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Analyzing the impact of natural capital on socio- economic objectives under the framework of sustainable development goals

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ABSTRACT

Natural capital plays an essential role in achieving socio-economic objectives and is connected to the basic conditions for human survival. Here, we discuss the role played by natural capital in sustainable socio-economic objectives (SDG1, 3, 5, and 8) in 131 countries and territories during the period 2000–2018. In the long term, the increased dependence on natural capital can contribute to decent work and economic growth, but it has negative impacts on poverty reduction as well as the promotion of good health, well-being, and gender equality. The relationship between natural capital and each socio-economic objectives changes with different levels of socio-economic. In addition, the regression results of countries at different stages of development show heterogeneity. Unlike low-income countries, the dependence on natural capital reduces poverty rates in high-income countries, and is conducive to gender equality in middle-income countries. Governments should create incentives to protect and enhance natural wealth to prevent the depletion of natural capital or its unsustainable conversion into other forms of capital.

1. Introduction

Natural capital refers to the natural resources and the ecological systems that provide the basic conditions for human survival (Missemer, 2018), which is a concept that criticizes industrial capitalism and traditional economic systems (Hawken et al., 2000; Ucal and Xydis, 2020). According to the observation in the report "2019 Natural Resources Outlook" by the United Nations Environment Programme, the exploitation of natural resources more than doubled between 2013 and 2019 (Usman et al., 2022). With the severe extraction of natural resources and their contribution to economic development, researchers have noticed the relationship between natural resources and economic growth (Chiesura and de Groot, 2003; Pelenc and Ballet, 2015). Natural capital plays a critical role in socio-economic development and is irreplaceable (Dedeurwaerdere, 2014; Erum and Hussain, 2019; Lawn, 2001; Omri and Ben Mabrouk, 2020; Pelenc and Ballet, 2015). Many countries have transformed their depleted natural capital into human capital and produced capital, resulting in an increasing combined stock of wealth (Van Krevel, 2021). The natural resources as blessings hypothesis have proposed that natural resource rents facilitate economic growth and financial development (Nawaz et al., 2019). On the other hand, the empirical results associated with the resource curse hypothesis have proven that abundant natural resources can impede a country's economic growth (Abou-Ali and Abdelfattah, 2013; Sachs and Warner, 2001). The studies conducted by Frynas and Buur (2020) showed that countries that are rich in natural resources have low levels of savings and investment, weak financial development processes, and unstable economic growth due to rent-seeking activities.

In addition to the economic growth, the importance of natural capital in maintaining human development has been widely recognized (Costanza, 2020). Environmental economists have further expanded the scope of economic analysis by including the ecological impact of the process of natural resource use (Ravn Boess and González Del Campo, 2023; Song et al., 2019; Wang et al., 2021). Natural resource rents increase the associated ecological footprint (Ahmed et al., 2020a; Nathaniel et al., 2021). The "constancy of total natural capital" rule widely be seen as a minimum condition for assuring sustainable development (Costanza and Daly, 1992). The research conducted by Scherr (2000) research indicated the degradation of natural resources in turn leads to declines in human health, food security, and the economy. Some policies have been developed with the aim of eliminating negative human impacts on resources and the environment based on technological

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advances, but that goal might be difficult to achieve (Huesemann, 2003; Jahanger et al., 2022). With further research of the relationship between natural resources and human development, some comprehensive indicators have been used to characterize socio-economic conditions (Cook and Davíðsdóttir, 2021; Paz et al., 2021; Pelenc and Ballet, 2015; Silva et al., 2020; Ullah et al., 2021). Usubiaga-Liaño and Ekins (2021) constructed the Strong Environmental Sustainability Index (SESI) and discovered that several natural capital functions in Europe were being compromised. Experience from over 30 Asia Pacific countries indicates that individual natural resource rents contribute to the HDI, while total rents from natural resources harm the HDI (Sinha and Sengupta, 2019). In 2015, the United Nations put out the “17 Sustainable Development Goals”, which provides a more comprehensive measure of sustainable socio-economic development (Jiang et al., 2022). According to expert surveys, key interactions take place between the social-economic clusters and the resource use clusters (Bennich et al., 2021; Qazi et al., 2023; Van Soest et al., 2019). The relationships and interrelations between SDGs and natural capital remain to be further elaborated to help humans judge how to treat natural capital properly (Polishchuk and Rauschmayer, 2012).

Although several scholars have focused on the relationship between natural capital and socio-economic as outlined in the above literature review (Koff, 2021; Ullah et al., 2021), certain research limitation still exist (Wei et al., 2023). First, it is not sufficient to focus merely on the contributions of natural capital to economic growth. The relationship between natural capital and other socio-economic objectives must be emphasized and verified. Second, comprehensive indicators (such as human well-being, total wealth, and sustainability index (Marti and Puertas, 2020), etc.) are difficult to reflect the specific situation of different aspects of society and economy. The calculation method of comprehensive indicators is diverse, with significant differences in connotation, and the subjectivity of evaluation results is relatively high. On the other hand, the trade off and synergies between different factors may have an impact on evaluation results. Third, there is still a lack of research on the interaction between natural capital and socio-economic goals at the global level. We assume that natural capital will have different impacts on various socio-economic development goals, and this impact will also vary in different countries and different stages of sustainable development. For further in-depth research in this area, this study tries to examines the relationship between natural capital and various socio-economic development goals on a global dataset. This research aims to address the following questions: (1) The relationship between three major capitals (natural capital, produced capital, and human capital) and socio-economic objectives in the global context. We consider develop an indicator set, which not only can reflect the status of full socio-economic development, but also can reveal the situation of different dimensions. (2) The role of natural capital in achieving each socio-economic objective on a global scale. (3) The relationship between natural capital and socio-economic objectives in different development stages and different sustainable development processes. Answering these questions will help to deeply understand the natural capital wealth and the stage of the goal of social and economic sustainable development in various countries, to provide reference for decision-makers. This study draws on the results of the World Bank's Global Wealth Accounting Project (WorldBank, 2021) and the *Sustainable Development Report 2021* prepared by the Sustainable Development Solutions Network and the Bertelsmann Stiftung (Sachs et al., 2021).

2. Material and methods

2.1. Measurement considerations

Natural capital, produced capital, and human capital work together to promote human development and well-being (Missemer, 2018). And the effects of natural ecosystems and their products and services on human well-being have received increasing attention. Based on previous studies, we have constructed an analytical framework for natural capital and socio-economic objectives to reveal the role played by natural capital in human development. Natural capital comprises renewable natural capital, such as agricultural land (cropland and pastureland), protected areas, forests (timber and ecosystem services), mangroves, and fisheries, and nonrenewable natural capital, such as fossil fuels and minerals (WorldBank, 2021). Renewable energy resources such as hydropower, solar and wind energy are not currently included in the category of natural capital. Produced capital includes machinery, buildings, equipment, intangible wealth, and both residential and nonresidential urban land. Human capital represents workers' knowledge and skills, cultural and technical levels, and health status.

