
Energy first, friendship forward: Research on the influencing factors of sustainable green energy trade between China and the Asian-African Belt and Road countries

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Quote as: Hu, J., Chen, S., Xie, H., & Ma, S. (2026). Energy first, friendship forward: Research on the influencing factors of sustainable green energy trade between China and the Asian-African Belt and Road countries. *Argumenta Oeconomica*, 56(2), 93-114.

DOI: [10.15611/aoe.2026.2.06](https://doi.org/10.15611/aoe.2026.2.06)

JEL: F14, Q43, F18

Abstract

Aim: The article examines the determinants of bilateral energy trade between China and 32 Asian-African Belt and Road countries from 2000 to 2020. It investigates how various economic, technological, environmental, and social factors influence energy trade cooperation in the context of

the Belt and Road Energy Cooperation Vision and Action Plan and the Belt and Road Energy Partnership. The authors explored direct effects and mediating mechanisms through bilateral political relations and urbanisation, while also analysing the way these impacts vary across different development stages, regions, and income levels.

Methodology: The study employed a gravity model of trade using panel data covering the 21-year period from 2000 to 2020. Key explanatory variables included economic scale (GDP), labour market size, carbon dioxide emissions, air transport volume, mobile cellular subscriptions, renewable energy consumption, electrification rate, medium-high-tech manufacturing value added, and the share of goods and services imports. Bilateral political relations and urbanisation were introduced as mediating variables to examine indirect effects. Robustness tests were conducted to confirm the reliability and validity of the results. The analysis also included heterogeneity analysis to examine variations across different country groupings.

Results: The findings revealed that GDP, renewable energy consumption, and import ratios significantly enhanced China's energy imports, while electrification levels had an inhibiting effect. Economic size was found to enhance bilateral political ties, whereas electrification weakened them. Renewable energy consumption constrained urbanisation, while electrification encouraged it. The heterogeneity analysis demonstrated that impacts varied significantly across development stages, regions, and income levels. GDP and trade openness consistently promoted energy trade across all country groups, but environmental and technological factors showed divergent effects between Middle Eastern and non-Middle Eastern economies, as well as between high-income and low-income countries.

Implications and recommendations: The article suggests that policymakers should leverage economic growth and trade openness as consistent drivers of energy cooperation among the 'Belt and Road' countries. Differentiated strategies are needed for countries at various development stages and income levels. For Middle Eastern and non-Middle Eastern countries, and both high-income low-income economies, tailored approaches addressing environmental and technological factors are essential. The findings highlight the importance of considering renewable energy consumption and electrification rates when designing energy cooperation policies, as these factors have complex effects on both trade volumes and mediating variables such as political relations and urbanisation. Strengthening bilateral political relations through economic engagement can facilitate energy trade cooperation.

Originality/value: This study contributes original insights by comprehensively analysing energy trade determinants within the 'Belt and Road' framework using an extensive 21-year panel dataset. It uniquely incorporates mediating variables (bilateral political relations and urbanisation) to reveal indirect mechanisms affecting energy trade. The heterogeneity analysis across development stages, geographical regions (Middle Eastern compared to non-Middle Eastern), and income levels provides nuanced understanding of how factors differentially impact various country groupings. This multi-dimensional approach offers valuable empirical evidence for understanding the complexities of China's -energy cooperation with Asian-African Belt and Road countries, filling a gap in existing literature on regional energy trade dynamics.

Keywords: energy trade, Belt and Road Initiative (BRI), influencing factors, gravity model

1. Introduction

Energy is the fundamental element supporting economic development and a vital guarantee for social progress and national security (Karpavicius et al., 2025; Ma et al., 2025). With the profound transformation of the global energy landscape, energy issues have become a key topic in international relations and economic cooperation. Since the introduction of the Belt and Road Initiative (BRI) in 2013,

China's energy cooperation with countries along the route has continuously deepened (Zhao et al., 2019). In particular, partnerships in Asia and Africa have advanced regional energy integration through collaborations in energy infrastructure construction, resource development, and clean energy utilisation. Guided by "The Belt and Road Energy Cooperation Vision and Action Plan" and the establishment of the Belt and Road Energy Partnership, China and participating countries have made significant progress in energy connectivity, clean energy development, and technological innovation, providing new pathways for global energy cooperation (Yuan et al., 2014).

The BRI not only serves as a crucial strategy for China's opening-up but also as an important platform for optimising the global energy trade pattern. By promoting cross-border cooperation in energy resources and infrastructure interconnection, the initiative has encouraged participating countries to diversify energy supplies, reduce dependence on single sources, and enhance energy security (Aslam et al., 2024). Moreover, the rational allocation and joint development of regional energy resources has improved energy use efficiency, facilitated investment in clean energy projects, and accelerated the dissemination of energy technologies. These developments have contributed to low-carbon transformation and the achievement of sustainable development goals. In addition, policy coordination and market integration under the BRI framework have enhanced trade facilitation, transparency, and competition within regional energy markets (Chen et al., 2023; Z. Yang et al., 2024).

As a key component of the BRI, the Asian-African region has played a pivotal role in global energy trade. Middle Eastern countries such as Saudi Arabia, Iran, and Iraq possess abundant oil and natural gas reserves and remain major global energy exporters. Central Asian nations, including Kazakhstan and Uzbekistan, are key in natural gas supply and pipeline construction. African countries such as Nigeria, Angola, and Algeria rely on their rich oil, gas, and mineral resources to maintain a stable presence in the global energy market. In addition to traditional energy, many Asian and African nations also possess substantial renewable energy potential, including solar, wind, and hydro power. The exploitation of these resources not only satisfies domestic demand but also contributes to the global energy transition (Mohammed et al., 2013).

Given the strategic importance of Asian-African BRI countries in global energy trade, examining the factors influencing energy trade between China and these nations carry both theoretical and practical significance. In terms of theory, such a study enriched the analytical framework for international energy trade and regional economic cooperation, offering conceptual support for building a new global energy governance framework. In practice, identifying the determinants of energy trade helped China optimise its import structure, strengthen energy security strategies, and promote clean-energy cooperation and technological exchange, thereby fostering mutual benefits and sustainable development among partner countries (Wang et al., 2024).

This study employed panel data covering China and 32 Asian-African BRI countries from 2000 to 2020. Using a gravity model of trade, it systematically analysed the main factors influencing China's energy imports from these countries. Bilateral political relations and urbanisation levels were introduced as mediating variables to explore their roles within the energy trade relationship. Through empirical testing and heterogeneity analysis, the authors aimed to reveal the varying effects of energy trade across different development stages, geographical regions, and income levels, providing empirical evidence and policy insights for deepening China's energy cooperation under the Belt and Road framework.

