

The Belt and Road Initiative and environmental sustainability: role of ICT development and renewable energy consumption

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Online Appendix

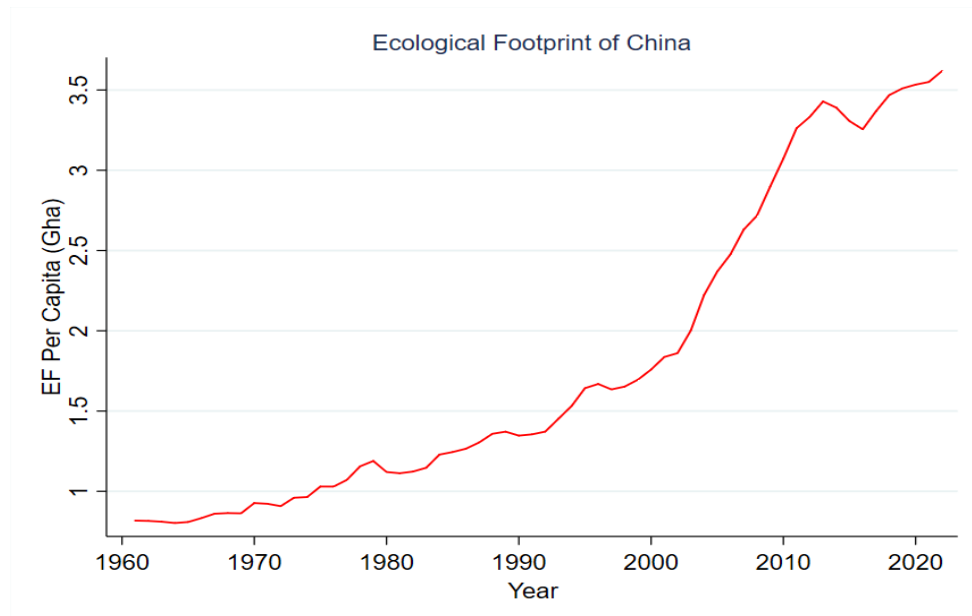


Figure A1. Trend in China's ecological footprint per capita, increasing to >3 gha per capita by 2022 (1961–2022).