The connotation of socio-economic sustainable development goals is very broad, and a comprehensive indicator set should be established to characterize it. At the same time, different socio-economic goals are equal and should be taken into account in their respective situations, rather than being offset in the calculation of comprehensive indicators. Indicator set has advantage in reducing the subjectivity of the evaluation process and improving the accuracy of the evaluation results, which can satisfy for the purpose of this research. The SDGs covers the universal issues of three core elements: economic growth, social inclusion, and environmental protection, which is aim at promote sustainable, inclusive and equitable economic growth, including 17 sustainable development goals and 169 specific goals. It is currently a set of goals that can reflect the status of full socio-economic development (Gao et al., 2021). Thus, we divide the socio-economic related goals from the 17 SDGs as the indicator set in this study. Previous studies have divided the various targets in SDGs. Fu et al. (2019) divided the 17 SDGs into three categories: essential needs, expected objectives, and governance. The expected objectives refer to the ultimate socio-economic objectives that are to be achieved, which include the seven goals of no poverty (SDG 1), good health and well-being (SDG 3), quality education (SDG 4), gender equality (SDG 5), decent work and economic growth (SDG 8), reduced inequalities (SDG 10) and strong peace and justice institutions (SDG 16). Similarly, Van Soest et al. (2019) divided the SDGs into four groups: efficient and sustainable resource use (SDGs 2, 6, 7, 12), earth system (SDGs 13, 14, 15), human development goals (SDGs 1, 3, 4, 5, 8, 10), and good governance and infrastructure (SDGs 9, 11, 16, 17). It can be seen that the division of goals related to socio-economic development is consistent in existing research. Thus, SDG1, SDG3, SDG4, SDG5, SDG8, and SDG10 were selected as a set of socio-economic development indicators in this research, without categorizing other SDGs.

Apart from the three types of capital, financial development, and trade, which are often considered to be factors affecting socio-economic development, are also included in the analytical framework (Fig. 1). The research conducted by Çakar et al. (2021), Sun et al. (2020), and Sinha and Sengupta (2019) found that financial development and trade openness also plays a role in the achievement of socioeconomic development goals. Financial inclusion promotes deposits and savings, which is conducive to promoting infrastructure investment and increasing social welfare (Hunjra et al., 2022). Furthermore, digital financial development has allowed new opportunities for closing the wealth gaps between the “haves” and “have-nots” in the developing world to emerge and has been essential to the achievement of sustainable economic development (Pradhan et al., 2021). International trade has promoted sustainable economic development in transition economies through the spillover of green technology and the promotion of goods and services (Essandoh et al., 2020). On the other hand, when a country's production capacities are not internationally competitive, trade openness is harmful to sustainable economic development (Rahman et al., 2020). Therefore, it can be assumed that trade openness has a double-sided impact on socio-economic sustainable development.

2.2. Data source

The socio-economic objectives data were obtained from the

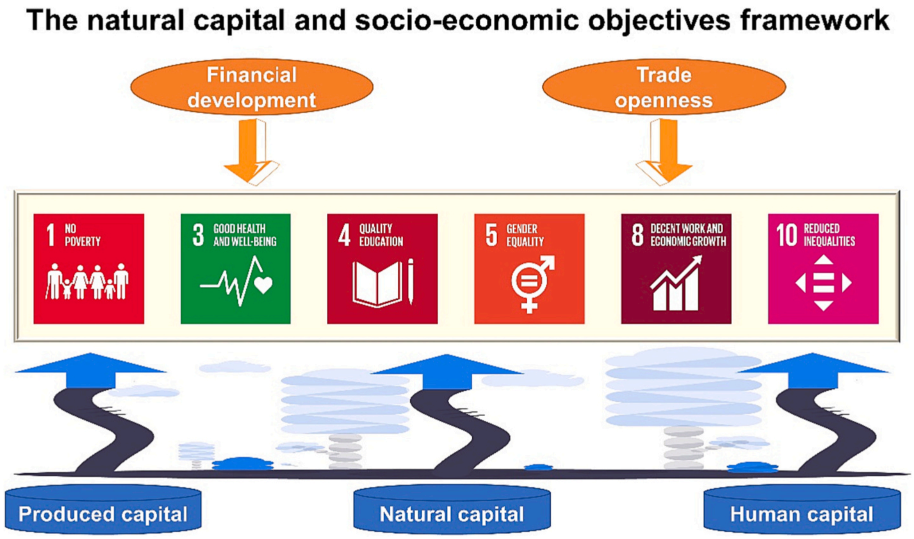

Fig. 1. The natural capital and socio-economic objectives framework.

Sustainable Development Report 2021 prepared by the Sustainable Development Solutions Network and the Bertelsmann Stiftung (Sachs et al., 2021), which includes data regarding 165 countries' performance on the 17 SDGs. SDG1, SDG3, SDG5, and SDG8 were selected as indicators for measuring socio-economic objectives in this study, due to the severe data deficiencies associated with SDG4 and SDG10 (Scrucca et al., 2023). Each targets consists 2– 6 sub-targets, included a total of 12 sub-targets, which is mainly refers to the *Sustainable Development Report 2021* and the SDG Indicators Database provided by the United Nations Statistics Division. Natural capital, produced capital, and human capital jointly form the productive base of a country's national economy, and data regarding this series were obtained from the Changing Wealth of Nations 2021 (Essandoh et al., 2020). The financial development index and the proportion of total exports and imports in GDP were taken from the International Monetary Fund database (IMF) and the World Bank and OECD National Accounts data, respectively. The data of variables cover 131 countries from 2000 to 2018 in this study, and the symbolic, descriptions, units, and sources of each variable are shown in Table 1.

In the process of calculation of SDGs (SDGs 1, 3, 5, 8) values, to make the data comparable across sub-target, each variable was measured linearly on a scale ranging from 0 to 100. Before standardization, we need to establish the upper and lower bound. The upper bound represents the optimum performance in each variable, rather than the numerical maximum. Similarly, the lower bound is the worst performance in each variable. In order to eliminate the effect of limits and extremes in the tails of the distribution on the relative ranking of individual countries, we need to be cautions in selecting of the upper bound and the lower bound. The upper bound for each variable was determined by using the five-step decision tree proposed in the Sustainable Development Report 2021 (Table 2), which describing optimum performance. After sorting variables from worse performance to optimum performance, the lower bound was defined at the 2.5th percentile of the distribution. Then, each indicator distribution was censored by using the Eq. (1) for the range [0,100]. And all values exceeding the upper bound scored 100, and values below the lower bound scored 0. This equation can eliminate the impact of different attributes between different indicators and facilitates comprehensive analysis, as well as comparative analysis between countries. Finally, the four SDGs value were calculation in terms of the arithmetic averages of their sub-targets.

$$x^{'} = \frac{x - min(x)}{max(x) - min(x)} \times 100 \tag{1}$$

where x was the raw data value; max/min denoted the upper and lower bounds, respectively; and $x^{'}$ was the normalized value after rescaling.

