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Does China's poverty alleviation policy improve the quality of the ecological environment in poverty-stricken areas?

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Poverty eradication and environmental protection as the two global goals of sustainable development. China's poverty alleviation policy attempts to achieve green development in poverty-stricken areas by eliminating poverty while also promoting environmental protection. Since the Poverty-stricken counties on the Qinghai-Tibet Plateau also have the dual attributes of ecological degradation and ecological fragility, it is of great significance to study the impact of poverty alleviation policy on their environment. In this research, taking poverty alleviation policy as the entry point, based on panel data and Remote Sensing Ecological Index for poverty-stricken counties on the Qinghai-Tibet Plateau from 2011 to 2019, and using the difference-in-differences (DID) method to verify the impact of policy on environmental quality. The main findings of the study were: 1) The poverty alleviation policy has a significant improvement effect on the ecological environment quality of counties in the Qinghai-Tibet Plateau region, and this conclusion still holds in a series of robustness tests using methods including the changing sample size method and the variable replacement method. Moreover, the policy effect has a certain time lag and its effect persists in the long term; 2) It is mainly due to the increased level of government public expenditure and the easing of government financial pressure that has contributed to the improvement of environmental quality in poverty-stricken areas; 3) Policy heterogeneity suggests that industrial poverty eradication policies are more conducive to promoting synergistic economic and environmental development in poverty-stricken areas.

KEYWORDS

Qinghai-Tibet plateau, poverty-stricken counties, remote sensing ecological index, poverty alleviation, difference-in-difference (DID) method

1 Introduction

The Chinese government implemented the poverty alleviation policy in 2015, which attempts to completely eliminate absolute poverty in the Chinese region. In 2020, China achieved the total alleviation of poverty in rural areas under the current standard and the removal of all poverty-stricken counties. The average annual number of poverty reduction

in the past 5 years is more than 11 million, and regional overall poverty has been solved (Zhu et al., 2014). However, existing studies show that poverty reduction and economic development also bring rapid consumption of resources and environmental damage (Mafi-Gholami and Baharlouii, 2019; Liu et al., 2021), and Poverty-stricken counties overlap highly with ecologically fragile areas geographically and spatially (Wu and Jin, 2020; Wu et al., 2021), which are more likely to cause serious environmental quality deterioration problems in the process of poverty alleviation. At the same time, the policy of poverty alleviation requires ecological poverty alleviation, so it is of great significance to study the impact of poverty alleviation policy on the environment in poor areas to achieve sustainable development.

Environmental quality, a key component of the wellbeing of the world's poor, is deteriorating at an alarming rate (Assessment, 2005). In the current research on poverty governance, scholars generally agree that the "environmental poverty trap" is a major constraint on economic development and environmental protection in poverty-stricken areas (Haider et al., 2018; Zhen et al., 2014). The main reason is that people in poverty-stricken areas are usually located in fragile environments (Zhen et al., 2014), and they are highly dependent on natural resources as a source of economic income and tend to overuse land, forests and other natural resources, causing damage to the ecological environment (Cavendish, 2000; Samal et al., 2003), which in turn may lead to "ecological poverty" (Dasgupta et al., 2005; Guo and Liu, 2021), i.e., in the absence of natural resources and ecological degradation, people are unable to obtain the natural resources they need to sustain their living activities, thus further increasing poverty and creating a vicious spiral. In this vicious cycle, poverty leads to environmental degradation, and environmental degradation further exacerbates poverty (Gupta and Vegelin, 2016; Zhou et al., 2019). At the same time, since poverty governance has been a hot issue of international concern, many countries have implemented a series of policies to try to eliminate poverty. For example, Bangladesh has implemented the Employment Poverty Alleviation Program (Ravallion, 1990); Nigeria has implemented the National Economic Empowerment and Development Strategy (Pereira, 2008). However, these policies only focus on economic benefits and neglect environmental protection, which will easily lead to "resource plundering poverty alleviation" (Comim et al., 2009; Skutsch et al., 2017). Many governments in poor areas will seek economic development at the expense of destroying the environment (Gray and Moseley, 2005), i.e., emphasizing economic benefits at the expense of ecological benefits, short-term benefits at the expense of long-term benefits, accelerating and intensifying the plundering and exploitation of natural resources, which will lead to the deterioration of the environment in their areas. In general, academics generally agree that there is a vicious cycle of poverty and ecological degradation (Cavendish, 2000; Dasgupta et al., 2005; Liu et al., 2008).

