 0.47 0.01 1.05 11.07 5.22 0.00 0.00 0.00 0.04 0.00 0.07 0.13 0.00 0.00 0.00 0.00 0.00 0.00
Malaysia 0.00 0.01 0.00 0.00 0.00 0.79 0.01 0.00 0.96 12.43 0.14 0.00 0.00 0.00 0.00 0.00 0.01 0.07 0.00 0.00 0.00 0.00 0.00 0.00
Peru 0.00 0.01 0.00 0.00 0.00 0.19 0.02 0.01 0.43 4.13 0.01 0.00 0.00 0.00 0.00 0.00 0.00 0.17 0.00 0.00 0.00 0.00 0.00 0.00
Russian Federation 0.01 0.72 0.00 0.00 0.00 0.49 0.24 0.02 50.67 3.38 19.71 0.00 0.00 0.04 0.00 0.02 0.02 1.00 0.00 0.01 0.00 0.01 0.00 0.00
Saudi Arabia 0.00 0.24 0.00 0.00 0.00 0.17 0.02 0.05 44.43 4.60 0.00 0.00 0.00 0.01 0.00 0.00 0.00 0.58 0.00 0.00 0.00 0.00 0.00 0.00
Country
1 AgriFish
2 Extraction
3 ProcFood
4 TextWapp
5 Woodpaper
6 Petrochemi
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10 EnergyOil
11 EnergyCoal
12 EnergyHydro
13 EnergyAlter
14 Energyrelate
15 Water
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17 WholesaleTra
18 Transport
19 Telecommun
20 Business
21 Estate
22 Social
23 PublicAdmin
24 EduHeaOhter
Sector
140
120
100
80
60
40
20
0

(b)

Figure 4. Impact of energy investments on CO_2 emissions by sector and by country in the eight countries along the BRI (a) Impact of energy investments on CO_2 emissions by country (unit: Mtoe) (a) Impact of energy investments on CO_2 emissions by sector (unit: Mtoe)

3.4 Heterogeneity of Energy Investments

3.4.1 Economic Impact of China's Energy Investments in the BRI Countries

The differential impacts on the total output across sectors and countries corroborate the investment heterogeneity hypothesis. The energy sector, which includes oil processing, extractive industries, and metal products, has reaped the most significant benefits. This concentration of investment-induced output growth in energy-intensive sectors reflects China's strategic focus on these industries, serving as pillars of industrial development in many recipient countries, like the oil industry in Saudi Arabia (Chen, 2020). This heterogeneity underpins the differential economic and environmental impacts observed across various regions and industries, warranting a detailed analysis of optimal policy formulation.

The sectoral benefits and geographical variances in output suggest that the allocation and effects of Chinese investment are contingent on the recipient country's industrial profile and energy cooperation with China, which is similar to previous literature (Tarr et al., 2022). The notable output surge in Russia, mainly concentrated in the energy sector, indicates extensive cooperation between China and Russia. The economic benefits are unevenly distributed across sectors, with electricity, gas sectors, extractive industries, and oil processing reaping the most rewards. This pattern is partly due to initiatives like the "China-Mongolia-Russia Economic Corridor Planning Outline," which has made significant progress through stable political conditions and continued cooperation (You et al., 2022).

The results further illuminate China's strategic focus on countries rich in energy resources like Southeast Asia, the Middle East, and Central Asia. Given China's high investments in the oil and gas sectors, its influence on the industrial sectors in countries like Indonesia, Saudi Arabia, and Kazakhstan is profound. In addition to energy-related sectors, the analysis indicates a spillover effect. Chinese energy investments have amplified the value-added of tertiary industries like wholesale and retailing, post and telecommunications, and transportation. Similar to (Demir & Lee, 2022), this outcome suggests that an increase in output within the energy sector might precipitate an accelerated demand for productive services, thus driving the integrated development of manufacturing and service sectors.

Geographically, BRI investments span countries with diverse development stages and industrial competencies. Nations with well-established industrial ecosystems can potentially gain immediate economic impetus from BRI investment. Well-industrialised nations like Italy (Manello, 2017) can use these investments to enhance modernisation and efficiency further. The environmental footprint of such investment might be subdued, given the likely existence of stringent environmental regulations and a robust framework for their enforcement. However, other influencing factors should be considered cautiously.