2.3. Econometric model and statistical analysis

In order to address the above questions, an econometric model of the relationship between natural capital and socio-economic objectives was designed in this study. The dependent variable was composed of a set of socio-economic objectives, including SDG1, SDG3, SDG5, and SDG8. First, the basic ordinary least squares (OLS) regression model was used for estimation, as shown in Eq. (2). Secondly, The OLS regression approach was based on the mean and was only able to capture the overall relationship between natural capital and socio-economic goals. In order to capture the distribution heterogeneity of the relationship between socio-economic goals and the three types of capital (natural capital, human capital, and productive capital), the quantile regression was conducted to estimate the model and to test the robustness of the OLS regression, as shown in Eq. (3). Finally, considering the possibly nonlinear relationship between natural capital and socio-economic objectives, we added the quadratic and cubic terms of natural capital, as shown in Eq. (4). In order to narrow the differences between data and avoid the impact of individual extreme values, the indicators of natural capital per capita, human capital per capita, and produced capital per capita were calculated by using population data and were treated logarithmically. *ln* indicates the natural logarithm, while $\beta_{1i}\dots\dots\beta_{7i}$ represents the slope coefficients, and ε is the error term. Stata 15.0 supports all the estimates shown throughout the paper.

$$SDG_{it} = \beta_{1i} lnNC_{it} + \beta_{2i} lnPC_{it} + \beta_{3i} lnHC_{it} + \beta_{4i} FD_{it} + \beta_{5i} TO_{it} + \varepsilon_{it} \tag{2}$$

$$SDG = f(lnNC, lnPC, lnHC, FD, TO) \tag{3}$$

$$SDG_{it} = \beta_{1i} lnNC_{it} + \beta_{2i} lnNC_{it}^2 + \beta_{3i} lnNC_{it}^3 + \beta_{4i} lnPC_{it} + \beta_{5i} lnHC_{it} + \beta_{6i} FD_{it} + \beta_{7i} TO_{it} + \varepsilon_{it} \tag{4}$$

The results of multicollinearity test on variables are shown in Table 3. Econometricians believe that a level where the VIF coefficient does not exceed 10 is tolerable and there is no need to worry about multicollinearity issues (Gujarati, 2022; Saint Akadiri et al., 2019). In the context of globalization, the study variables might be interdependent. Cross section dependency is a key issue, and ignoring it can lead to significant estimation bias and size distortion. So, before analyzing the stationarity of variables, it is necessary to verify whether there is a cross-sectional dependency in the panel (Pesaran, 2015). In order to avoid the problem of "spurious regression", a panel unit root test is conducted. Given the cross-sectional dependence of panel data, it is considered more suitable to use the second generation panel unit root test with

Table 1
Description of variables.

Variable	Symbol	Sub-target/description	Units	Sources
Socio-economic objectives (No Poverty)	SDG1	The proportion of the population using basic sanitation services	%	UNICEF et al. https://unstats.un.org/sdgs/dataportal/analytics/GlobalRegionalTrends (Series: Indicator 1.4.1 SP_ACS_BSRVSAN)
	SDG1	The proportion of the population using basic drinking water services	%	UNICEF et al. https://unstats.un.org/sdgs/dataportal/analytics/GlobalRegionalTrends (Series: Indicator 1.4.1 SP_ACS_BSRVH20)
Socio-economic objectives (Good Health and Well-being)	SDG3	Neonatal mortality rate	per 1000 live births	UNICEF et al. http://data.worldbank.org/indicator/SH.DYN.NMRT
	SDG3	Mortality rate, under-5	per 1000 live births	UNICEF et al. http://data.worldbank.org/indicator/SH.DYN.MORT
	SDG3	Incidence of tuberculosis	per 100,000 population	WHO http://data.worldbank.org/indicator/SH.TBS.INCD
	SDG3	Traffic deaths rate	per 100,000 population	WHO https://www.who.int/data/gho/data/indicators/indicator-details/GHO/estimated-road-traffic-death-rate-(per-100-000-population)
	SDG3	Adolescent fertility rate	births per 1000 women ages 15–19	UNDESA http://data.worldbank.org/indicator/SP.ADO.TFRT
	SDG3	Percentage of surviving infants who received 2 WHO-recommended vaccines	%	Europe Sustainable Development Report 2022 https://eu-dashboards.sdgindex.org/explorer?metric=surviving-infants-who-received-2-who-recommended-vaccines
Socio-economic objectives (Gender Equality)	SDG5	The ratio of female to male mean years of schooling in the population aged 25 and above	%	UNESCO http://data.uis.unesco.org/ (Other policy relevant indicators: Mean years of schooling)
	SDG5	The ratio of female to male labor force participation rate	%	ILO https://data.worldbank.org/indicator/SL.TLF.CACT.FM.ZS
Socio-economic objectives (Decent Work and Economic Growth)	SDG8	Unemployment rate	%	ILO https://data.worldbank.org/indicator/SL.UEM.TOTL.ZS
	SDG8	The annual growth rate of real GDP per employed person	%	ILO https://unstats.un.org/sdgs/dataportal/analytics/GlobalRegionalTrends (Series: Indicator 8.2.1 SL_EMP_PCAP)
Natural capital	NC	Natural capital per capita	constant 2018 US $	The Changing Wealth of Nations 2021 https://databank.worldbank.org/source/wealth-accounts
Produced capital	PC	Produced capital per capita	constant 2018 US $	The Changing Wealth of Nations 2021 https://databank.worldbank.org/source/wealth-accounts
Human capital	HC	Human capital per capita	constant 2018 US $	The Changing Wealth of Nations 2021 https://databank.worldbank.org/source/wealth-accounts
Financial development	FD	A relative ranking of countries on the depth, access, and efficiency of their financial institutions and financial markets	/	The International Monetary Fund database https://data.imf.org/?sk=f8032e80-b36c-43b1-ac26-493c5b1cd33b
Trade openness	TO	The ratio of total imports and exports to GDP	/	The World Bank and OECD National Accounts data https://data.worldbank.org/indicator/NE.IMP.GNFS.ZS?view=chart https://data.worldbank.org/indicator/NE.EXP.GNFS.ZS?view=chart

cross-sectional correlation (Im-Pesaran-Shin (Pesaran, 2007) and Herwartz and Siedenburg (2008)) to control for cross-sectional correlation. Subsequently, Westerlund (2007), Kao (1999), and Pedroni (2004) were used to analyze the long-term relationships among the variables, indicating that the coefficients of SDG1, SDG3, SDG5, and SDG8 were significant regarding the independent variables. It could thus be concluded that there are long-term equilibrium relationships among the variables.