Since the 21st century, poverty and the environment have received increasing attention in developing countries as two key elements of sustainable development strategies (Zhen et al., 2014), and there is a large degree of international consensus that environmental protection should be part of all poverty eradication policies and that poverty alleviation and ecological conservation must develop in tandem (Qin and Zhang, 2022; Wiedmann and Allen, 2021; Zhu et al., 2020). Therefore, for the study of current poverty alleviation policies, we should not only focus on the economic effects of poverty alleviation, but also on multi-dimensional improvements (Huang et al., 2022; Zhen et al., 2014). A growing number of scholars believe that pro-poor policies should take into account their environmental effects and give due consideration to the elimination of multidimensional poverty as a way to promote sustainable development strategies (Davies et al., 2014). Therefore, it is now necessary to analyze the impact of economic growth brought about by poverty alleviation on the quality of ecological environment, and to consider its ecological improvement benefits when studying the economic effects of poverty alleviation (Fu et al., 2021). In the current context, quantifying the conflict between poverty alleviation and ecological protection is nothing less than an emerging area of concern (Li R. Q et al., 2021). Unlike the poverty eradication policies implemented in other countries, China's poverty eradication policy emphasizes the relationship between ecological environmental protection and socioeconomic development in the process of poverty eradication, and further clarifies the principles of poverty alleviation policies, requiring ecological protection as the main focus, not at the expense of ecology, and exploring new ways of ecological poverty alleviation to develop the economy and get rid of poverty (Huang, 2022). Although China has successfully established a developmental approach to poverty alleviation with Chinese characteristics and achieved total poverty eradication, the impact of this policy on the ecological environment in poor areas has been generally overlooked (Zhang and Feng, 2020).

Known as the "roof of the world" and the "third pole of the Earth", the Qinghai-Tibet Plateau is a "sensor" and "sensitive area for climate change in Asia and even the Northern Hemisphere (Wang et al., 2016; Wu et al., 2014). The Qinghai-Tibet Plateau is different from other regions of the world because of its high altitude, complex landscape and fragile ecology (Cao et al., 2015). At the same time, as the "water tower of Asia", the ecological protection of the Qinghai-Tibet Plateau is of great importance, not only for the sustainable development of the whole East Asia region, but also for the environmental changes that will indirectly affect other regions of the world (Dong et al., 2020; Mahmood et al., 2020; Wang et al., 2015). Therefore, ecological changes on the Qinghai-Tibet Plateau have been one of the hot spots for global environmental and sustainable development research (Jiang et al., 2017). According to the national-level poverty counties

TABLE 1 Descriptive statistics of the main variables.

Variable name	Variable definition	Average value	Standard deviation	Minimum value	Maximum value
RSEI_Index	Ln (RSEI*100 + 1)	3.902	0.282	2.511	4.410
Treat·T		0.497	0.500	0	1
ID	The ratio of the number of industrial enterprises above the scaleto the area of the jurisdiction*10	0.0555	0.421	0	8.696
second	The ratio of gross value of secondary industry (million yuan) to gross regional product (million yuan)	0.290	0.193	0.00522	0.921
NDVI	Normalized Difference Vegetation Index	0.719	0.116	0.323	0.864
pd	The ratio of total population to jurisdictional area at the end of year for each county	0.0286	0.176	0.0000086	3.545
lnPGDP	The logarithm of GDP *per capita*	9.805	0.692	7.931	12.94
Third	The ratio of gross tertiary sector product (million yuan) to gross regional product (million yuan)	0.41	0.162	0.02	0.960
EPI	GDP annual growth rate	0.154	0.413	-0.872	7.977
GFP	Local government fiscal vertical imbalance rate	0.49	2.53	0.007	26.438
GPS	Logarithm of local government fiscal expenditures	11.395	0.87	7.2	13.271