The research contribution of this article is as follows. First, it proposes an integrated framework that links factor endowments, policy governance, and trade relations by combining economic scale, energy structure, and openness with relational variables such as bilateral political ties and urbanisation. Second, it identifies and tests two transmission channels (political relations and urbanisation) through which economic and environmental drivers shape energy trade. Third, it adopts a phase-based identification strategy that divides 2000 to 2020 into three historically grounded subperiods, revealing time variation in the effects of core determinants. Fourth, it documents heterogeneity across regions and income groups, clarifying the distinct roles of technological and environmental factors.

2. Literature review

2.1. The Belt and Road Initiative and energy cooperation

The literature on the Belt and Road Initiative has increasingly highlighted its roles in deepening cross-border cooperation, accelerating green technology diffusion, and shaping sustainable development outcomes. Studies demonstrated that incentive-compatible collaboration frameworks fostered joint carbon-reduction efforts between Chinese firms and partner economies, while BRI arrangements have continued to sustain trade, investment, and social exchange even under pandemic conditions (Lu & Wolszczak-Derlacz, 2025). Empirical work further showed that the BRI has expanded outward green investment and advanced efficiency improvements in participating countries, with heterogeneous effects conditioned by institutional quality and environmental performance, whilst green total factor productivity also rose, albeit from a level below the global average (Li et al., 2022).

2.2. Applications of the gravity model in international trade

Parallel research using gravity-type models has refined understanding of frictions and facilitators of cross-border flows. International borders exerted declining or time-invariant effects, whereas regional agreements, infrastructure quality, and policy risk have materially shaped trade efficiency (Freeman & Lewis, 2021). Extensions to services, migration, agriculture, and knowledge cooperation confirmed the centrality of economic scale and macro risk, while revealing sector-specific sensitivities to prices, exchange rates, and institutional settings. The strength of regionalism varied with agreement design and membership composition (Arif, 2022).

2.3. Determinants of energy trade

Work on energy trade determinants has moved beyond simple scale-distance formulations by integrating demand, technology, and urban dynamics. Evidence indicated that economic growth, carbon emissions, trade openness, and urbanisation influenced renewable energy consumption with marked regional heterogeneity; participation in global value chains and improvements in energy intensity have altered the magnitude and direction of embodied energy flows (Chen, 2018). Network analyses identified GDP differentials and geography as structural drivers of the world energy trade system, and emerging evaluations of energy-data markets underlined compliance, social-environmental benefits, product development, sharing technologies, and privacy protection as foundational conditions for market building (Schneiders et al., 2022).

2.4. Conventional and renewable energy transitions

Comparative studies of conventional and renewable energy highlighted the environmental advantages of low-carbon generation, the pro-innovation signal of higher oil prices for renewable patenting in net-importing economies, and strong spillover linkages between renewable energy, global finance, and traditional energy markets (Amin et al., 2021). Evolutionary game and systems-dynamics modelling suggested that well-designed resource-sharing schemes increased governments' preference for cooperative strategies between fossil-fuel and renewable regions, while macro evidence from South America indicated that reducing fossil consumption and expanding renewables remained associated with higher per-capita growth (Yang et al., 2024).

2.5. Summary and implications

Taken together, the literature established robust theoretical and empirical grounds for examining the determinants of China's energy trade with its Asian-African BRI partners. The existing studies emphasised the role of economic scale, policy coordination, and green transition, but few

systematically combined these dimensions within a unified empirical framework. Building on this foundation, the study incorporated political relations, urbanisation, connectivity, and technology-related variables within a gravity-modelling approach to better capture the multi-dimensional factors shaping China's energy trade under the Belt and Road framework.

3. Analysis of the current status of China's energy trade with Asian-African Belt and Road countries

3.1. Definition of Asian-African Belt and Road countries

The sample countries in this study were primarily drawn from the official Belt and Road Portal of China. BRI encompassed 152 countries across six continents Asia, Africa, Europe, North America, South America, and Oceania. Among these, 92 countries were located in Asia and Africa, as listed in Table 1. These two regions are particularly rich in fossil energy resources, with reserves concentrated in Asia and Africa, especially in the Middle East, serving as a critical hub for global energy exports. Consequently, this study focused on China's energy trade with the Asian and African Belt and Road countries.

Table 1. Sample countries for energy trade between Asia and Africa

Asian Countries					
Afghanistan	Timor-Leste	Kyrgyzstan	Mongolia	Tajikistan	Syria
United Arab Emirates	Philippines	Qatar	Bangladesh	Thailand	Armenia
Oman	Georgia	Kuwait	Myanmar	Türkiye	Yemen
Azerbaijan	Kazakhstan	Lao PDR	Nepal	Turkmenistan	Iraq
Pakistan	Republic of Korea	Lebanon	Saudi Arabia	Brunei Darussalam	Iran
State of Palestine	Indonesia	Maldives	Cambodia	Uzbekistan	Singapore
Bahrain	Viet Nam	Malaysia	Sri Lanka	–	–
African Countries					
Algeria	Burkina Faso	Guinea	Lesotho	Mozambique	São Tomé and Príncipe
Egypt	Burundi	Guinea-Bissau	Liberia	Namibia	Sudan
Ethiopia	Equatorial Guinea	Ghana	Libya	South Africa	Somalia
Angola	Togo	Gabon	Rwanda	South Sudan	Tanzania
Benin	Eritrea	Zimbabwe	Madagascar	Niger	Tunisia
Botswana	Cabo Verde	Cameroon	Malawi	Nigeria	Uganda
The Gambia	Comoros	Mali	Sierra Leone	Zambia	Djibouti
Republic of the Congo	Côte d'Ivoire	Mauritania	Senegal	Chad	Central African Republic
Democratic Republic of the Congo	Kenya	Morocco	Seychelles	–	–

Source: authors' own statistics.

After excluding countries with missing data, zero trade volume, and/or negligible energy trade, a total of 32 Asian-African countries were selected as representative samples. The Asian countries included Bahrain, Brunei, Indonesia, Iran, Iraq, Kazakhstan, the Republic of Korea, Kuwait, Kyrgyzstan, Malaysia, Mongolia, Oman, the Philippines, Qatar, Saudi Arabia, Singapore, Viet Nam, Thailand, the United Arab Emirates, Türkiye, Uzbekistan, and Yemen. The African countries included Algeria, Angola, Chad, the Republic of the Congo, Equatorial Guinea, Gabon, Libya, Nigeria, South Africa, and Egypt.