Table 4 presents the descriptive statistics of the main variables. The kurtosis of the dependent variable SDG8 and the core independent variable NC were >3, thus indicating a fat-tailed distribution. The skewness of all dependent variables was <0, and there was a left bias. The skewness of all independent variables was >0, and there was a right bias. The Shapiro–Wilk W test (Shapiro-Francia W′ test) rejected the null hypothesis that the variables were normally distributed, which provided an argument for using a quantile regression. In contrast to the traditional panel quantile regressions developed by Koenker (2004), Lamarche (2010), and Canay (2011), the MMQR takes into account the possible presence of fixed effects for individuals in the panel, which allows the effects of the conditional heterogeneous variance of the drivers of the dependent variable to be captured, thereby leading to more efficient results. Therefore, a quantile regression model that considered the location and scale effect could be written as follows:

$$QSDG_{it}(\tau|X_{it}) = \beta_0 + \beta_1 lnNC_{it} + \beta_2 lnPC_{it} + \beta_3 lnHC_{it} + \beta_4 FD_{it} + \beta_5 TO_{it} + \varepsilon_{it} \quad (5)$$

$QSDG_{it}(\tau|X_{it})$ denoted τ^{th} conditional quantile function and the meaning of each independent variable were shown in Table 1. The residuals were orthogonal to X_{it} and normalized to satisfy the moment conditions described in Machado and Silva (2019). From Eq. (4), it implies that:

$$QSDG_{it}(\tau|X_{it}) = (\alpha_i + \delta_i q(\tau)) + X_{it}^{'}\beta + Z_{it}^{'}\gamma q(\tau) \quad (6)$$

Where $\alpha_i(\tau) \equiv (\alpha_i + \delta_i q(\tau))$ was the scalar parameter which was indicative of the quantile τ fixed effect for individual *i*. *Z* was a k-vector of identified components of X which were differentiable transformations with element l given by $Z_l = Z_l(X), l = 1, \ldots, k$. Contrasting the least-squares fixed effects; the individual effects in this method did not represent intercept shifts (Viana et al., 2022). They were time-invariant parameters whose heterogeneous impacts differ across the quantiles of

Table 2
Indicator thresholds and justifications for optimal values (Take 2018 as an example).

SDGs	Sub-targets	Upper bound (Value = 100)	Lower bound (Value = 0)	Justification for optimum
SDG1	The proportion of the population using basic sanitation services	100	12	Leave no one behind
SDG1	The proportion of the population using basic drinking water services	100	45	Leave no one behind
SDG3	Neonatal mortality rate	1.02	40.7	Average of 5 best performers
SDG3	Mortality rate, under-5	2.32	114.2	Average of 5 best performers
SDG3	Incidence of tuberculosis	0	554	SDG target
SDG3	Traffic deaths rate	2.40	38.22	Average of 5 best performers
SDG3	Adolescent fertility rate	2.96	157.91	Average of 5 best performers
SDG3	Percentage of surviving infants who received 2 WHO-recommended vaccines	100	47	Leave no one behind
SDG5	The ratio of female to male mean years of schooling in the population aged 25 and above	100	24.5	SDG target
SDG5	The ratio of female to male labor force participation rate	100	22.55	SDG target
SDG8	Unemployment rate	0.39	22.37	Average of 5 best performers
SDG8	The annual growth rate of real GDP per employed person	9.56	−4.3	Average of 5 best performers

Table 3
The VIF test.

	lnNC	lnPC	lnHC	FD	TO
VIF	1.46	6.42	8.13	3.67	1.22

the conditional distribution of the environmental performance variable. From Eq. (4), the conditional quantile environmental performance's function was estimated based on the MMQR approach, which gave a solution to the following optimization problem (Viana et al., 2022):

$$min_q \sum_i \sum_t \rho_\tau \left(\widehat{R_{it}} - \left(\widehat{\delta}_i + Z_{it}^{'} \widehat{\gamma}\right) q\right) \quad (7)$$

here, $\rho_\tau(A) = (\tau - 1)AI\{A \le 0\} + \tau AI\{A > 0\}$ was the standard quantile loss function. Due to the marginal change in i, the parameter for a dependent variable (SDG) i might represent the marginal change in the τ^{th}conditional quantile of $QSDG_{it}(\tau|X_{it})$.

3. Results

3.1. Overall regression results

3.1.1. Baseline regression results

After confirming the stationarity and cointegration of the variables, the results are presented below using the ordinary least squares regression of clustering robust standard errors, and Table 5 shows the results of using OLS robust regression for different SDGs. In this context, when natural capital increases by 10%, SDG1, SDG3, and SDG5 decrease by 0.072, 0.217, and 0.139 percentage points, respectively, while SDG8 increases by 0.085 percentage points. It showed that SDG1, SDG3, and SDG5 are all in a situation of trade-off with natural capital, but SDG 8 is synergistic with natural capital, indicating that increase in natural resource income aggravates poverty and gender inequality and harms good health and well-being but also promotes sustainable decent work and economic growth. Similarly, research based on global panel data from 1992 to 2014 indicated that fossil energy resources exacerbate poverty (Apergis and Katsaiti, 2018). At the same time, dependence on natural resources, especially the use of fossil energy resources, will have a negative impact on the level of pollution emissions (Taiwo Onifade et al., 2021), thus making health conditions worse (Kim and Lin, 2017). Air pollution poses a major health risk in countries that rely on fossil energy to drive economic development (Fisher et al., 2021). There is a risk that gender inequality may be exacerbated in areas that are dependent on the mining sector (Kaggwa, 2020; Yakovleva et al., 2022). In addition, Van Krevel (2021) showed that a 1% reduction in natural capital per capita increases, the growth rate of inclusive wealth per capita by approximately 0.06 percentage points. These results do not imply that natural capital hinders the achievement of sustainability goals but rather that the conversion of natural capital to other forms of capital occurs in this process.