data released by the Chinese government, it can be found that the regional poverty rate in the Qinghai-Tibet Plateau region is high, and its regional GDP only accounts for 0.64% of China's GDP (Qi and Li, 2021; Qi et al., 2022), and the poverty-stricken counties on the Qinghai-Tibet Plateau suffer from backward productivity, single industrial structure, and inefficient resource development, which greatly limit their economic development. On the other hand, the poverty-stricken counties on the Qinghai-Tibet Plateau overlap geographically and spatially with the "Protection Plan for China's Ecologically Fragile Areas" issued by the Chinese Ministry of Environmental Protection. Therefore, the poverty-stricken counties on the Qinghai-Tibet Plateau have multiple characteristics such as ecological fragility, ecological degradation, high incidence of poverty, and backward productivity, which are more special and representative than other poor regions (Qi et al., 2022; Wang et al., 2020), and it is easier to identify the environmental impacts caused by the economic development and human production and life carried out during the implementation of the poverty alleviation policy, which provides a good research sample for the study of this paper, so this paper chooses the poverty-stricken counties on the Qinghai-Tibet Plateau as the research object.

In summary, scholars have now begun to approach policies related to poverty eradication from several aspects and dimensions (Hou et al., 2021; Howe et al., 2013; Huang et al., 2022; Rakatama and Pandit, 2020). However, there are fewer studies on the impact of poverty eradication on the environment (Fu et al., 2021), and few papers quantify the policy effects of poverty alleviation policies on environmental protection from the perspective of policy evaluation (Li T et al., 2021; Malerba, 2020), so it is impossible to make a scientific and accurate evaluation of the policy effects, and the conclusions drawn from the existing literature through correlation analysis are not sufficient to truly reflect the law of causality. In view of this, this paper considers poverty alleviation policy as a "quasi-natural experiment" and takes the Qinghai-Tibet Plateau region, where poverty and ecological degradation coexist, as a sample to evaluate the ecological conservation effect of poverty alleviation policy using the difference-in-differences model, which provides a reference for the design of green poverty alleviation policy. In particular, based on a systematic and rigorous empirical study, this paper attempts to explore the following central but not yet well answered questions: Does poverty alleviation policy help improve the ecological and environmental quality of counties in the Tibetan Plateau region? What is the mechanism of its impact on environmental quality? In order to provide a basis and reference for eliminating relative poverty and achieving common prosperity in poor areas, and to provide policy reference for poverty alleviation undertakings and ecological governance in other poor countries.

Compared with the existing research results, the contributions of this paper are reflected in the following four aspects: 1) Starting from the environmental effects of policy, we examine the effects and transmission mechanisms of poverty alleviation policy, and identify the policy effects by using the difference-in-differences model, which makes up for the lack of research on the environmental effects of poverty alleviation policy in current studies. 2) Discuss the environmental effects of different kinds of policy in terms of heterogeneity, and provide proven policy recommendations for further improving the

TABLE 2 Baseline return.

Variable name	Environmental quality level							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Treat·T	0.407***	0.445***	0.223***	0.209***	0.152*	0.152*	0.193**	0.195**
	(4.65)	(4.85)	(3.38)	(3.20)	(1.96)	(1.96)	(2.21)	(2.22)
Third		0.204**	0.275***	0.253***	0.554***	0.544***	0.496***	0.496***
		(2.11)	(3.52)	(3.38)	(6.77)	(6.73)	(6.61)	(6.59)
lnPGDP			−0.205***	−0.211***	−0.261***	−0.263***	−0.269***	−0.270***
			(−6.64)	(−6.88)	(−7.78)	(−7.65)	(−7.72)	(−7.67)
EPI				0.045***	0.050***	0.051***	0.058***	0.058***
				(3.72)	(3.76)	(3.70)	(4.02)	(4.02)
second					0.380***	0.383***	0.418***	0.419***
					(4.72)	(4.71)	(4.99)	(5.00)
ID						0.161	−2.526*	−2.513*
						(0.84)	(−1.79)	(−1.78)
pd							0.703**	0.699*
							(1.97)	(1.96)
NDVI								0.038
								(0.50)
Constant term	4.082***	4.004***	5.883***	5.941***	6.190***	6.212***	6.275***	6.260***
	(137.68)	(80.44)	(22.04)	(22.54)	(21.88)	(21.34)	(21.22)	(21.41)
Regional fixed effects	YES	YES	YES	YES	YES	YES	YES	YES
Time fixed effects	YES	YES	YES	YES	YES	YES	YES	YES
N	513	513	513	513	513	513	513	513
R^2	0.420	0.431	0.593	0.597	0.627	0.627	0.636	0.636