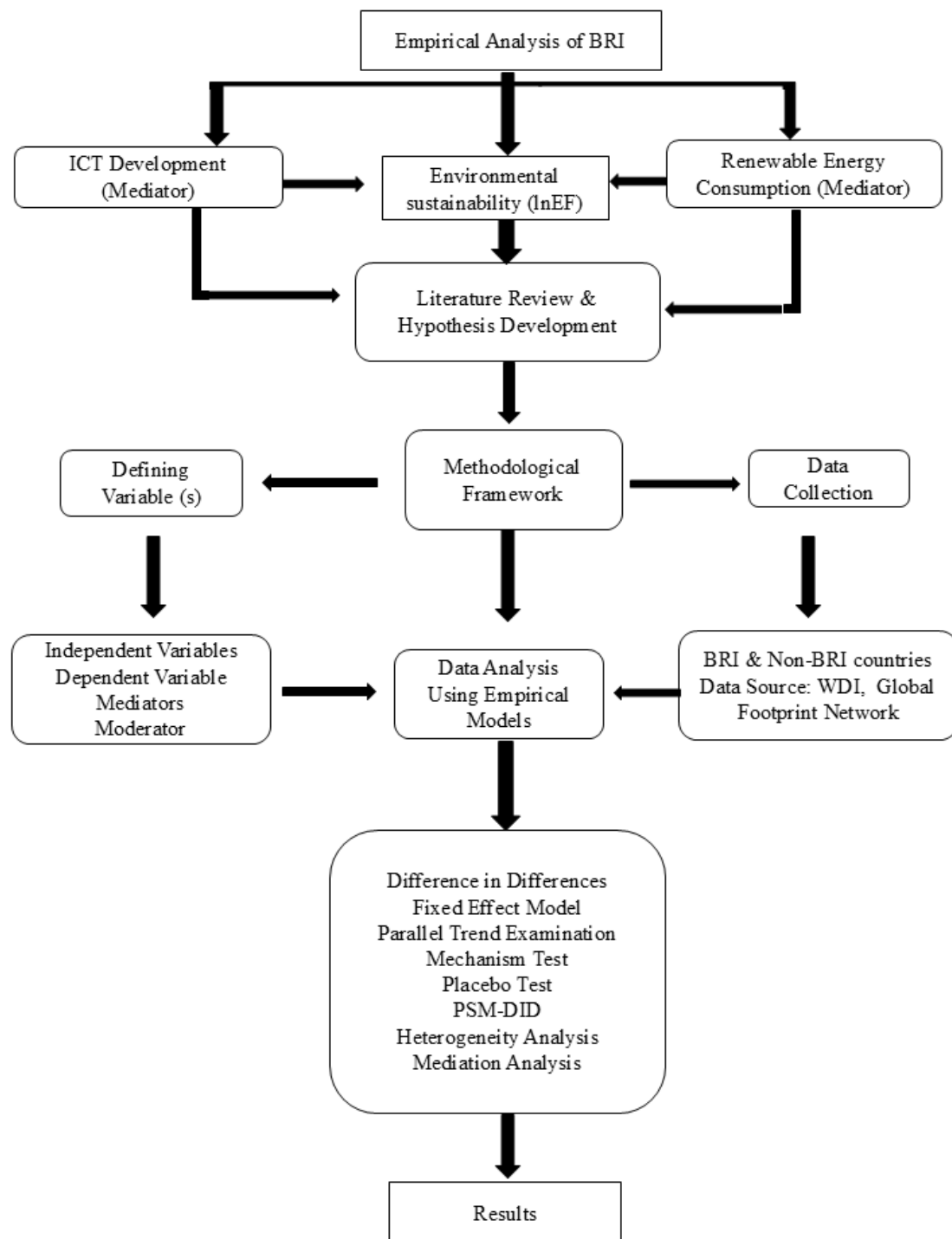


Figure A2. Research process, data, and methodology of the study.

Table A1. Data description

Variable(s)	Abbreviation	Definition	Source(s)
Dependent variable			
(s)			
Ecological Footprint	EF	Global hectares Per Capita (Gha)	GFN
Independent Variable (s)			
Belt and Road Participation	BRI	Dummy (1 for participating and 0 otherwise)	Own work
BRI*Post	BRI*Post	Interaction term of BRI participation and post-treatment	Own work
POST	POST	Dummy (1 for post 2013 and 0 otherwise)	Own work
Mediating Variable (s)			
ICT development Index	ICT		
Internet	INT	Internet penetration rate (per 100 people)	WDI
Mobile	MOB	Mobile phone penetration rate (per 100 people)	WDI
Broadband	BRO	Fixed broadband penetration rate (per 100 people)	WDI
Telephone	TEL	Fixed telephone penetration rate (per 100 people)	WDI
Renewable Energy Consumption	RE	% of total final energy consumption	WDI
Control Variables			
GDP	GDP	GDP (constant 2015 US\$)	WDI
Regulatory Quality	RQ	Percentile Rank	WDI
Surface Area	SA	Square Km	WDI
Population	POP	Population in millions	WDI
Foreign Direct Investment	FDI	FDI net inflows/GDP (%)	WDI
Political Stability and Absence of Violence	PS	Percentile Rank	WDI
Manufacturing	MAN	Manufacturing, value added (% of GDP)	WDI

Note: This table summarizes the variables, including their definitions and data sources.