Furthermore, according to the regression results, an increase in produced capital contributes to the achievement of poverty reduction and good health and well-being, with SDG1 and SDG3 increasing by 1.188 and 0.832 percentage points, respectively, for every 10% increase in produced capital. Produced capital might impede the promotion of gender equality and decent work and economic growth, with SDG5 and SDG8 decreasing by 0.267 and 0.572 percentage points, respectively, for every 10% increase in produced capital. In this study, SDG8 represents the employment rate and the annual growth rate of real GDP per employed person. Since capital and labor are complementary in the production function, an increase in produced capital has a crowding-out effect on the employment rate (Bauducco and Janiak, 2018). The increase in human capital contributes to the achievement of the four sustainable development goals (Ahmed et al., 2020b), a finding which is consistent with the results of the research conducted by Cheng et al. (2021) and Olopade et al. (2019). When human capital increases by 10%, SDG1, SDG3, SDG5, and SDG8 increase by 0.454, 0.467, 0.661, and 0.343 percentage points, respectively.

Financial development has a significant positive association with SDG1 and SDG8 but harms the promotion of gender equality. Ofori et al.

Table 4
Descriptive statistics for the variables used.

	Obs.	Mean	Std. Dev.	Min	Max	Kurtosis	Skewness	Shapiro-Wilk W test
SDG1	2489	70.475	30.615	0	100	2.277	−0.807	0.874***
SDG3	2489	69.473	22.183	5.756	99.527	2.163	−0.532	0.933***
SDG5	2489	56.462	17.510	6.708	86.832	2.576	−0.443	0.972***
SDG8	2489	60.644	15.095	4.259	99.221	3.562	−0.578	0.980***
lnNC	2489	8.888	1.233	4.131	13.280	5.414	0.494	0.944***
lnPC	2489	9.654	1.683	5.292	12.930	2.280	0.002	0.981***
lnHC	2489	10.257	1.530	5.998	13.588	2.409	0.157	0.980***
FD	2470	0.317	0.232	0.029	1	2.873	0.935	0.887***
TO	2489	0.823	0.487	0.127	4.373	15.590	2.783	0.782***

Note: Shapiro–Wilk W test，significance levels are as follows: * 10%, ** 5%, *** 1%.

Table 5
OLS robust regression results.

	SDG1	SDG3	SDG5	SDG8
lnNC	−0.720**	−2.170***	−1.387***	0.850***
	(0.316)	(0.206)	(0.404)	(0.273)
lnPC	11.88***	8.315***	−2.671***	−5.720***
	(0.562)	(0.357)	(0.469)	(0.437)
lnHC	4.537***	4.673***	6.606***	3.434***
	(0.685)	(0.478)	(0.591)	(0.539)
TO	1.515**	0.655	−1.825***	1.062*
	(0.706)	(0.481)	(0.669)	(0.609)
FD	−6.538**	−5.009**	13.81***	8.130***
	(2.702)	(1.948)	(2.634)	(2.530)
Constant	−83.47***	−38.26***	23.76***	69.67***
	(3.726)	(2.575)	(3.888)	(3.294)
N	2470	2470	2470	2470
R^2	0.673	0.728	0.231	0.073

Note: OLS robust regression, significance levels are as follows: * 10%, ** 5%, *** 1%. Standard errors are in parentheses.

(2021) found that financial development has reduced poverty in sub-Saharan Africa, with economic growth playing an important mediating role in this process (Zameer et al., 2020; Zheng et al., 2021). In addition, there may be a two-way causal relationship between financial development and poverty reduction, with higher poverty rates undermining a country's financial development and reducing trade openness (Gnangnon, 2021). The research conducted by Asongu et al. (2020) indicated that financial channels have a negative net effect on the Gini coefficient and Palma ratio with respect to female employment. In contrast to produced capital, an increase in trade openness harms poverty reduction and good health and well-being in this context. Experience from Africa has shown that greater trade is associated with higher levels of poverty, but this adverse relation is reversed if the associated financial sectors are deep, education levels are high, and institutions are strong; otherwise, this situation has an impact on national well-being (Agénor, 2004; Le Goff and Singh, 2014; Shackleton et al., 2008). However, trade openness has a positive effect on promoting gender equality and decent work, and economic growth, a result which is consistent with the findings reported by Connolly (2022), Potrafke and Ursprung (2012), and Sikder et al. (2019).

3.1.2. *Quantile regression results*

Considering that quantile regression is particularly suitable for situations with fat-tailed and skewed distributions, and can provide fitting regression results for the dependent variable at any quantile. In this section, we examine the distributional and heterogeneous effects across quantiles by using the MMQR technique to test the robustness of the results reported above. As shown in Table 6, in most quantiles, natural capital still has a negative effect on SDG1, 3, and 5, while it has a positive effect on SDG8, which proves the robustness of OLS regression results. Before the 6th quantile, as the level of SDG1 and SDG5 increased, the negative impact of natural capital on SDG1 and SDG5 is gradually decreasing. After the 6th quantile, the correlation coefficient between natural capital and SDG1 was not significant. Similarly, the correlation coefficient between natural capital and SDG5 was not significant at the 7th quantiles and 8th quantiles but became positive at the 9th quantile. In other words, at higher levels of SDG1 and SDG5, the negative impact of natural capital extraction on poverty reduction and gender equality will weaken or even disappear. There are other possibilities, for example, when the poverty rate decreases to a certain level and gender equality reaches a certain level, it will control the loss of natural capital, so that there is no significant correlation between the two. For SDG3, reliance on natural capital reduced the level of good health and well-being, the negative impact of natural capital utilization on health is even stronger. There was a positive relationship between natural capital and SDG8, and as the level of SDG8 increased, the more obvious the contribution of natural capital to decent work and economic growth became. On a global scale, even at high levels of economic development, economic growth still heavily relies on natural capital, and the correlation between the two shows an upward trend. The trade-offs and synergies between natural capital and the four socio-economic goals are shown in Fig. 2. It can be seen that at a higher level of socio-economic development, natural capital development still has a strong promoting effect on economic growth, and at the same time, it will have a more negative impact on good health. However, for poverty and gender equality, it may achieve decoupling. Furthermore, the results based on scale parameters showed clearly that natural resources had a high positive dispersion across quantiles for SDGs 1, 5, and 8, thus indicating an increase in the variance of natural capital across quantiles and revealing the heterogeneity of the estimated coefficients of natural capital on SDGs.

Produced capital was positively significant across all quantiles for SDG1 and SDG3 but negatively significant across all quantiles for SDG5 and SDG8, which is consistent with the OLS regression results. This finding indicates that produced capital was not conducive to promoting gender equality, decent work, and economic growth. Human capital was positively significant across all quantiles for SDGs 1, 3,5, and 8. Therefore, human capital development plays an important role in achieving these four socio-economic objectives and should be viewed as a priority, a finding which is consistent with the results of the research conducted by Rahim et al. (2021).