Note: *, ** and *** denote 10%, 5% and 1% significant levels, respectively; t-statistics are in parentheses.

poverty alleviation strategy and achieving the dual goals of poverty alleviation and ecological improvement. 3) For the assessment of policy effects, some existing empirical studies in the literature use the single-difference method to assess policy effects by comparing the differences in economic performance before and after poverty alleviation measures, and this simple comparison method cannot identify the net growth effects of poverty alleviation policy after excluding other influencing factors (Wu et al., 2021; Zhang et al., 2022), so this paper overcomes the estimation bias in some previous studies by using the difference-in-differences model to identify the poverty alleviation the net effect of poverty alleviation policy on environmental improvement, and applying multiple methods to robustness test the results. 4)Most of the existing studies carry out econometric analysis in terms of provinces and municipalities, and there is little literature on the effects of poverty alleviation policy on the ecological environment quality in ecologically fragile and poor areas. Current research generally agrees that environmental protection and poverty eradication are incompatible, that economic development in poor areas leads to environmental degradation, and that whether efforts to reduce poverty reduce or exacerbate environmental degradation remains a long-standing debate in the economics literature. This paper measures the environmental effects of China's poverty eradication policies through an empirical study, and the results show that China's poverty alleviation policy that requires synergistic development of economic development and environmental protection can achieve compatibility between environmental protection and economic development in poor areas, which makes certain

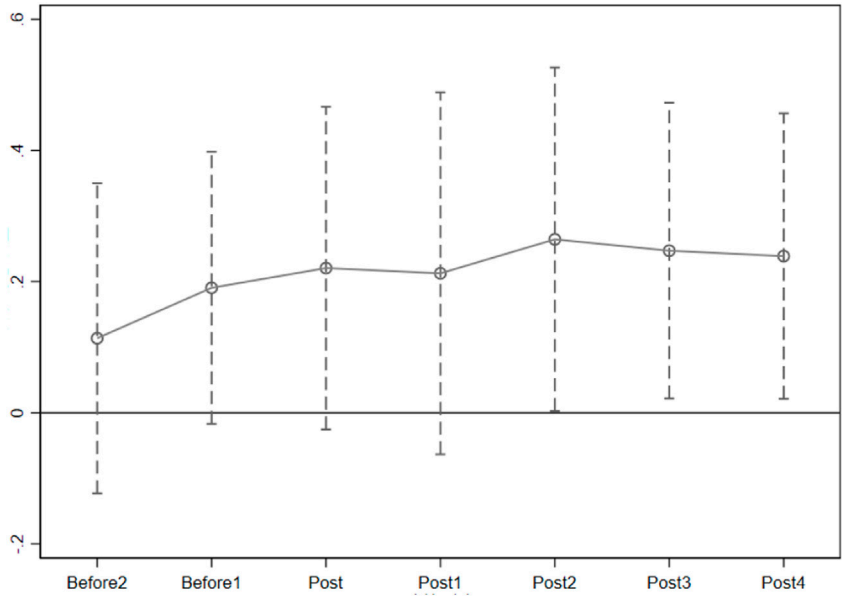

FIGURE 1
Parallel trend test.

additions to the relevant studies of poverty trap theory and provides suggestions for the formulation of poverty alleviation policies in other countries. This paper investigates the development of Poverty-stricken counties on the Qinghai-Tibet Plateau in China in the context of poverty alleviation policy.