To further demonstrate the representativeness of these selected countries, Table 2 shows the proportion of China's total energy imports sourced from these 32 countries between 2000 and 2020. In 2000, imports from these Asian-African BRI countries accounted for 99.43 per cent of China's total import volume and 99.48 per cent of total import value. Although the diversification of energy import sources increased with the advancement of the Belt and Road Initiative, Asian and African countries still collectively accounted for more than 90 per cent of China's total energy imports. Therefore, the selected sample was considered to be highly representative of China's overall energy import structure.

Table 2. China's energy imports from 32 countries along the Asia Africa Belt and Road, including import volume, import value, and proportion

Year	Import volume			Import value		
	Total import volume	Sample import volume	Proportion	Total import value	Sample import value	Proportion
2000	94919447.63	94373742.8	99.43%	18668843.9	18572215.25	99.48%
2001	79588187.69	79005965.63	99.27%	14670054.59	14572790.51	99.34%
2002	73419770.4	72963813.37	99.38%	13336074.39	13262204.36	99.45%
2003	103714441.4	103254348.6	99.56%	20558348.72	20443328.84	99.44%
2004	127909578.7	127515227.7	99.69%	33342946.88	33235270.4	99.68%
2005	140002883.1	139718251.6	99.80%	45750765.68	45657533.39	99.80%
2006	160680176.3	159663563.4	99.37%	61986047.3	61571509.05	99.33%
2007	201434849.5	200553542.3	99.56%	74684026.47	74302824.96	99.49%
2008	206907649.2	204762636	98.96%	117746682.1	116611026.8	99.04%
2009	259499062.8	258091427.9	99.46%	84998706.47	84429978.47	99.33%
2010	403162423.8	337254558.7	98.82%	124534626.1	122921258.6	98.70%
2011	555986520.8	390963850.5	96.97%	183660558.2	178393922.6	97.13%
2012	442665028.4	419324816.9	94.73%	208778697.8	197066377.1	94.39%
2013	468648819.2	443823217.2	94.70%	215531961.8	202339030.1	93.88%
2014	449693859.2	414300960.8	92.13%	217373079.9	198905207.8	91.50%
2015	431394438.8	389557044.7	90.30%	132310505.3	116278907	87.88%
2016	443114871.7	401870286.9	90.69%	107494326.6	96805060.59	90.06%
2017	518840998.5	481024656.5	92.71%	144255852.7	131972525.1	91.49%
2018	552167965.5	521346030.9	94.42%	191603352	178987119.6	93.42%
2019	644428431.9	594827862.7	92.30%	202330073	185944255.1	91.90%
2020	649891867.9	592519974.7	91.17%	147951439.9	135579437.1	91.64%

Source: results were analysed by using Stata software.

3.2. Classification of energy products

Fossil energy products were generally classified into three categories of coal, petroleum, and natural gas together with their related derivatives. This study drew on energy trade data from CEPII's HADI database, which was based on the HS-92 system. At the HS six-digit level, products under Chapter 27 were selected, covering traditional fossil energy commodities, including coal, crude oil, natural gas, and associated derivatives, with HS codes ranging from 270111 to 271600 (Pérez-Hernández et al., 2025). In total, 39 product types were included and their classification adopted by the authors is presented in Table 3.

Table 3. Energy product classification and HS-6 code

Classification	HS-6 code
Coal products	270111、270112、270119、270120、270210、270220、270300、270400、270500
Petroleum products	270710、270720、270730、270740、270750、270760、270791、270799、270810、270820
Natural gas products	270900、271000、271111、271112、271113、271114、271119、271121、271129
Other related derivatives	271210、271220、271290、271311、271312、271320、271390、271410、271490、271500、271600

Source: authors' own statistics.

4. Empirical analysis

4.1. Research design

4.1.1. Variable selection

This section focused on the variables used in the regression analysis and examined, from a theoretical and practical perspective, how they affected energy trade. The analysis incorporated traditional determinants of bilateral trade such as economic scale while extending to environmental conditions, infrastructure, and national development, thereby providing a more comprehensive assessment of China's energy import determinants.

(1) Dependent variable

The authors investigated the determinants of China's energy trade. Bilateral trade value, a core indicator of the scale and intensity of trade, reflects the aggregate value of goods or services exchanged between countries. As the foundation of economic activity and technological progress, energy has been central to national development and an informative proxy for the closeness of bilateral economic relations. Accordingly, the dependent variable was the bilateral energy trade value between China and the Asian-African Belt and Road countries (*AAETV*) (Zhao & Wu, 2007).

(2) Explanatory variables

Economic scale (*GDP*). GDP served as a key indicator of market size and purchasing power. Higher GDP typically implies stronger economic capacity and larger energy demand; exporters with higher GDP generally recorded larger energy export values (Szustak et al., 2021).

Labour market size (*P*). Population size captures both labour supply and consumption potential. More populous countries tend to possess larger domestic markets which attract imports to satisfy demand and, in many cases support greater export capacity through labour-intensive production (Bloom & Freeman, 1986).

Carbon dioxide emissions (*CO₂*) are increasingly recognised as a trade determinant, reflecting environmental constraints and policy responses to pollution-intensive goods. Rising global commitments to low-carbon development have heightened the salience of this factor for fossil-fuel trade (Lin & Zhao, 2024).

Air transport volume and global departures (*AIR*). This indicator proxies international logistics capacity and trade connectivity. Expanded air transport strengthens cross-border market linkages and improves the timeliness and efficiency of trade flows.

Mobile cellular subscriptions (*MIO*). The diffusion of mobile communications reduces information frictions, facilitates e-commerce, and enhances market access, thereby supporting trade growth in a rapidly digitalising global economy.

Renewable energy consumption (*RE*). The greater reliance on renewables signals efforts to mitigate climate change and could reshape energy trade structures by reducing dependence on fossil fuels and lowering geopolitical risks, thus influencing market stability (Hoffart et al., 2022; Hu et al., 2025).

Electrification rate (*EG*). Higher electrification denotes a broader and more reliable power infrastructure, underpinning industrial production and export capacity. Improvements in electricity access support continuous operations and productivity, thereby affecting trade performance (Zhang et al., 2023).

Medium and high-tech manufacturing value added (*MH*). This variable reflects industrial upgrading and technological capability in sectors such as machinery, electronics, and biopharmaceuticals. As economies shift towards knowledge and technology-intensive activities, MH shapes trade patterns, product sophistication, and competitiveness.

Imports of goods and services as a share of GDP (*HF*). This ratio captures participation in global markets and the domestic economy's dependence on foreign goods and services. While higher import shares diversify domestic consumption, they also increase exposure to external shocks; the measure remains informative for trade structure and policy evaluation.