The early stages of development facilitate the effective transformation of natural resource to satisfy the requirements of productive ambitions, but poverty, good health, and gender equality could thus be compromised, which also reflects the trade-off between efficiency and equity to some extent (Bonnedahl et al., 2022). Most economic growth strategies encourage rapid physical and financial accumulation but lead to the excessive depletion and degradation of natural capital (Langnel et al., 2021). According to the results of quantile regression, special attention needs to be paid to the harm of natural capital utilization to health. In the early stages of development, it is necessary to balance the use of natural capital with the achievement of socio-economic objectives and to promote the conversion of natural capital to poverty reduction, the achievement of gender equality, and good health and well-being to minimize ecological and environmental damage rather than merely focusing on economic growth. Therefore, more sound public policies are needed, including reforms to the property rights system, pricing and regulatory measures.

3.1.3. *Polynomial regression results*

The above regression analysis indicates that the relationship between natural capital and sustainable socio-economic development goals will also change at different stages of development. Considering the heterogeneity of the distribution of the variables and the possible nonlinear relationship between natural capital and socio-economic objectives, polynomial regression, was used for analysis. Additionally, the group-mean fully modified OLS (FMOLS) estimator of Pedroni (2004) for non-transformed and demeaned data was considered. The FMOLS estimator simultaneously corrects for serial correlation, endogeneity, and sample bias asymptotically via a non-parametric correction. The regression was conducted by adding the quadratic and cubic terms of natural capital to the fully modified OLS model, and the results are shown in Table 7. For SDG1, SDG3, and SDG5, the coefficients of the primary and cubic terms of natural capital were significantly negative, and the coefficient of the quadratic terms was significantly positive. For SDG8, the coefficients of the primary and cubic terms of natural capital were significantly positive, and the coefficients of the quadratic terms were significantly negative. The positions of the inflection points of the regression curves were calculated based on the primary, quadratic, and cubic coefficients and combined with the distribution of data.

Most of the data were on either side of the inflection point. It can be concluded that natural capital has an inverted U-shaped relationship

Table 6
MM-Quantile regression results for socio-economic objectives.

	Variables	Location	Scale	Quantiles								
				10	20	30	40	50	60	70	80	90
SDG1	lnNC	−0.720**	0.542***	−1.597***	−1.404***	−1.162***	−0.865***	−0.677**	−0.501*	−0.296	−0.114	0.0442
		(0.315)	(0.175)	(0.476)	(0.430)	(0.380)	(0.331)	(0.311)	(0.304)	(0.307)	(0.322)	(0.343)
	lnPC	11.88***	−1.266***	13.93***	13.48***	12.91***	12.22***	11.78***	11.37***	10.89***	10.47***	10.10***
		(0.586)	(0.326)	(0.886)	(0.801)	(0.708)	(0.618)	(0.580)	(0.566)	(0.573)	(0.599)	(0.638)
	lnHC	4.537***	−1.372***	6.756***	6.269***	5.655***	4.905***	4.428***	3.982***	3.464***	3.005***	2.603***
		(0.732)	(0.407)	(1.108)	(1.001)	(0.884)	(0.772)	(0.725)	(0.707)	(0.716)	(0.749)	(0.798)
SDG3	lnNC	−2.170***	−0.139	−1.930***	−2.028***	−2.088***	−2.136***	−2.180***	−2.227***	−2.271***	−2.308***	−2.368***
		(0.202)	(0.128)	(0.350)	(0.278)	(0.240)	(0.216)	(0.199)	(0.189)	(0.189)	(0.195)	(0.216)
	lnPC	8.315***	−0.859***	9.798***	9.193***	8.819***	8.522***	8.250***	7.958***	7.689***	7.457***	7.089***
		(0.391)	(0.247)	(0.677)	(0.539)	(0.464)	(0.417)	(0.384)	(0.366)	(0.365)	(0.376)	(0.418)
	lnHC	4.673***	−0.647**	5.789***	5.334***	5.052***	4.829***	4.624***	4.405***	4.202***	4.027***	3.751***
		(0.481)	(0.304)	(0.834)	(0.663)	(0.572)	(0.513)	(0.473)	(0.450)	(0.449)	(0.464)	(0.515)
SDG5	lnNC	−1.387***	1.478***	−4.048***	−2.937***	−2.296***	−1.496***	−0.945***	−0.546**	−0.174	0.179	0.617**
		(0.327)	(0.221)	(0.654)	(0.506)	(0.431)	(0.343)	(0.293)	(0.266)	(0.256)	(0.256)	(0.269)
	lnPC	−2.671***	−0.0969	−2.496**	−2.569***	−2.611***	−2.664***	−2.700***	−2.726***	−2.750***	−2.773***	−2.802***
		(0.502)	(0.339)	(1.005)	(0.777)	(0.654)	(0.518)	(0.445)	(0.409)	(0.391)	(0.391)	(0.414)
	lnHC	6.606***	−1.498***	9.302***	8.176***	7.527***	6.716***	6.157***	5.754***	5.376***	5.018***	4.575***
		(0.644)	(0.435)	(1.289)	(0.996)	(0.842)	(0.668)	(0.573)	(0.524)	(0.502)	(0.503)	(0.531)
SDG8	lnNC	0.850***	0.373*	0.246	0.506	0.664**	0.800***	0.912***	1.017***	1.121***	1.237***	1.397***
		(0.279)	(0.190)	(0.504)	(0.393)	(0.334)	(0.292)	(0.266)	(0.251)	(0.247)	(0.256)	(0.289)
	lnPC	−5.720***	0.0467	−5.795***	−5.763***	−5.743***	−5.726***	−5.712***	−5.699***	−5.686***	−5.671***	−5.651***
		(0.474)	(0.323)	(0.855)	(0.667)	(0.568)	(0.496)	(0.452)	(0.427)	(0.420)	(0.435)	(0.490)
	lnHC	3.434***	−0.998**	5.051***	4.354***	3.932***	3.566***	3.268***	2.987***	2.706***	2.396***	1.968***
		(0.600)	(0.409)	(1.083)	(0.844)	(0.718)	(0.627)	(0.572)	(0.540)	(0.531)	(0.551)	(0.621)

Note: MM-Quantile regression, significance levels are as follows: * 10%, ** 5%, *** 1%. Standard errors are in parentheses.

with SDG1, SDG3, and SDG5, which increased and subsequently decreased as natural capital increased. The U-shaped relationship between natural capital and SDG8, which decreased and subsequently increased as natural capital increased. SDG1 and SDG3 peaked at a natural capital per capita that was >8000, and SDG5 peaked at a natural capital per capita >20,000, while SDG8 reached the lowest point when natural capital per capita was >8000. It indicates that in the early stages of natural capital utilization, it may have a positive impact on poverty reduction, good health, and gender equality. While as the loss of natural capital deepens, it will mainly be beneficial for economic growth and have a negative impact on SDGs 1, 3, and 5. On both sides of the inflection point, the relationship between the loss of natural capital and the four socio-economic objectives will change. Since the distribution of natural capital with a right thick tail, thus, in the long term, natural capital was in a trade-off relationship with SDGs 1, 3 and 5, but its relationship with SDG8 was synergistic, which was consistent with the OLS regression results.