2 Literature review and research hypotheses

2.1 Literature Review

The current evaluation of poverty alleviation policy mainly focuses on one dimension of their policy, and most studies only focus on the relationship between support policy and economic aggregates, that is, on the growth effect of policy or the quantitative effect of policy, while some scholars also study the industrial structure upgrading effect, fixed investment effect, employment effect, and sustainable development capacity effect of policy (Busso et al., 2013; Cristina and Guido, 2011; Giua, 2017). For example, Park evaluated the economic growth effect of large-scale poverty alleviation program on counties and found that the implementation of the policy significantly promoted the economic development of counties (Park et al., 2002); Some scholars have also evaluated the economic effect of the establishment of poverty eradication policies and used the PSM-DID model to study the effect of the implementation of poverty eradication policies on local economic development, and empirically found that the implementation of poverty eradication policies has a significant and sustained promotion effect on local economic development, and the longer the poverty eradication policies are implemented, the greater the promotion effect (Deng et al., 2022; Jiang et al., 2021; Yang et al., 2022).

However, a growing number of scholars believe that poverty-stricken policies should take into account environmental effects and give due consideration to the elimination of multidimensional poverty as a way to promote sustainable development strategies (Brooks et al., 2012; Leffel et al., 2022; Porras and Asquith, 2018). For example, Barbier argues that emissions reduction policy may affect economic development for poverty reduction and that there is a need to assess how the design and implementation of emissions reduction policy affect the potential trade-offs between positive and negative impacts on poverty reduction and to study emissions reduction and poverty reduction together (Barbier, 2014); Howe argues that there are complex interlinkages between ecology and poverty and that it is important to develop policy in these areas recognize the importance of these linkages and study them together (Howe et al., 2013); Meijaard argues that previous studies have focused on the environmental outcomes of policy and ignored their economic consequences, and that there is now a need to focus on the impact of policy on both poverty reduction and environmental protection outcomes (Meijaard et al., 2020); Brashares argues that poverty is a key constraint on environmental protection, that poverty must be addressed to achieve environmental protection goals, and that environmental

TABLE 3 Robustness tests.

Variable name	Change time interval			Replacing variable measurements	Using the tobit model	Truncation processing	Change model settings	Propensity score matching	Lagged core explanatory variables
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Treat·T	0.221*	0.232**	0.202**	0.118***	0.027***	0.326***	0.190**	0.606**	0.261***
	(1.88)	(1.98)	(2.18)	(3.87)	(2.96)	(2.95)	(2.08)	(2.53)	(2.79)
Third	−0.174	−0.103	−0.013	0.156**	0.028	0.602***	0.507***	0.555***	0.440***
	(-1.22)	(−0.92)	(−0.14)	(2.31)	(0.76)	(6.20)	(6.35)	(4.56)	(5.25)
lnPGDP	−0.226***	−0.218***	−0.250***	0.001	−0.067***	−0.269***	−0.259***	−0.272***	−0.291***
	(−3.60)	(−4.65)	(−6.15)	(0.07)	(−8.60)	(−6.93)	(−6.89)	(−4.33)	(−6.95)
EPI	0.091***	0.079***	0.082***	−0.013	0.025**	−0.107	0.055***	0.081***	0.073***
	(3.06)	(2.66)	(2.87)	(−1.12)	(2.32)	(−0.75)	(4.26)	(2.75)	(3.97)
second	0.175	0.148	0.232**	0.104*	0.078**	0.584***	0.406***	0.781***	0.489***
	(1.06)	(1.30)	(2.19)	(1.69)	(2.45)	(7.14)	(4.48)	(7.40)	(5.04)
ID	−0.544	−1.678	−1.828*	2.960***	−0.483	−21.910**	−2.189	−17.726**	−2.070*
	(−0.55)	(−1.47)	(−1.78)	(3.89)	(−1.09)	(−2.59)	(−1.55)	(−2.36)	(−1.74)
pd	1.122**	1.461***	1.394***	−0.882***	0.144	2.029***	0.600*	12.217	1.158***
	(2.30)	(3.23)	(3.69)	(−4.57)	(1.29)	(3.38)	(1.68)	(1.21)	(2.98)
NDVI	−0.467***	−0.296***	−0.029	0.300***	−0.275***	−0.036	0.039	−0.147**	0.012
	(−3.91)	(−3.04)	(−0.28)	(4.07)	(−6.94)	(−0.48)	(0.48)	(−2.12)	(0.16)
var(e.mean)					0.010***				
					(16.02)				
Constant term	6.436***	6.267***	6.343***	4.173***	1.302***	4.726***	6.159***	6.249***	6.501***
	(11.26)	(14.66)	(17.36)	(32.09)	(18.42)	(29.57)	(19.65)	(11.56)	(18.23)
Regional fixed effects	YES	YES	YES	YES	YES	YES	YES	YES	YES
Time fixed effects	YES	YES	YES	YES	YES	YES	YES	YES	YES
N	171	285	399	513	513	513	456	211	456
R^2	0.427	0.410	0.444	0.479		0.572	0.634	0.766	0.647