Table A2. Descriptive statistics by BRI & non-BRI economies

Variable(s)	Obs.	Mean	Std. Dev.	Obs.	Mean	Std. Dev.
	BRI Economies			Non-BRI Economies		
lnEF	2720	0.813	0.718	800	1.191	0.72
ICT	2710	34.767	22.209	799	47.38	22.585
lnSA	2720	11.778	2.16	800	12.179	2.295
POP	2720	32.634	120.843	800	67.692	204.184
FDI	2651	5.638	21.451	799	4.228	8.217
RE	2607	34.662	30.511	768	31.239	25.8
PS	2709	41.911	26.374	800	54.667	28.363
MAN	2527	11.536	6.642	792	13.374	6.226
RQ	2707	42.144	26.134	799	64.653	29.524
lnGDP	2700	24.091	1.866	800	25.647	2.651

Note: This table reports summary statistics for key variables.

Table A3. Matrix of correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1) lnEF	1.000										
(2) BRI*POST	-0.103	1.000									
(3) ICT	0.690	0.238	1.000								
(4) lnSA	-0.132	0.008	-0.122	1.000							
(5) POP	-0.075	-0.029	-0.030	0.311	1.000						
(6) FDI	0.074	-0.042	0.059	-0.180	-0.041	1.000					
(7) RE	-0.620	-0.005	-0.553	0.174	-0.034	-0.072	1.000				
(8) PS	0.635	-0.084	0.521	-0.393	-0.168	0.110	-0.362	1.000			
(9) MAN	0.129	-0.057	0.147	0.204	0.232	-0.049	-0.075	0.001	1.000		
(10) RQ	0.707	-0.138	0.714	-0.195	-0.021	0.092	-0.461	0.689	0.165	1.000	
(11) lnGDP	0.378	-0.056	0.467	0.538	0.387	-0.074	-0.354	0.035	0.416	0.434	1.000

Note: The table presents pairwise correlation coefficients among the main variables used in the analysis.

Table A4. Diagnostic tests: multicollinearity and heteroskedasticity

	VIF	1/VIF		
lnGDP	4.020	0.249	Breusch-Pagan Test	
RQ	3.940	0.254	chi ² (1)	2.590
ICT	3.910	0.256	Prob > chi2	0.108
POST	3.440	0.290		
BRI*POST	3.120	0.321		
lnSA	2.420	0.414		
PS	2.400	0.417		
RE	1.710	0.583		
POP	1.290	0.777		
MAN	1.240	0.805		
FDI	1.040	0.958		
Mean VIF	2.594			

Table A5. Impact of BRI on ecological footprint

Variable(s)	EF	EF ²	lnEF	lnEF ²
	(1)	(2)	(3)	(4)
BRI	-0.878** (0.388)	-6.080 (4.242)	-0.253** (0.108)	-0.579** (0.241)
POST	-0.563*** (0.080)	-6.200*** (1.139)	-0.122*** (0.016)	-0.350*** (0.048)
BRI*POST	0.342** (0.096)	3.653** (1.447)	0.0521** (0.022)	0.212*** (0.058)
ICT	0.003 (0.002)	0.002 (0.038)	0.002*** (0.000)	0.002 (0.001)
lnSA	-0.045*** (0.017)	-0.436** (0.222)	-0.010** (0.005)	-0.027** (0.011)
POP	0.000 (0.001)	-0.001 (0.006)	0.000 (0.000)	-0.000 (0.000)
FDI	0.002** (0.001)	0.037** (0.016)	0.000 (0.000)	0.001* (0.001)
RE	-0.012*** (0.004)	-0.141*** (0.052)	-0.003*** (0.001)	-0.006** (0.002)
PS	0.006** (0.003)	0.073** (0.036)	0.002*** (0.001)	0.002 (0.002)
MAN	0.001 (0.009)	0.006 (0.116)	-0.001 (0.003)	-0.002 (0.006)
RQ	0.011*** (0.003)	0.077** (0.037)	0.004*** (0.001)	0.007*** (0.002)
lnGDP	0.040 (0.076)	0.630 (0.643)	-0.002 (0.027)	0.040 (0.052)
Constant	3.025 (1.887)	9.677 (16.10)	1.062 (0.661)	0.918 (1.279)
Observations	3474	3474	3489	3489

Notes: This table reports the baseline regression results examining the relationship between participation in the BRI and ecological footprint, using both the EF and its lnEF, along with their squared terms to account for potential non-linearities. Columns (1) and (2) utilize the ecological footprint and its square, while columns (3) and (4) use the logarithmic transformation of the ecological footprint and its square, respectively, to provide robustness to the functional form. Robust standard errors are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Computations were performed using Stata 15.