3.2. Grouped country-level results

Considering the diversity of individual countries worldwide, the role of natural capital in the process of achieving the socio-economic objectives varies across countries at different levels of development. Therefore, we classified the 131 countries into the four categories of high income, upper-middle income, lower-middle income, and low income based on the Changing Wealth of Nations 2021 report and conducted OLS regressions (Table 8). The role of natural capital in SDGs varies at different income levels. Compared to overall regression, the dependence on natural capital of high income and middle-income countries is not only beneficial for economic growth, but also for poverty reduction and gender equality, respectively. In low income country, the dependence on natural capital is only beneficial for economic growth, which is consistent with Khan et al. (2022)'s research.

The relationship between natural capital and the four socio-economic objectives in each type of country indicated that countries with high levels of development should be aware of the damage to gender equality and good health and well-being that can result from a reliance on natural capital. For upper-middle-income countries versus lower-middle-income countries, the main concern was the negative impact on poverty reduction in the use of natural capital, while in low-income countries, reliance on natural capital might impede poverty reduction and harm gender equality as well as good health and well-being. The role of natural capital in the achievement of sustainability goals varies at different stages of economic development, thus requiring each country to choose the best development path based on a trade-off between the country's natural capital situation and socio-economic objectives. As for the relationship between natural resources and economic growth in low- and middle- income countries, Topcu et al. (2020) found a positive association. A natural resource boom shifts labor from non-resource-intensive sectors to resource-intensive sectors, thereby increasing stable employment opportunities. However, many studies have shown the existence of a resource curse, according to which many resource-rich countries fall into the trap of economic development (Yilanci et al., 2021).

4. Discussion

The objective of this research was to understand the role played by natural capital in sustaining human development. Our study provided new insights into the impact of natural capital on socio-economic objectives in the global context and help to address the problem of natural resource utilization.

The relationship between natural capital and socio-economic objectives observed in this study proves to be consistent with existed studies (Wu et al., 2022). The massive exploitation of natural resources and their transformation into human capital and produced capital have

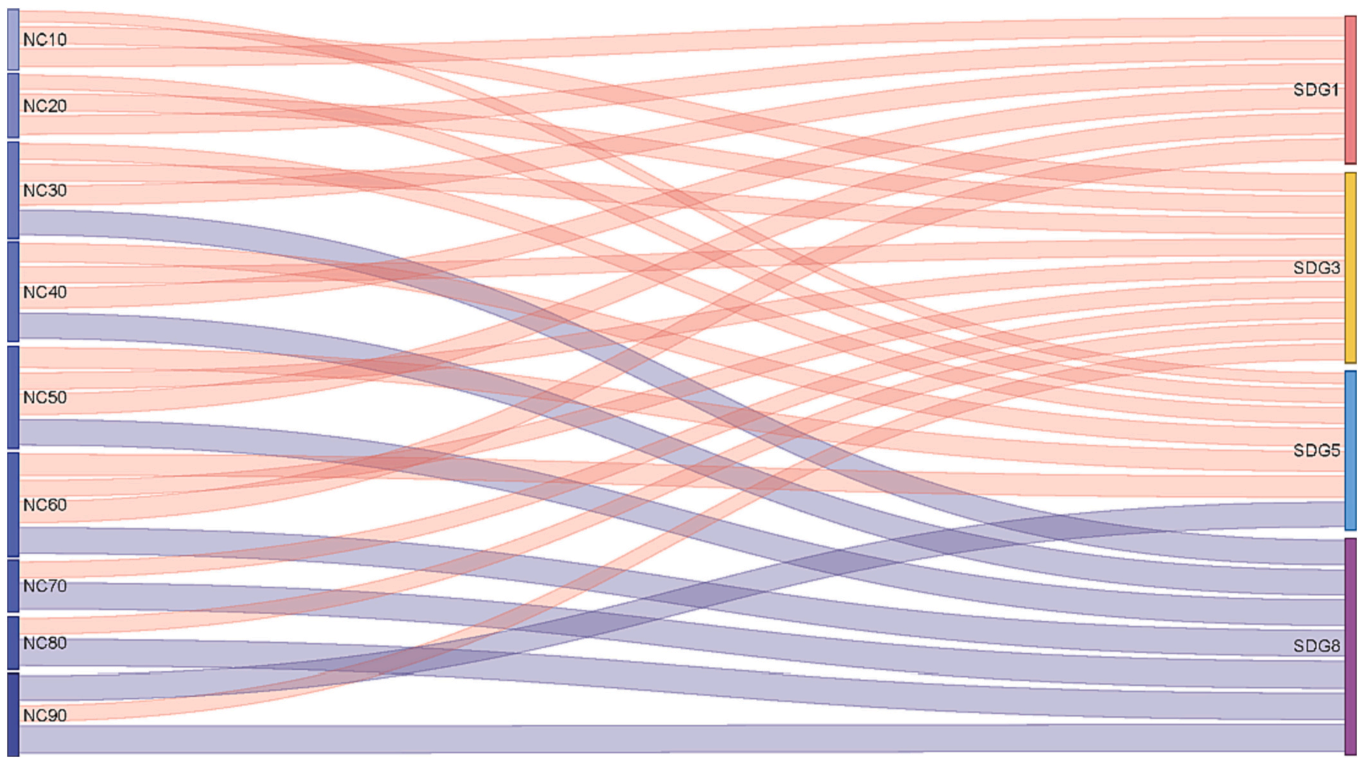

Fig. 2. Trade-offs and synergies between natural capital and socio-economic objectives.
Note: The blue line indicated the synergies; the red line indicated the trade-offs. The thicker the line, the closer the relationship between the two.

contributed to rapid economic growth but have also increased poverty and gender inequality, led to global environmental degradation, and had negative impacts on good health and well-being (Bateman and Mace, 2020). In the polynomial results, we found that the impact of natural capital on SDG1 and SDG3 is completely opposite to the impact on SDG8. In addition, when it reaches a particular stage of development, the nature of natural capital loss will be changed. Therefore, the relationship between natural capital and socio-economic objectives may be more complex, and having an efficient governance system and consistent policies is the key to implementing many sustainable development goals (Nilsson et al., 2018). Admittedly, during the process of development, we could not avoid the necessity of sacrificing natural capital in pursuit of economic growth. However, different patterns of natural resource use, levels of depletion, and ecological conditions may affect the synergistic effect of natural capital and socio-economic objectives during later stages (Reynolds et al., 2010). In addition, science, technology, and innovation are critical to achieving the goal of sustainable socio-economic development through the use of natural capital (Cohen et al., 2019).