Note: *, ** and *** indicate 10%, 5% and 1% significant levels, respectively; t-statistics in parentheses.

protection activities must not undermine poverty reduction, so that environment and poverty need to be studied in a unified framework (Brashares et al., 2004); Huang argues that scholars should not only focus on the poverty alleviation effects of policy, but also on the multidimensional improvement effects of policy, and that the assessment of policy should be comprehensive (F. B. Huang et al., 2022); Hayes et al. (2015) argues that in the process of horizontal ecological compensation policy implementation, the implementation objectives should gradually change from the initial single objective (improving the ecological environment) to multiple objectives (ecological environment and economic development); Chen argues that the current design of the policy needs to focus on both the environment and the economy, and breaking the dilemma of economic growth and environmental quality improvement is an urgent problem to be solved at present (Chen et al., 2021).

Therefore, with the gradual advancement of practical and theoretical understanding, scholars began to incorporate both ecological and environmental governance and poverty reduction into the research framework of policy (Alix-Garcia et al., 2013;

TABLE 4 Mechanisms of the impact of poverty alleviation policy on RSEI_Indexit.

Variable name	Public expenditure level				Government financial pressure			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	GPS_{it}	GPS_{it}	$RSEI\_Index_{it}$	$RSEI\_Index_{it}$	GFP_{it}	GFP_{it}	$RSEI\_Index_{it}$	$RSEI\_Index_{it}$
Treat·T	0.594**	0.641**	0.327***	0.128**	−2.417*	−2.101*	0.278***	0.104*
	(2.27)	(2.31)	(6.18)	(2.12)	(−1.88)	(−1.72)	(6.21)	(1.71)
GPS			0.135***	0.104***				
			(4.43)	(5.30)				
GFP							−0.053***	−0.043***
							(−6.01)	(−5.39)
Controls	NO	YES	NO	YES	NO	YES	NO	YES
Constantterm	10.771***	13.459***	2.628***	4.864***	0.430*	−15.478***	4.107***	5.592***
	(85.50)	(16.73)	(7.77)	(17.06)	(1.86)	(-3.52)	(173.31)	(26.24)
Regional fixed effects	YES	YES	YES	YES	YES	YES	YES	YES
Time fixed effects	YES	YES	YES	YES	YES	YES	YES	YES
N	513	513	513	513	511	511	511	511
R^2	0.318	0.383	0.539	0.699	0.068	0.383	0.630	0.727

Note: *, ** and *** indicate 10%, 5% and 1% significant levels, respectively; t-statistics in parentheses.

Barbier, 2014)and began to study the environmental effects of poverty alleviation policy and the poverty reduction effects of environmental policy, for example, Huang studied whether photovoltaic poverty alleviation achieved low carbon development while achieving poverty reduction (F. B. Huang et al., 2022); Meijaard studied whether community forestry policy were local economic downturns when they achieved forest conservation outcomes (Meijaard et al., 2020); Jennifer used discontinuities in community-level eligibility rules for conditional cash transfer projects in Mexico and stochastic changes in the pilot phase of the project to study the impact of poverty-stricken projects on environmental degradation (Jennifer et al., 2013); Zhou studied whether the implementation of action plan of air pollution prevention and control was again at the expense of economic growth (Zhou and Tang, 2021).

It is clear from the above analysis that scholars have mostly focused on the economic effects of poverty alleviation policy, and a few have begun to discuss how to achieve sustainable development while eradicating poverty, however, the environmental effects of poverty alleviation policy have not been effectively measured. We discuss the effects of China's poverty alleviation policy on local environmental quality.