(3) Mediating variables

Bilateral political relations (*BIO*). Political relations function as a key mediator of trade flows and composition, particularly for strategic commodities such as oil and gas. The short-run non-substitutability and scarcity of fossil fuels constrain the policy autonomy of importers and elevate exporters' leverage in bilateral relations. Growing global demand and finite resources incentivise cooperation to secure stable, reliable supplies (Tang et al., 2024).

Urbanisation (*URB*). Urbanisation accompanies economic development, industrial upgrading, and shifts in consumption structure. Population agglomeration expands domestic demand and often increases imports of goods and services. As urbanisation deepens, the focus of activity moves towards medium and high-end manufacturing and services, increasing the demand for energy and advanced equipment, and stimulating exports of service and technology-oriented products.

4.1.2. Variable source

For the study of the determinants of China's energy trade with Asian-African Belt and Road partners, the empirical analysis drew on two principal sources: (i) China's total trade in energy commodities with Asian-African BRI economies and (ii) country-level macro indicators capturing multiple dimensions that had affected bilateral energy trade. The dependent variable was the value of China's imports of energy commodities from 32 Asian-African BRI partner countries over 2000-2020. The raw data were obtained from the CEPII-BACI database at the HS six-digit level. Products under Chapter 27 were identified as energy commodities, and, for each sample country, annual totals of exports to China were aggregated across all relevant HS codes to construct the import value series. Explanatory and mediating variables were compiled from the World Bank's datasets, covering domains such as urban development, infrastructure, climate change, environment, energy and minerals, and economy and growth. Table 4 presents the variable definitions and corresponding data sources.

Table 4. Data source

Variable	Variable description	Data source
<i>AAETV</i>	Energy trade value between China and Asian-African BRI	CEPII-BACI database
<i>GDP</i>	Exporter GDP	World Bank national accounts data
<i>P</i>	Exporter total population	United Nations Statistics Division
<i>CO₂</i>	Carbon dioxide emissions	Carbon Dioxide Information Analysis Center (CDIAC), Environmental Sciences Division, Oak Ridge National Laboratory
<i>AIR</i>	Air transport volume and global departures	International civil aviation statistical databases
<i>MIO</i>	Mobile cellular subscriptions	International Telecommunication Union (ITU), World Telecommunication/ICT Indicators database and reports
<i>RE</i>	Renewable energy consumption	International Energy Agency (IEA)
<i>EG</i>	Electrification rate	Global Electrification Database
<i>MH</i>	Medium and high-tech manufacturing value added	Competitive Industrial Performance (CIP) database
<i>HF</i>	Imports of goods and services (percent of GDP)	World Bank national accounts data
<i>BIO</i>	Bilateral political relations	Harvard Dataverse
<i>URB</i>	Urbanisation	United Nations, World Urbanisation Prospects

Source: authors' own statistics.

4.1.3. Construction of trade gravity model

The gravity model of trade was originally developed to predict bilateral trade flows and inspired by the logic of Newton's law of universal gravitation. Its core proposition suggested that countries with larger economic size and closer geographic proximity tended to trade more intensively. Owing to its conceptual simplicity, data availability, and econometric versatility, the gravity framework was extensively extended beyond traditional variables such as GDP to include a wide range of factors that could influence trade flows. Building on this, the study integrated multiple dimensions relevant to energy trade and specified the following log-linear gravity equation. Equation (1) was defined as follows:

$$\ln A A E T V_{f,t} = \mu_0 + \mu_1 \ln G D P_{f,t} + \mu_2 \ln P_{f,t} + \mu_3 \ln C O_{2f,t} + \mu_4 \ln A I R_{f,t} + \mu_5 \ln M I O_{f,t} + \dots + \mu_6 R E_{f,t} + \mu_7 E G_{f,t} + \mu_8 M H_{f,t} + \mu_9 H F_{f,t} + \eta_f + \lambda_t + \varepsilon_{f,t}. \quad (1)$$

In this equation (1), μ_0 was the constant term. The subscripts f represented the energy-exporting country, while t denoted the trade year. H_f referred to the country-specific fixed effects, λ_t represented the time fixed effects, and $\varepsilon_{c,f,t}$ was the error term. The dependent variable $A A E T V_{f,t}$ denoted the total value of China's energy imports from country f in year t . All the remaining variables following their respective coefficients represented explanatory factors associated with energy exports from the partner country or China's energy imports.

4.2. Empirical result analysis

4.2.1. Descriptive statistics

To obtain an overall understanding of the distributional characteristics of the sample data, the authors first conducted a descriptive statistical analysis of all the variables in the initial section of the empirical analysis. Table 5 shows the descriptive statistics for each variable. For the dependent variable – China's total imports of energy commodities – there were significant differences in export values across countries and years. The data for GDP, represents economic development. The descriptive results for AIR, indicating air transport volume and global departures, showed substantial variation in aviation capacity among countries. The remaining influencing factors exhibited relatively dispersed data distributions.

Table 5. Descriptive statistics of variables

Variable	Unit	N	Mean	Standard deviation	Min	Max
<i>AAETV</i>	Thousand US dollars	672	3316467.893	5798514.000	17.712	39000000.000
<i>GDP</i>	Ten million dollars	672	20584.500	27756.190	104.600	172000.000
<i>P</i>	Ten thousand people	672	3977.900	5277.410	33.393	27185.800
<i>CO₂</i>	Per capita metric ton	672	8.128	8.921	0.060	47.657
<i>AIR</i>	Million tonne-kilometres	672	106472.100	150322.500	560.000	959307.400
<i>MIO</i>	Per hundred people	672	81.332	53.835	0.024	221.309
<i>RE</i>	Percentage of final energy consumption	672	18.260	26.866	0	90.120
<i>EG</i>	Population percentage	672	63.169	39.642	0	100
<i>HF</i>	%	672	45.811	28.350	13.723	208.333
<i>MH</i>	Percentage of Value Added in Manufacturing Industry	672	23.280	18.685	1.261	83.727
<i>BIO</i>	\	672	0.413	0.348	0.003	1.716
<i>URB</i>	%	672	64.457	20.689	21.637	100

Source: results were analysed by using Stata software.

4.2.2. Benchmark regression

First, the bilateral energy trade panel data between China and 32 Asian and African Belt and Road partner countries from 2000 to 2020 were incorporated into regression Equation (1). The estimations were conducted using three different approaches: Pooled Ordinary Least Squares (OLS), Fixed Effects (FE), and Random Effects (RE) models. The estimation results are presented in Table 6. Columns (1) to (3) of Table 4-3 show the regression outcomes for traditional trade determinants affecting China's energy import flows, while columns (4) to (6) include several new trade-related dimensions to further verify the impact of multiple influencing factors on China's energy trade flows.