The research results provide a method for each country to judge the relationship between natural capital and socio-economic objectives. Through the estimation of natural capital and socio-economic objectives, the decision-makers preliminarily determine the stage they are in and identify the possible risks in the use of natural capital and the realization of social and economic sustainable development goals, as

Table 7
Nonlinear regression results.

	SDG1	SDG3	SDG5	SDG8
$lnNC^3$	−3.690***	−25.02***	−1.492***	37.27***
	(0.507)	(0.815)	(0.390)	(7.748)
$lnNC^2$	68.73***	451.6***	31.80***	−674.9***
	(9.019)	(14.50)	(6.937)	(137.9)
lnNC	−338.4***	−2025.2***	−188.9***	3101.2***
	(40.11)	(64.47)	(30.85)	(613.1)
Control variables	YES	YES	YES	YES
N	18	18	18	18
R^2	0.929	0.967	0.992	0.668
Shape	Inverted U shape	Inverted U shape	Inverted U shape	U shape
Inflection point (NC per capita)	8349.86	8518.54	21,590.31	8022.46

Note: Fully Modified OLS regression, significance levels are as follows: ** 5%, *** 1%. Standard errors are in parentheses.

Table 8
OLS robust regression results by country's development level.

	Variables	SDG1	SDG3	SDG5	SDG8
High income	lnNC	0.696***	−1.210***	−6.513***	0.632*
		(0.171)	(0.155)	(0.508)	(0.344)
	Control variables	YES	YES	YES	YES
	R^2	0.564	0.738	0.541	0.13
	N	722	722	722	722
Upper middle income	lnNC	−2.484***	−4.961***	3.082***	0.0899
		(0.382)	(0.374)	(0.573)	(0.582)
	Control variables	YES	YES	YES	YES
	R^2	0.234	0.254	0.339	0.019
	N	722	722	722	722
Lower middle income	lnNC	−12.75***	0.585	6.153***	6.319***
		(1.127)	(0.829)	(0.885)	(1.002)
	Control variables	YES	YES	YES	YES
	R^2	0.46	0.378	0.206	0.186
	N	608	608	608	608
Low income	lnNC	−8.701***	−12.13***	−8.209***	3.826***
		(1.237)	(0.679)	(1.016)	(1.39)
	Control variables	YES	YES	YES	YES
	R^2	0.37	0.667	0.383	0.199
	N	418	418	418	418

Note: OLS robust regression, significance levels are as follows: * 10%, ** 5%, *** 1%. Standard errors are in parentheses.

well as the complex trade-offs and synergies between them, to formulate a better development plan. In the process of using natural resources, we should not only focus on the economic benefits they can provide but also evaluate the impact they have on the human well-being. Policy-makers should discover the best use of natural capital without compromising it (Sinha and Sengupta, 2019), thereby generating social, economic, and environmental benefits and contributing to the achievement of sustainable development goals in all areas (Gómez Martín et al., 2020). The utilization of natural resources should be based on the principle of strong sustainability (Bateman and Mace, 2020; Brand, 2009; Daly, 2019). However, the mutual constraints among many stakeholders reduce the likelihood of win-win outcomes due to the complexity of the real world (Hegwood et al., 2022). Many current sustainability theories and assessment methods are anthropocentric, which has led to conflicting contradictions and perspectives. We must consider the definition of development and the relationship between people and other creatures on the planet in further detail. With respect to natural capital, governments must make public investments and create corresponding incentives to prevent depletion or unsustainable conversion to other forms of capital (Ruggeri, 2009).

Although this study provides important and interesting findings, there are some limitations in the data and methodology. First, the SDGs data were not comprehensive, and several socio-economic objectives were not included in this study due to missing data (for example SDG4 and SDG10). Second, natural capital was assessed only in terms of the characteristics of assets in response to the existing market value, which could have been distorted and may have deviated from the real value due to externalities, national policies, and property rights systems. Accordingly, this approach might have led us to misunderstand the utilization status of natural capital. Third, structural changes in nonrenewable capital, such as coal, oil, and natural gas, as well as in renewable capital, such as forests, grasslands, and farmland, were not reflected in the research reported in this paper. For nonrenewable capital, an increase in its value might entail an increase in extraction, while for renewable capital, such an increase might involve the conversion of land types. Treating natural capital merely as an overall value entailed ignoring the interactions and offsets of internal values, and more microscopic studies would be important for guiding local practice.

5. Conclusion

This study is the first to examine the role played by natural capital in the achievement of four socio-economic objectives based on global panel data concerning 131 countries during the period 2000 to 2018. In the long term, the dependence on natural capital improves a country's economic development and offers decent work but is detrimental to poverty reduction, good health and well-being, and gender equality. At a higher level of socio-economic development, the negative impact of natural capital on poverty reduction and gender equality may be decoupled. In polynomial regression, natural capital has an inverted U-shaped relationship with SDGs 1,3,5, and a U-shaped relationship with SDG8. Additionally, the relationships between natural capital and each objective are different for countries that exhibit different levels of development. Compared to overall regression, the dependence on natural capital of high income and middle-income countries is not only beneficial for economic growth, but also for poverty reduction and gender equality, respectively.

Compared to existing literature, this study can be used to deeply understand the consumption of natural capital and the stage of the goal of social and economic sustainable development in various countries. Future research can analyze the impacts of different types of natural capital on local socio-economic objectives at the project case level, especially some key types of natural capital (Saiu et al., 2022). Meanwhile, we should consider the characteristics of each country's natural capital utilization and the role of technological change when exploring the relationship between natural capital and socio-economic objectives in various types of countries, which should allow us to find the best development paths and the appropriate levels of conversion of natural capital into other forms of capital for different countries.

CRediT authorship contribution statement

Yating Dai: Conceptualization, Methodology, Writing – original draft. **Yuze Ding:** Formal analysis, Writing – review & editing. **Shuya Fu:** Formal analysis, Writing – review & editing. **Lixin Zhang:** Formal analysis, Writing – review & editing. **Jian Cheng:** Formal analysis, Writing – review & editing. **Daolin Zhu:** Conceptualization, Supervision, Funding acquisition.

Declaration of Competing Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Data availability

The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding authors.

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