Table A6. Parallel trend assumption

VARIABLES	lnEF
BRI*Year 2006	0.003 (0.019)
BRI*Year 2007	-0.007 (0.017)
BRI*Year 2008	0.002 (0.019)
BRI*Year 2009	0.031 (0.020)
BRI*Year 2010	-0.009 (0.017)
BRI*Year 2011	0.023 (0.016)
BRI*Year 2012	0.004 (0.019)
BRI*Year 2014	0.026 (0.019)
BRI*Year 2015	0.035* (0.021)
BRI*Year 2016	0.038** (0.019)
BRI*Year 2017	0.033* (0.017)
BRI*Year 2018	0.045** (0.021)
BRI*Year 2019	0.048** (0.019)
BRI*Year 2020	0.060*** (0.021)
Constant	0.830 (0.779)
Observations	3,489
R-squared	0.165
Covariates	Yes
Country FE	Yes
Year FE	Yes

Notes: This table presents the results of the parallel trend assumption test, conducted by interacting the BRI variable with each year from 2006 to 2020, seven years before and after the initiation of the Belt and Road Initiative (BRI). The dependent variable is the ecological footprint (lnEF). Robust standard errors are reported in parentheses, with significance levels indicated as *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$. The analysis controls for covariates, country fixed effects (FE), and year fixed effects (FE). Computations were conducted using Stata 15.

Table A7. Placebo test for the fake time variable

VARIABLES	Placebo test
Fake_BRI1	-0.017 (0.024)
Fake_BRI2	-0.028 (0.021)
Fake_BRI3	-0.018 (0.021)
Fake_BRI4	0.010 (0.022)
BRI*2010	-0.030 (0.018)
Post_BRI1	0.002 (0.019)
Post_BRI2	-0.018 (0.019)
Post_BRI3	-0.004 (0.021)
Post_BRI4	0.004 (0.016)
Constant	0.816 (0.790)
Observations	3,489
Year FE	Yes
Country FE	Yes
Covariates	Yes
R-squared	0.162

Notes: This table presents the placebo test for the Belt and Road Initiative (BRI), using a false intervention year (2010) and fake BRI years prior to the false intervention (2006-2009). The placebo variables (Fake_BRI1 to Fake_BRI4) and post-BRI effects are examined. Robust standard errors are provided in parentheses. Year and country fixed effects (FE) are included, and computations were performed using Stata 15.

Table A8. Robustness using counterfactual test

	(1)	(2)	(3)
	lnEF	lnEF	lnEF
BRI*POST	0.017 (0.014)	0.001 (0.015)	-0.017 (0.016)
ICT	-0.000 (0.001)	0.000 (0.001)	0.000 (0.001)
lnSA	-0.015*** (0.005)	-0.015*** (0.005)	-0.0146*** (0.005)
POP	0.000 (0.001)	0.000 (0.001)	0.000 (0.001)
FDI	0.000 (0.000)	0.000 (0.000)	0.000 (0.0002)
RE	-0.001** (0.001)	-0.003** (0.001)	-0.00283*** (0.001)
PS	0.002** (0.001)	0.002** (0.001)	0.002** (0.001)
MAN	-0.000 (0.003)	-0.000 (0.003)	-0.001 (0.003)
RQ	0.004*** (0.001)	0.004*** (0.001)	0.004*** (0.001)
lnGDP	-0.035** (0.018)	-0.034* (0.018)	-0.031* (0.019)
Constant	1.753*** (0.423)	1.719*** (0.437)	1.672*** (0.455)
R-squared	0.078	0.077	0.078
Observations	3489	3489	3489

Notes: This table presents the results of the counterfactual test to assess the robustness of the main findings. Column (1) assumes 2007 as the fake intervention year, column (2) assumes 2008, and column (3) assumes 2009. The dependent variable across all specifications is the logarithm of ecological footprint (lnEF). Standard errors are reported in parentheses. Statistical significance is denoted by * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$.