The estimation results from columns (1) and (4) of Table 6, derived from the ordinary least squares (OLS) regressions, provided preliminary evidence of the significant impact of key factors such as GDP on China's energy import flows. However, the OLS estimation did not adequately account for country-specific characteristics or time trends, which could lead to biased or imprecise estimates. To enhance the accuracy of the analysis, the study employed panel data estimation techniques and first conducted a Hausman test. The test results indicated a chi-square statistic of $\chi^2(9) = 142.71$ with 9 degrees of freedom and a p-value of 0.000, suggesting that the fixed effects model was the appropriate estimation method. Accordingly, subsequent empirical discussions in this study were based on the fixed effects model results.

Table 6. Benchmark regression results

Variables	lnAAETV					
	(1) OLS	(2) FE	(3) RE	(4) OLS	(5) FE	(6) RE
lnGDP	0.101*** (0.032)	0.772* (0.433)	1.244*** (0.077)	0.086*** (0.032)	1.520*** (0.417)	0.742*** (0.106)
lnP	0.102 (0.063)	0.248 (0.773)	0.367* (0.213)	0.494*** (0.115)	-0.245 (0.913)	0.463* (0.252)
lnCO ₂	—	—	—	0.681*** (0.155)	0.018 (0.590)	0.671*** (0.245)
lnAIR	—	—	—	-0.458*** (0.116)	0.053 (0.178)	0.147* (0.078)
lnMIO	—	—	—	0.572*** (0.068)	0.005 (0.155)	0.360*** (0.048)
RE	—	—	—	0.401 (0.524)	6.859*** (2.055)	4.614*** (1.032)
EG	—	—	—	-1.457*** (0.244)	-3.506* (1.829)	-1.307* (0.719)
MH	—	—	—	3.522*** (0.837)	-0.513 (1.290)	0.846 (0.773)
HF	—	—	—	0.358 (0.412)	1.349* (0.690)	0.769* (0.419)
Constant	14.399 (2.006)	-5.217 (12.594)	31.708*** (7.688)	4.162* (2.283)	-11.245 (14.760)	15.563* (8.391)
National FE	—	YES	YES	—	YES	YES
Time FE	—	YES	YES	—	YES	YES
N	672	672	672	672	672	672
R ²	0.025	0.037	0.027	0.238	0.122	0.073

Note: Clustered robust standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. as shown in the table. The following tables are the same.

Source: results were analysed by using Stata software.

The baseline regression results revealed that lnGDP and RE were positively signed and statistically significant at the 1 per cent level, while EG was negatively signed and HF was positively signed, both

significant at the 10 per cent level. The positive and significant coefficient of $\ln GDP$ suggest that countries with higher GDP typically possessed larger economic scales. Such countries tended to have stronger industrial foundations, enabling them to produce and export more energy products. Moreover, as holders of substantial energy resources, these economies often wielded greater influence in the global market, thereby providing China with a stable and long-term foundation for energy trade and cooperation.

A higher share of renewable energy consumption in exporting countries also corresponded to greater energy exports to China. In the context of the global energy transition, even traditional energy exporters were compelled to consider long-term energy security and sustainable development. By promoting renewable energy, fossil fuel exporters could not only lay the groundwork for their domestic energy transition but also maintain competitiveness in the evolving global energy market. For resource-rich fossil fuel exporters, energy exports remained a crucial means of earning foreign exchange and driving economic growth. However, the simultaneous expansion of renewable energy reduced dependence on fossil fuels, strengthened energy security, and stimulated domestic clean energy industries.

For energy-exporting countries, a low electrification rate typically reflected deficiencies in energy infrastructure and investment, which constrained domestic energy consumption and distribution. Consequently, these nations were more inclined to export energy resources to high-demand and well-developed markets such as China. China's trade relationships with low-electrification countries not only met its growing domestic energy needs but also embodied its commitment to supporting global sustainable development and poverty reduction. Through such energy trade partnerships, China had the opportunity to assist these countries in improving energy infrastructure and fostering economic growth, thereby strengthening bilateral ties and reinforcing its international image as a responsible major power.

In addition, energy-exporting countries with a high ratio of goods and services imports to GDP tended to exhibit robust external trade, reflecting strong market demand and mature logistics networks. Such favourable trade environments provided China with a stable and diversified energy supply, crucial for meeting its rising consumption needs. For these exporting countries, energy trade was closely interconnected with other goods and services exchanges, jointly driving economic growth. As one of the world's largest energy consumers, China's energy import strategy aimed to optimise the global energy supply chain, ensuring both stability and diversity of supply. This approach not only underscored China's determination to safeguard domestic energy security but also highlighted its active role in global trade and economic cooperation, further promoting the integration and development of international energy markets.

4.2.3. Robustness test

To further verify the accuracy and reliability of the baseline regression results, the study employed multiple robustness tests, which included the use of alternative estimation methods, clustered robust standard errors, adjustments to the sample time span, sample size modification, and data winsorisation. Collectively, these five robustness approaches provided a comprehensive assessment of the stability of the empirical findings. The detailed results of these robustness tests are presented in the following section.

Considering that trade data often contained a large number of zero observations, the use of conventional panel estimation methods might have led to biased estimates. Therefore, the authors applied the Poisson Pseudo Maximum Likelihood (PPML) method to address the issue of zero-valued trade flows. This approach allowed the consistent estimation even under heteroskedasticity. In addition, the standard errors of the regression coefficients were clustered at country level to correct for potential intra-group correlations. The re-estimation results are reported in Appendix Table A1. Column (1) shows the estimation results based on the panel PPMLHDFE model. The coefficients and

significance levels of the key influencing factors, such as $\ln GDP$ and RE, remained largely consistent with the baseline regression results. Similarly, columns (2) and (4), which incorporated clustered robust standard errors, showed that both the sign and significance of the main explanatory variables remained stable. These results collectively confirmed the robustness and reliability of the empirical findings.

Since 2019, the COVID-19 pandemic has rapidly spread across the globe, exerting an unprecedented impact on the economic and social activities of countries worldwide. Production and development were severely disrupted, and international communication and cooperation faced significant challenges. The international trade sector, in particular, suffered substantial setbacks due to the pandemic's far-reaching effects. Given the profound influence of the COVID-19 pandemic on global economic activities during 2019–2020, the authors adjusted the sample period by excluding data from these two years to obtain a more accurate reflection of long-term trends and influencing factors. By removing data from this exceptional period and re-estimating the regression models, the study aimed to eliminate the abnormal effects induced by the pandemic, thereby ensuring the robustness and reliability of the empirical results. The robustness test results presented in Appendix Table A2 indicated that the signs and significance levels of the key influencing variables remained largely unchanged. This consistency demonstrated that the primary conclusions of the study were stable and reliable, successfully passing the robustness verification.