3.4.2 Carbon Emissions Impact of China's Energy Investments in the BRI Countries

Our study finds that China's economic collaboration with BRI nations yields notable financial contributions but also amplifies carbon emissions, which is consistent with previous findings in the literature (Tian et al., 2019; Sheraz et al., 2022; Huang et al., 2020). Investments in sectors like natural gas, oil, and especially coal, drive up emissions. Moreover, the issue is compounded when investments stimulate rapid infrastructure development in countries at certain stages of economic advancement, inadvertently exacerbating CO_2 emissions (Tritto, 2021). For example, when investing in energy in Areas with weak infrastructure development, some additional infrastructure needs to be built for the smooth progress of energy investment. Countries like Saudi Arabia and Kazakhstan particularly witness this surge due to their carbon-centric economic structures. Consequently, while conventional energy investments bolster economic prosperity, they intensify environmental strains in emission-heavy sectors. However, renewable energy investments remain a promising path towards sustainable growth and reducing emissions. In summation, even though renewables might not match the immediate returns of fossil fuels, they provide enduring economic benefits and are crucial in mitigating CO_2 emissions.

The heterogeneity of energy investments is apparent in how they stimulate different economies and sectors, thus highlighting the absence of a 'one-size-fits-all' investment approach (Connolly et al., 2022). As Stiglitz (2010) argues, the impacts of economic stimuli are contingent upon a country's specific context, including its sectoral strengths, structural dynamics, and stages of economic development. Accordingly, policy implications from this study underline the importance of recognising this heterogeneity in energy investments when devising investment strategies or forecasting their economic and environmental outcomes.

3.5 Policy suggestions

Several comprehensive policy recommendations arise to address the complexities of BRI energy investments. An essential initial step involves advocating a more comprehensive assessment of investment impacts. Current decision-making models may unintentionally overemphasise short-term economic gains, thereby overlooking potentially severe, long-term environmental consequences. To rectify this unsustainable situation, there is an urgent need to establish a comprehensive impact assessment framework that encompasses the multi-dimensional effects of these investments. Such a framework should include rigorous environmental impact assessments alongside traditional financial analyses (Beaussier et al., 2019). Furthermore, the role of capacity building in recipient countries emerges as a critical determinant of the efficacy of these investments. Enhanced technical and regulatory capacities can equip these countries to manage their energy infrastructures effectively and sustainably (Manello, 2017). This could entail various initiatives, from technical assistance and knowledge transfer to local workforce training in managing and maintaining green technologies. Finally, strengthening cooperation and exchanges between China and recipient countries is crucial to these policy recommendations. Such a cooperative relationship can foster a shared understanding of the complexities and interdependencies inherent in these investment projects, thereby facilitating harmonious and sustainable outcomes (Yin, 2019). In conclusion, through the recommended policy measures, it is possible to work towards a BRI that promotes sustainable economic development without compromising environmental integrity.

4. Conclusion

This study investigates the economic and environmental repercussions of China's energy investments in eight representative BRI countries, employing an MRIO model as the methodological framework. The findings demonstrate that while China's investments enhance output growth in the energy sectors, they also contribute to increased carbon emissions. It is noteworthy that these investments stimulate growth in high value-added tertiary industries such as wholesale, retail, post and telecommunications, and transportation. However, the environmental implications associated with heightened CO_2 emissions cannot be overlooked, and the severity of these impacts fluctuates based on the type of investment and recipient BRI country's developmental stage. An examination of the environmental impact, primarily concerning carbon emissions, shows that a significant proportion of this environmental toll is attributable to heightened CO_2 emissions in the coal, oil, and gas sectors. Balancing these economic benefits with environmental implications requires informed policymaking.

However, this study seems to rely heavily on an appraisal of short-term economic gains, potentially side-lining a thorough analysis of the enduring environmental implications. Furthermore, there appears to be a lack of detailed examination of recipient countries' regulatory landscapes, industrial capacities, and stages of economic development — all pivotal factors in assessing investment impacts. Future research should offer a more comprehensive assessment of long-term environmental effects. This involves immediate impacts and enduring effects these investments might have on host countries' ecological sustainability. Comparative studies across diverse regions and sectors could further illuminate the contextual influences that contribute to impact heterogeneity. Finally, research should investigate the social implications of these investments, aligning them with broader development goals for a balanced perspective on the BRI's costs and benefits.

5. Reference

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