Table A9. Additional robustness check: influence of BRI on lnEF releases

	lnEF (1)	lnEF (2)	lnEF (3)	lnEF (4)	lnEF (5)	lnEF (6)	lnEF (7)	lnEF (8)	lnEF (9)
BRI*POST	0.048* (0.024)	0.048** (0.024)	0.052** (0.023)	0.053** (0.023)	0.044** (0.022)	0.044* (0.022)	0.046** (0.022)	0.047** (0.022)	0.050** (0.022)
ICT	0.005*** (0.001)	0.005*** (0.001)	0.005*** (0.001)	0.005*** (0.001)	0.004*** (0.001)	0.004*** (0.001)	0.004*** (0.001)	0.004*** (0.001)	0.004*** (0.001)
lnSA		-0.002 (0.001)	0.001 (0.006)	0.001 (0.006)	0.003 (0.006)	0.001 (0.006)	0.000 (0.006)	-0.000 (0.001)	-0.001 (0.001)
POP			0.001*** (0.000)	0.001*** (0.000)	0.001** (0.000)	0.001** (0.000)	0.001** (0.000)	0.001** (0.000)	0.001** (0.000)
FDI				0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
RE					-0.002** (0.001)	-0.002** (0.001)	-0.002** (0.001)	-0.002** (0.001)	-0.002** (0.001)
PS						0.002*** (0.001)	0.002*** (0.001)	0.001** (0.001)	0.001** (0.001)
MAN							-0.002 (0.003)	-0.002 (0.003)	-0.002 (0.003)
RQ								0.003*** (0.001)	0.003*** (0.001)
lnGDP									-0.007 (0.031)
Constant	0.807*** (0.020)	0.836*** (0.07)	0.746*** (0.071)	0.737*** (0.0702)	0.822*** (0.075)	0.750*** (0.082)	0.785*** (0.076)	0.679*** (0.0834)	0.856 (0.767)
R-squared	0.123	0.123	0.131	0.132	0.145	0.158	0.160	0.172	0.166
Observation	3509	3509	3509	3509	3509	3509	3509	3509	3489
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: This table provides additional robustness checks to assess the effect of the BRI on lnEF. The nine model specifications sequentially introduce control variables to examine the stability and reliability of the estimated coefficients, all while accounting for both country and year fixed effects. Robust standard errors are reported in parentheses, with significance levels indicated as *** p<0.01, ** p<0.05, and * p<0.1.

Table A10. Summary statistics for matching quality

Sample	Pseudo R ²	LR Chi ²	p-value	Mean Bias	Median Bias	B	R	% Variance
Unmatched	0.151	566.28	0.000	37.8	28.6	96.5*	0.52	78
Matched	0.017	25.61	0.002	8.9	10.3	31.0*	0.92	33

Note: * If B>25%, R outside [0.5; 2].

Table A11. Balance test results of PSM on covariates

Variable	Probit Model	Matched/Unmatched	Treated Mean	Control Mean	t-test (t)	p- value
RQ	−0.0147	U	42.445	64.680	−20.56	0.000
	(0.00178)	M	53.129	51.839	0.77	0.443
ICT	0.00119	U	34.770	47.380	−14.01	0.000
	(0.00183)	M	41.490	38.709	2.05	0.041
lnSA	0.0308	U	11.759	12.177	−4.73	0.000
	(0.0181)	M	11.873	11.723	1.07	0.285
POP	−0.000336	U	32.758	67.749	−6.00	0.000
	(0.000171)	M	72.573	51.081	1.60	0.109
FDI	0.00254	U	5.652	4.230	1.85	0.065
	(0.00143)	M	5.805	5.156	0.72	0.469
RE	−0.0107	U	34.778	31.281	3.00	0.003
	(0.00119)	M	31.775	34.816	−1.79	0.074
MAN	0.00156	U	11.561	13.367	−7.03	0.000
	(0.00436)	M	13.023	13.044	−0.05	0.960
PS	−0.00283	U	42.151	54.724	−11.64	0.000
	(0.00144)	M	48.908	44.109	2.88	0.004
lnGDP	−0.1645	U	24.087	25.650	−18.72	0.000
	(0.0238)	M	24.843	24.607	1.73	0.083