In Asia and Africa, particularly in the Middle East, countries rich in oil and natural gas resources have often become focal points of energy disputes and conflicts. These disputes frequently escalated into prolonged wars, severely undermining the socioeconomic stability of the affected nations. To ensure the accuracy and reliability of the analysis, the authors excluded data from five countries that had long been affected by warfare, namely Iran, Iraq, Yemen, Libya, and Nigeria. Furthermore, to mitigate the influence of extreme values and enhance the robustness of the regression analysis, all the variables were subjected to a 1% two-sided winsorisation. This procedure effectively eliminated potential outliers that might have distorted the estimation results. The robustness test results presented in Appendix Table A3 confirmed that the exclusion of war-affected countries and the winsorisation treatment did not materially alter the main conclusions, thereby further validating the reliability and robustness of the study's findings.

5. Further analysis

5.1. Mechanism analysis

The empirical results in the previous section indicated that economic scale, renewable energy consumption, electricity access, and imports of goods and services had significant impacts on China's total energy imports. This naturally raised the question: through what mechanisms do these factors influence China's energy trade?

The results of the mediation effect tests are presented in Table 7. Column (1) reported the baseline regression results without mediating variables, Columns (2) and (4) incorporated the two mediators, and Columns (3) and (5) showed the empirical outcomes of the transmission mechanisms. The mediation test results revealed that, in Column (3), where bilateral political relations were included, economic scale had a significant positive effect on bilateral political relations, while electricity access exerted a significant negative effect. A larger economic scale enhanced the political ties between energy-exporting countries and China, thereby promoting the growth of China's total energy imports. Since countries with larger economies generally possessed greater political and economic influence on the global stage, this enabled them to occupy a more advantageous position in bilateral negotiations and to foster a more favourable environment for energy trade. In contrast, higher electricity access in energy-exporting countries tended to weaken bilateral political relations with China, as it often implied

reduced dependence on external energy markets. Consequently, these countries might focus more on developing their domestic energy markets and improving internal energy utilisation, thus decreasing energy exports particularly to large importers such as China.

Table 7. Mechanism path analysis

Variable	(1) <i>lnAAETV</i>	(2) <i>lnAAETV</i>	(3) <i>BIO</i>	(4) <i>lnAAETV</i>	(5) <i>URB</i>
<i>BIO</i>	–	0.414** (0.183)	–	–	–
<i>URB</i>	–	–	–	3.131*** (0.887)	–
<i>lnGDP</i>	1.520*** (0.417)	–	0.157** (0.062)	–	0.005 (0.004)
<i>RE</i>	6.859*** (2.055)	–	-0.234 (0.409)	–	-0.156*** (0.026)
<i>EG</i>	-3.506* (1.829)	–	-0.737** (0.315)	–	0.134*** (0.022)
<i>HF</i>	1.349* (0.690)	–	-0.080 (0.137)	–	-0.013 (0.010)
Constant	-11.245 (14.760)	-28.308*** (4.896)	-4.938* (2.470)	5.481** (2.252)	-0.448*** (0.116)
Other variables	YES	YES	YES	YES	YES
National FE	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES
N	672	672	672	672	672
<i>R</i> ²	0.122	0.010	0.089	0.197	0.044

Source: results were analysed by using Stata software.

As shown in Column (5), which included urbanisation level as a mediator, renewable energy consumption had a significant negative effect on urbanisation, whereas electricity access had a significant positive effect. A higher share of renewable energy consumption in exporting countries tended to constrain domestic urbanisation progress, thereby indirectly dampening China's energy import growth. Greater renewable energy consumption reflected an ongoing transition towards sustainable energy structures, reducing reliance on fossil fuels and subsequently lowering fossil energy exports, including those to China. Conversely, higher levels of electrification typically indicated a more reliable and extensive power supply an essential condition for urbanisation. Stable electricity provision supported residential life, commercial activities, and industrial production, all of which were crucial for urban development. Therefore, a higher degree of electrification promoted the exporting country's urbanisation and increased domestic energy demand and consumption. Moreover, improved electricity access facilitated industrialisation and economic expansion, both of which required substantial fossil energy inputs, particularly in energy-intensive sectors. This industrial and economic growth in exporting countries created additional export opportunities, including energy exports to China, to support ongoing production and development.

5.2. Heterogeneity analysis

From a macroeconomic perspective, examining the determinants of China's energy imports from Asian and African BRI countries was of significant importance. However, given the diversity in development stages, regional characteristics, and income levels, the effects of these countries or regions on China's energy imports may vary considerably. Therefore, to gain a deeper understanding of these heterogeneous effects and to inform effective energy import strategies, the authors further considered the variations across countries in terms of economic development stages, geographical regions, and income levels. Differences in development stages can influence national energy policies

and demand structures, while regional geopolitical, economic, and resource conditions may shape trade patterns, and income levels can determine a country's energy consumption structure and import capacity. By exploring these heterogeneities, this study aimed to reveal more accurately the dynamics and patterns of China's energy imports under different conditions, thereby providing a sound empirical basis for policy formulation.

(1) Different development stages

China's economy passed through three stages: WTO accession (2000-2007), the global financial crisis (2008-2013), and the 'new normal' (2014-2020), hence the 2000-2020 period was partitioned accordingly in Table 8. This allowed a nuanced assessment of how these junctures shaped the heterogeneity of China's energy import determinants.

Table 8. Different stages of development

Variables	lnAAETV		
	(1) 2000-2007	(2) 2008-2013	(3) 2014-2020
lnGDP	1.056** (0.496)	1.758*** (0.566)	0.758* (0.377)
lnP	-5.222*** (1.794)	1.408 (1.809)	3.377 (2.754)
lnCO ₂	-1.273* (0.719)	-0.899 (1.166)	0.878** (0.354)
lnAIR	-0.018 (0.349)	0.055 (0.094)	-0.184 (0.145)
lnMIO	0.011 (0.121)	-1.021 (0.606)	-0.004 (0.442)
RE	-0.114 (2.143)	2.144 (2.350)	4.501* (2.369)
EG	-3.991 (3.483)	-1.642 (1.794)	-0.842 (2.306)
MH	0.800 (1.862)	-0.495 (1.226)	0.630 (0.894)
HF	1.361** (0.636)	1.560* (0.783)	0.558 (0.649)
Constant	81.818** (30.132)	-37.433 (27.615)	-56.588 (49.176)
National FE	YES	YES	YES
Time FE	YES	YES	YES
N	256	192	224
R ²	0.080	0.115	0.060

Source: results were analysed by using Stata software.