Note: This table reports covariate balance from propensity score matching, comparing group mean differences and significance before and after matching.

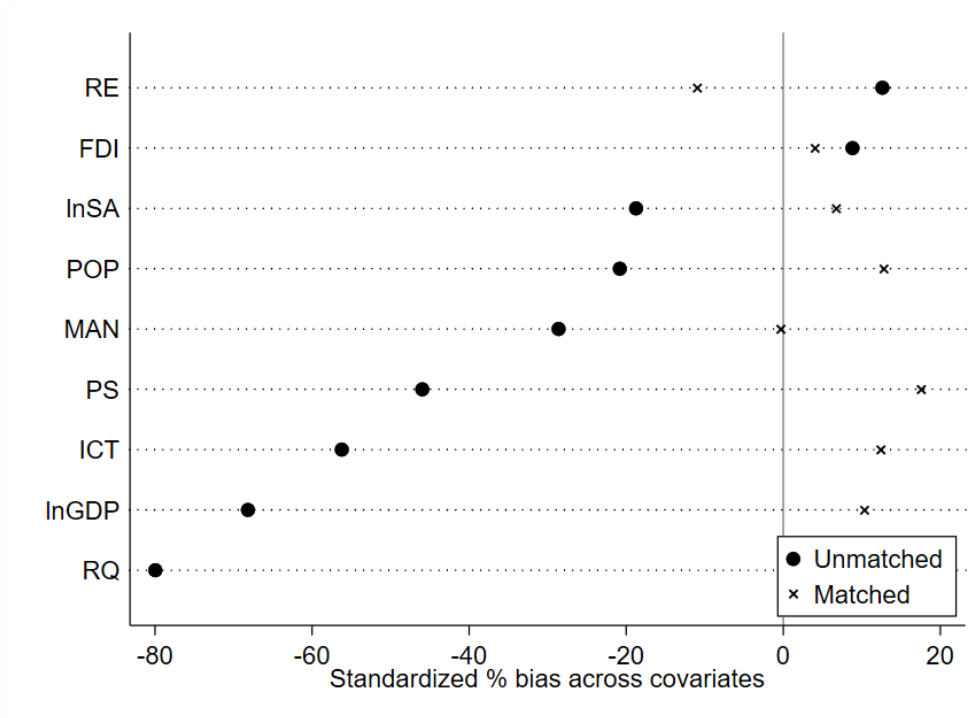


Figure A3. Standardized bias across covariates.

Table A12. Heterogeneous time effect

Variables	Fixed Effects Model
BRI*Year 2015	0.038* (0.022)
BRI*Year 2016	0.042* (0.022)
BRI*Year 2017	0.037* (0.022)
BRI*Year 2018	0.049* (0.026)
BRI*Year 2019	0.052** (0.025)
BRI*Year 2020	0.064** (0.027)
BRI*Year 2021	0.050* (0.026)
BRI*Year 2022	0.064** (0.028)
Constant	0.863 (0.769)
Observations	3,489
R-squared	0.167
Year FE	Yes
Country FE	Yes
Covariates	Yes

Notes: This table presents the results of the heterogeneous time effects analysis using a fixed effects model, examining the impact of the Belt and Road Initiative (BRI) for the years 2015 to 2022. The dependent variable is the ecological footprint (lnEF). Robust standard errors are reported in parentheses, with significance levels indicated as *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$. The analysis controls for country fixed effects (FE), year fixed effects (FE), and covariates. Computations were conducted using Stata 15.

Table A13. Mechanism analysis

	ICT	lnSA	POP	FDI	RE	PS	MAN	RQ	lnGDP
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
BRI*POST	6.474*** (1.345)	0.0595 (0.0514)	-3.609 (4.314)	-1.784 (1.655)	-3.141*** (1.115)	0.355 (1.655)	0.710 (0.515)	-0.460 (1.155)	0.0828 (0.0684)
Constant	20.59 (24.95)	12.72*** (0.555)	2.681 (37.36)	48.29 (37.75)	65.99** (28.36)	-20.09 (25.91)	-10.86 (7.119)	11.34 (15.52)	23.65*** (0.257)
R-squared	0.761	0.375	0.101	0.013	0.035	0.004	0.046	0.009	0.246
Observations	3509	3520	3520	3520	3520	3520	3520	3520	3500
Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Robust standard errors are shown in parentheses, with significance denoted by *, **, and *** at the 10%, 5%, and 1% levels, respectively.

Table A14. List of BRI countries, their income group, and date of joining

Country	Income Group	Likely date of joining	Country	Income Group	Likely date of joining	Country	Income Group	Likely date of joining
Afghanistan	Low	5/1/2023	Ghana	Lower middle	9/1/2018	Pakistan	Lower middle	12/1/2013
Albania	Upper middle	5/1/2017	Greece	High	8/1/2018	Panama	High	6/1/2017
Algeria	Upper middle	7/10/2018	Grenada	Upper middle	9/1/2018	Papua New Guinea	Lower middle	7/1/2016
Angola	Lower middle	9/1/2018	Guinea	Low	9/1/2018	Peru	Upper middle	5/1/2019
Antigua & Barbuda	High	6/1/2018	Guinea-Bissau	Low	11/24/2021	Philippines	Lower middle	11/1/2017
Argentina	High	2/6/2022	Guyana	Upper middle	7/1/2018	Poland	High	11/1/2015
Armenia	Upper middle	12/1/2015	Honduras	Lower middle	10/18/2023	Portugal	High	12/1/2018
Azerbaijan	Upper middle	12/1/2015	Hungary	High	6/1/2015	Qatar	High	1/1/2019
Bahrain	High	7/1/2018	Indonesia	Lower middle	3/1/2015	Romania	Upper middle	6/1/2015
Bangladesh	Lower middle	3/1/2019	Iran, Islamic Rep.	Upper middle	11/1/2018	Russian Federation	Upper middle	
Barbados	High	2/1/2019	Iraq	Upper middle	12/1/2015	Rwanda	Low	7/1/2018
Belarus	Upper middle	12/1/2013	Jamaica	Upper middle	4/1/2019	Samoa	Upper middle	10/1/2018
Benin	Low	9/1/2018	Jordan	Upper middle	12/2/2023	Saudi Arabia	High	8/1/2018
Bolivia	Lower middle	6/1/2018	Kazakhstan	Upper middle	8/1/2015	Senegal	Low	7/1/2018
Bosnia & Herzegovina	Upper middle	5/1/2017	Kenya	Lower middle	6/1/2017	Serbia	Upper middle	11/1/2015
Botswana	Upper middle	1/7/2021	Kiribati	Lower middle	1/1/2020	Seychelles	High	9/1/2018
Brunei Darussalam	High	11/1/2018	Korea, Rep.	High	5/1/2018	Sierra Leone	Low	8/1/2018
Bulgaria	Upper middle	11/1/2015	Kuwait	High	5/1/2018	Singapore	High	4/1/2018
Burundi	Low	9/1/2018	Kyrgyz Republic	Lower middle	12/1/2013	Slovak Republic	High	11/1/2015
Cabo Verde	Lower middle	9/1/2018	Lao PDR	Lower middle	9/1/2018	Slovenia	High	11/1/2017
Cambodia	Lower middle	12/1/2013	Latvia	High	11/1/2016	Solomon Islands	Lower middle	10/1/2019
Cameroon	Lower middle	8/1/2015	Lebanon	Upper middle	9/1/2017	Somalia	Low	8/1/2015
Central African Rep.	Low	Nov-21	Lesotho	Lower middle	6/1/2019	South Africa	Upper middle	12/1/2015
Chad	Low	9/1/2018	Liberia	Low	4/1/2019	South Sudan	Low	9/1/2018