In 2000-2007, WTO entry deepened integration and lifted energy demand. lnGDP was significantly positive, indicating larger exporters supplied more stably; lnP was significantly negative, consistent with populous exporters prioritising domestic use. lnCO₂ was significantly negative, reflecting ongoing reliance on high-emission producers, while HF was significantly positive, suggesting that more open, logistics-ready economies facilitated China's imports.

In 2008-2013, amid the crisis, large-scale economies became stable suppliers as China's demand stayed robust. Population and CO₂ effects were insignificant, implying demand rather than demographics drove imports, while short-term energy security took precedence over environmental concerns.

In 2014-2020, under the ‘new normal’, growth slowed and structure upgraded; the influence of $\ln GDP$ weakened. China increasingly favoured partners with stronger renewable development. $\ln CO_2$ was significantly positive, indicating higher-emission exporters had larger energy scales, and RE was also significantly positive, consistent with continued cost advantages and reliable supply from exporters integrating renewables.

(2) Different geographical regions

The Middle East holds a pivotal role in global energy due to its abundant oil and gas, shaping China’s import structure. To assess regional heterogeneity, the 32 countries were split into Middle Eastern and non-Middle Eastern groups in Table 9. For non-Middle Eastern countries, $\ln GDP$ had a larger, significantly positive effect on China’s energy imports, consistent with China’s diversification strategy to reduce dependence on the Middle East. $\ln AIR$ was significantly negative, indicating capacity limits and higher costs of air transport eroded price competitiveness and constrained exports to China. For Middle Eastern countries, higher CO_2 emissions had a significant negative effect, reflecting China’s growing low-carbon preference aligned with domestic and international climate commitments. In this subsample, $\ln AIR$ was significantly positive: despite higher costs, high-value fossil fuels still yielded substantial profits for exporters. A higher renewable energy share significantly reduced China’s imports from the Middle East (but was not significant outside the region), as rising domestic renewables substituted local fossil use and curtailed exportable volumes. While Middle Eastern renewables expanded supported by solar and wind potential, this transition most likely reduced fossil exports to China in the short run.

Table 9. Different geographical regions

Variables	$\ln AAETV$		
	(1) All	(2) Middle East region	(3) non-Middle East region
$\ln GDP$	1.520*** (0.417)	1.582*** (0.422)	1.838*** (0.531)
$\ln P$	-0.245 (0.913)	-1.574 (1.358)	-1.222 (1.775)
$\ln CO_2$	0.018 (0.590)	-1.004** (0.380)	-0.960 (0.621)
$\ln AIR$	0.053 (0.178)	0.552** (0.218)	-0.332* (0.152)
$\ln MIO$	0.005 (0.155)	0.211 (0.191)	-0.084 (0.168)
RE	6.859*** (2.055)	-43.032** (15.157)	3.664 (2.369)
EG	-3.506* (1.829)	-2.914 (1.753)	0.183 (2.486)
MH	-0.513 (1.290)	1.455 (1.539)	-3.594 (2.273)
HF	1.349* (0.690)	1.857* (1.039)	1.644* (0.794)
Constant	-11.245 (14.760)	7.492 (17.631)	2.064 (33.342)
National FE	YES	YES	YES
Time FE	YES	YES	YES
N	672	273	399
R^2	0.122	0.297	0.199

Source: results were analysed by using Stata software.

(3) Different income levels

A country's income level reflected its development stage and shaped energy trade roles. High-income economies, with advanced industrialisation and efficient use, tended to diversify consumption and deprioritise energy exports in favour of efficiency and sustainability. Low-income economies relied more on exporting energy and other primary commodities to finance growth, revealing stronger export incentives. Heterogeneity results for high and low-income groups are shown in Table 10.

The impact of economic scale ($\ln GDP$) on China's energy imports was larger for low-income exporters, consistent with their export-oriented structures and dependence on resource sales for foreign exchange, despite smaller current GDP and limited domestic markets. For air transport (including global departures), the effects were significant for low-income exporters only, indicating that aviation expansion was closely linked to broader trade activity, including energy exports. Regarding renewable energy consumption (RE), the effects were weaker for high-income exporters and stronger for low-income exporters. Advanced transitions in high-income economies reduced reliance on fossil-fuel exports, whereas low-income economies remained dependent on primary commodity exports. Finally, medium and high-tech manufacturing value added (MH) was positively associated with China's imports from high-income exporters but negatively associated for low-income exporters, reflecting, stronger industrial demand and export capacity in the former and structural constraints and weaker competitiveness in the latter.

Table 10. Different income levels

Variables	$\ln AAETV$		
	(1) All	(2) High-income countries	(3) Low-income countries
$\ln GDP$	1.520*** (0.417)	0.772** (0.372)	1.969*** (0.306)
$\ln P$	-0.245 (0.913)	-0.305 (0.667)	-2.128 (1.357)
$\ln CO_2$	0.018 (0.590)	-0.313 (0.487)	-0.034 (0.338)
$\ln AIR$	0.053 (0.178)	-0.041 (0.117)	0.200* (0.110)
$\ln MIO$	0.005 (0.155)	0.124 (0.102)	-0.179 (0.114)
RE	6.859*** (2.055)	3.635** (1.668)	8.763*** (1.605)
EG	-3.506* (1.829)	-4.639*** (1.379)	-3.028* (1.721)
MH	-0.513 (1.290)	1.974** (0.986)	-4.775*** (1.689)
HF	1.349* (0.690)	0.852 (0.766)	1.099* (0.583)
Constant	-11.245 (14.760)	6.750 (9.594)	9.959 (25.633)
National FE	YES	YES	YES
Time FE	YES	YES	YES
N	672	399	273
R^2	0.122	0.095	0.293

Source: results were analysed by using Stata software.

6. Research conclusions and policy implications

6.1. Research conclusions

This study systematically analysed the determinants of China's energy trade with 32 Asian and African BRI partners between 2000 and 2020, utilising a gravity model across economic, technological, and environmental dimensions. The core findings revealed that China's energy import patterns were shaped by complex and highly context-dependent interactions. GDP, the share of renewable energy consumption, and the proportion of goods and services imports were found to be robust promoters of energy trade. Crucially, the electrification rate exhibited a significant inhibiting effect, suggesting a potential 'electrification paradox' where increased domestic power access in partner countries may diminish their fossil fuel export focus. Furthermore, mediation analysis indicated that while economic scale strengthened political relations, the electrification level weakened them, and the impact of renewable energy on urbanisation was negative. The study confirmed significant heterogeneity across different contexts: CO₂ emissions shifted from being an inhibitor to a promoter of imports after 2014, reflecting changing supply priorities. Geographically, air transport volume promoted trade in the Middle East but hindered it in non-Middle Eastern regions. Finally, the value added of medium/high-tech manufacturing promoted trade with high-income partners but constrained it with low-income partners, suggesting that technological capacity in low-income states may lead to a shift away from reliance on energy exports. These conclusions collectively underline that a one-size-fits-all approach is inadequate for understanding this trade dynamic, which is dictated by the specific economic, technological, and environmental structure of each BRI partner.