Chile	High	11/6/2018	Libya	Upper middle	7/1/2018	Sri Lanka	Lower middle	4/1/2017
China, P.R.	Upper middle	12/1/2013	Lithuania	High	11/1/2017	Sudan	Lower middle	9/1/2018
Comoros	Low	12/1/2015	Luxembourg	High	3/1/2019	Suriname	Upper middle	7/1/2018
Congo, Dem. Rep.	Low	1/6/2021	Madagascar	Low	3/1/2017	Syrian Arab Rep.	Low	01/2022
Cook Islands	Upper middle	11/1/2018	Malawi	Low	3/24/2022	Tajikistan	Low	10/1/2018
Costa Rica	Upper middle	9/1/2018	Malaysia	Upper middle	5/1/2017	Tanzania	Low	9/1/2018
Côte d'Ivoire	Lower middle	5/23/2017	Maldis	Upper middle	8/1/2017	Thailand	Upper middle	12/1/2014
Croatia	High	5/1/2017	Mali	Low	7/26/2019	Timor-Leste	Lower middle	4/1/2017
Cuba	Upper middle	6/20/2019	Malta	High	11/1/2018	Togo	Low	9/1/2018
Cyprus	High	4/1/2019	Mauritania	Lower middle	9/1/2018	Tonga	Upper middle	3/1/2018
Dominican Republic	Upper middle	12/1/2019	Micronesia, Fed. Sts.	Lower middle	11/1/2018	Trinidad & Tobago	High	5/1/2018
Czech Republic	High	11/1/2015	Moldova	Lower middle	12/1/2013	Tunisia	Lower middle	7/1/2018
Djibouti	Lower middle	9/1/2018	Mongolia	Lower middle	12/1/2013	Turkey	Upper middle	11/1/2015
Dominica	Upper middle	7/13/2018	Montenegro	Upper middle	5/1/2017	Turkmenistan	Upper middle	06/2017
Ecuador	Upper middle	12/1/2018	Morocco	Lower middle	11/1/2017	Uganda	Low	9/1/2018
Egypt, Arab Rep.	Lower middle	1/1/2016	Mozambique	Low	9/1/2018	Ukraine	Lower middle	12/1/2017
El Salvador	Lower middle	11/1/2018	Myanmar	Lower middle	8/1/2016	United Arab Emirates	High	7/1/2018
Equatorial Guinea	Upper middle	4/1/2019	Namibia	Upper middle	9/1/2018	Uruguay	High	2/1/2018
Eritrea	Low	11/25/2021	Nepal	Low	5/1/2017	Uzbekistan	Lower middle	6/1/2015
Estonia	High	11/1/2017	New Zealand	High	3/1/2017	Vanuatu	Lower middle	11/1/2018
Ethiopia	Low	9/1/2018	Nicaragua	Lower middle	1/6/2022	Venezuela, RB	Upper middle	9/1/2018
Fiji	Upper middle	11/1/2018	Nigeria	Lower middle	9/1/2018	Vietnam	Lower middle	11/1/2017
Gabon	Upper middle	9/1/2018	Niue	Lower middle	7/1/2018	Yemen, Rep.	Low	11/1/2017
Gambia, The	Low	9/1/2018	North Macedonia	Upper middle	12/1/2013	Zambia	Lower middle	9/1/2018
Georgia	Lower middle	12/1/2016	Oman	High	5/1/2018	Zimbabwe	Low	9/1/2018

Source: Nedopil, 2023