6.2. Policy implications

(1) Enhance economic investment and cooperation

China should prioritise investment in potential BRI energy markets, specifically increasing financial commitment to developing partners' energy infrastructure and industries. This strategy aims to boost their energy supply capacity and simultaneously generate new trade opportunities. Furthermore, deepening regional economic cooperation through industrial transfer and fostering complementary development will stimulate local economic activity, thereby expanding overall energy demand and bilateral trade volume.

(2) Drive renewable energy adoption and consumption

China should jointly develop renewable energy projects with BRI countries, providing essential technological assistance and financial support for clean energy infrastructure. The Chinese government should champion incentive policies, such as subsidies and tax reductions, in order to encourage partners to increase their renewable energy share and reduce reliance on fossil fuels. Strengthening technological cooperation is critical to jointly developing advanced renewable technologies, reducing costs, and accelerating widespread adoption across these regions.

(3) Expand market share for Chinese goods and services

China should strategically increase its trade presence by establishing production facilities and marketing networks within BRI countries to boost local demand for its products, consequently raising their import ratios. A key step is conducting in-depth analysis of local consumer behaviour and cultural preferences to tailor products and marketing strategies effectively. Continuous efforts to improve product quality to meet international standards and robust brand promotion are necessary to build long-term trust and solidify sustainable trade and energy relationships.

6.3. Limitations and future research

This article faced several limitations that suggest avenues for future research. The use of aggregated trade data may conceal variations across different energy products and transaction types. Future studies could employ product-level or contract-specific data to better capture the heterogeneity of energy flows. Potential endogeneity between political relations and trade remains unresolved; employing exogenous shocks or instrumental variables could strengthen causal identification. The present proxies for development and green transition urbanisation, renewable energy consumption, and electrification are relatively unclear. Future research should refine these measures by decomposing urbanisation into industrial and infrastructural dimensions and by incorporating indicators such as clean-energy generation shares, energy efficiency, and grid flexibility to provide a more nuanced understanding of the economic and environmental mechanisms at work.

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Received: November 2025, revised: February 2026

Acknowledgement: This research was funded by National Social Science Foundation of China (25BKS102).

Appendix

Additional robustness checks were placed in the Appendix because they do not affect the flow of the main text. These results are discussed briefly in the main sections where relevant, and the detailed tables are provided in the Appendix for reference.

Table A1. Conversion estimation method and use of cluster robust standard error

Variables	lnAAETV			
	(1) PPMLHDFE	(2) PPMLHDFE (Cluster)	(3) REGHDFE	(4) REGHDFE (Cluster)
lnGDP	0.125*** (0.019)	0.125*** (0.036)	1.520*** (0.211)	1.520*** (0.417)
lnP	-0.035 (0.035)	-0.035 (0.078)	-0.245 (0.448)	-0.245 (0.913)
lnCO ₂	0.0001 (0.022)	0.0001 (0.049)	0.018 (0.268)	0.018 (0.590)
lnAIR	0.002 (0.007)	0.002 (0.014)	0.053 (0.080)	0.053 (0.178)
lnMIO	0.002 (0.007)	0.002 (0.014)	0.005 (0.062)	0.005 (0.155)
RE	0.557*** (0.071)	0.557*** (0.159)	6.859*** (1.127)	6.859*** (2.055)
EG	-0.305*** (0.069)	-0.305** (0.143)	-3.506* (0.961)	-3.506* (1.829)
MH	-0.091* (0.045)	-0.091 (0.101)	-0.513 (0.792)	-0.513 (1.290)
HF	0.146*** (0.034)	0.146** (0.064)	1.349*** (0.432)	1.349* (0.690)
Constant	0.841 (0.598)	0.841 (1.232)	-11.245 (7.499)	-11.245 (14.760)
National FE	YES	YES	YES	YES
Time FE	YES	YES	YES	YES
N	672	672	672	672
Pseudo R ² /R ²	0.088	0.088	0.122	0.122

Source: results were analysed by using Stata software.

Table A2. Adjusting sampling time range

Variable	lnAAETV		
	(1) All	(2) 2020	(3) 2020, 2019
lnGDP	1.520*** (0.417)	1.508*** (0.429)	1.501*** (0.434)
lnP	-0.245 (0.913)	-0.479 (0.941)	-0.800 (0.994)
lnCO ₂	0.018 (0.590)	-0.044 (0.637)	-0.095 (0.662)
lnAIR	0.053 (0.178)	0.039 (0.188)	0.048 (0.193)
lnMIO	0.005 (0.155)	-0.006 (0.157)	-0.031 (0.161)
RE	6.859*** (2.055)	6.376*** (2.112)	5.923*** (1.127)
EG	-3.506* (1.829)	-3.857** (1.873)	-4.098** (1.831)
MH	-0.513 (1.290)	-0.309 (1.328)	-0.039 (1.386)
HF	1.349* (0.690)	1.298* (0.709)	1.316* (0.719)
Constant	-11.245 (14.760)	-6.615 (15.064)	-1.012 (15.976)
National FE	YES	YES	YES
Time FE	YES	YES	YES
N	672	640	608
R ²	0.122	0.115	0.108

Source: results were analysed by using Stata software.

Table A3. Delete country samples and tail reduction processing

Variables	lnAAETV	
	(1) Delete country sample	(2) Winsorisation
lnGDP	1.583*** (0.441)	1.308*** (0.381)
lnP	-0.784 (0.983)	0.201 (0.812)
lnCO ₂	-0.811 (0.551)	0.256 (0.587)
lnAIR	-0.174 (0.185)	0.019 (0.172)
lnMIO	-0.029 (0.188)	0.087 (0.143)

Variables	lnAAETV	
	(1) Delete country sample	(2) Winsorisation
<i>RE</i>	5.183*** (1.790)	6.945*** (2.057)
<i>EG</i>	-1.904 (3.050)	-3.056* (1.868)
<i>MH</i>	-0.232 (1.325)	-0.411 (1.247)
<i>HF</i>	1.995*** (0.674)	1.127* (0.697)
Constant	-0.729 (18.241)	-15.133 (13.232)
National FE	YES	YES
Time FE	YES	YES
N	567	672
R^2	0.122	0.118

Source: results were analysed by using Stata software.