2.2 Theoretical mechanisms

First, the implementation of poverty alleviation policy will have a direct impact on the quality of ecological environment. The impact of current policy with environmental regulation effect on ecological and environmental quality mainly has two views: "push-back effect" and "regressive effect". The "regressive effect" refers to the government's efforts to increase production costs and restrain the production behavior of enterprises (especially those with high pollution and energy consumption) through mandatory orders and setting energy conservation and emission reduction targets, and to force enterprises to carry out green technological innovation and improve management models to reduce carbon emissions (Fuenfgelt and Schulze, 2016; Zhu et al., 2014). Both the "green paradox" and "bottom-up competition" will lead to a decline in environmental quality after the implementation of policy with environmental regulatory effects, i.e., the "regressive effect" (Blackman and Kidegaard, 2003; Gray and Shadbegian, 2003). The "green paradox" is that when the government introduces environmental policy to improve the environment, there is a sudden increase in the consumption of fossil energy, leading to environmental degradation (Sinn, 2008). The pursuit of economic benefits by local governments leads to the "bottom-up effect" of environmental regulations, resulting in the deterioration of local environmental quality (Ouyang et al., 2020; Ghanem and Zhang, 2014). In fact, with the increasingly prominent contradiction between economic development and environmental protection, the evaluation mechanism of government officials based on GDP assessment is being reversed, and environmental performance is gradually

becoming an important element of officials' performance assessment (Jia et al., 2014; Piotroski and Zhang, 2014), therefore, according to the promotion tournament theory, the policy of poverty alleviation will also certainly influence the governance behavior of local officials, which in turn will have an impact on local economic and social development. Therefore, the current impact of environmental regulation on regional ecological environment is mainly manifested as a push back effect (Huang, 2022). For the sustainable development of poor regions, the poverty alleviation policy has strengthened regional environmental regulation by quantifying factors such as changes in ecological environment and increasing environmental expenditure. Therefore, the following hypothesis is proposed in this paper.

Hypothesis 1: The poverty alleviation policy can significantly improve the ecological quality of counties on the Qinghai-Tibet Plateau.

Second, poverty alleviation policy may improve the level of ecological quality by raising the level of public expenditure and relieving government fiscal pressure. First, the policy of poverty alleviation can enhance the level of public expenditure of county governments, thus realizing the improvement of local ecological and environmental quality. Fiscal expenditure, as an important component of environmental finance, is closely related to environmental pollution (Shao et al., 2022; Zahra et al., 2022), and the level of fiscal expenditure largely influences the differentiation of provincial economic quality development (Wang et al., 2022), and increased government public expenditure tends to significantly improve the level of local ecological and environmental quality (Lin and Zhou, 2021a; Zhu et al., 2022), and some scholars even directly argue that the proportion of government expenditure to GDP is positively related to the level of air pollution (Carlsson and Gable, 2000; López et al., 2011). On the other hand, fiscal expenditure, as a mechanism factor, has a positive impact on the stability of industrial ecosystems (Guild, 2020; Schmidt et al., 2014; Zhu et al., 2022), and existing studies found that there is a significant spatial auto correlation between local fiscal expenditure and the level of industrial ecology, and the government can promote the stable development of local industrial ecosystems by guiding social funds through public expenditure (Guild, 2020; Schmidt et al., 2014), which is conducive to promoting the improvement of the local environment. And the implementation of the policy of poverty alleviation will make the local government pay more attention to the assessment from the higher level, thus changing the investment in environmental management and increasing public expenditure according to the importance of the assessment index from the higher level (Westmore, 2018; Zeng et al., 2021), so this will help the local improvement of the environmental quality condition. Secondly, the poverty alleviation policy can relieve the financial pressure of county governments and enhance the willingness and enthusiasm of local governments to protect the environment, thus improving the level of ecological and environmental quality. The Qinghai-Tibet Plateau region is constrained by the low level of economic development, the lack of own and external funds, and the high financial pressure, the poverty alleviation policy can alleviate the hindering effect of the local government to carry out environmental protection. From the dimension of financial resources, the implementation of environmental policy in different places usually depends on central financial incentives and local financial capacity (Dunlop and Corbera, 2016; Qi and Zhang, 2014), and sufficient financial resources are an important guarantee for local governments to implement environmental governance (He et al., 2012; Tacconi et al., 2008), while when there is a large financial pressure, it changes local government behavior, making local governments pay more attention to economic growth and neglect the environment, and this incentive effect formed by financial pressure is This incentive effect formed by fiscal pressure is an important reason for the growth of industrial pollution in China (Hui et al., 2022). In contrast, the implementation of the poverty alleviation policy has led the state to increase the intensity of investment in poverty alleviation funds in counties (Luo et al., 2021), and the financial transfer payments shared at the central, provincial, counties, and county levels have reconciled the contradictions between the central and local governments in terms of financial resources (financial power) and environmental governance matters (affairs) (Gong et al., 2020), bringing an increase in the level of financial security of local governments (Su et al., 2021; Wen and Lee, 2020), which has helped to alleviate the financial pressure on local contributes to the improvement of urban productivity and resource use efficiency (Hou et al., 2022; Hui et al., 2022), significantly increases the willingness and motivation of local governments to protect the environment (Zhang and Zhao, 2018), and therefore this will help localities to improve the environmental quality situation. Accordingly, this paper proposes hypotheses two and three:

Hypothesis 2: Due to the change in the level of government public expenditure, the poverty alleviation policy will affect the level of local environmental governance. According to the above discussion, the "poverty alleviation policy" will be beneficial to environmental governance, i.e., it will positively affect the remote sensing ecological index.

Hypothesis 3: Due to the change of government financial pressure, the poverty alleviation policy will affect the level of local environmental governance. According to the above discussion, the "poverty alleviation policy" will benefit environmental governance, i.e., positively affect the remote ecological index.

3 Study design and data description

3.1 Empirical model construction

The question explored in this paper is whether the implementation of poverty alleviation policies has been

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TABLE 5 Mechanistic test of government financial pressure.

Variable name	Small administrative area	Large administrative area	Low altitude	High altitude	Low industry advanced	High industrial sophistication	Industrial poverty alleviation	Ecological compensation
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Treat·T	0.171**	0.086*	0.188**	0.053	−0.038	0.340***	0.222***	0.194***
	(2.27)	(1.94)	(2.26)	(1.27)	(−0.87)	(3.45)	(2.62)	(2.94)
Third	0.364***	0.387***	0.381***	0.428***	−0.176	1.844***	0.381***	1.390***
	(3.29)	(4.36)	(3.43)	(4.73)	(-1.44)	(4.74)	(5.39)	(6.75)
lnPGDP	−0.288***	−0.149***	−0.290***	−0.124***	−0.268***	−0.406***	−0.244***	−0.378***
	(−7.38)	(−5.12)	(−6.48)	(−4.60)	(−3.95)	(−7.24)	(−6.69)	(−5.47)
EPI	0.066***	0.032	0.071***	0.034	−0.046	0.065***	0.058***	0.052**
	(4.57)	(1.01)	(4.92)	(0.98)	(−0.50)	(4.69)	(4.19)	(2.11)
second	0.107	0.549***	0.247*	0.581***	0.506***	1.488***	0.242***	1.433***
	(0.85)	(6.07)	(1.92)	(6.09)	(5.35)	(4.10)	(3.10)	(7.90)
ID	−1.753	−6.831	−2.167*	33.966	−0.889	−6.755***	−2.100	5.518
	(−1.59)	(−0.60)	(−1.74)	(1.45)	(−0.73)	(−3.17)	(−1.58)	(0.26)
pd	0.519*	206.124***	0.630*	147.107***	0.972	1.665***	0.581*	188.133***
	(1.82)	(5.88)	(1.96)	(7.32)	(1.44)	(3.17)	(1.71)	(7.70)
NDVI	−0.174	0.128*	0.106	−0.040	−0.019	−0.204	0.056	0.542**
	(−1.34)	(1.84)	(0.62)	(−0.84)	(−0.30)	(−1.56)	(0.63)	(2.19)
Constant term	6.693***	4.982***	6.493***	4.882***	6.537***	6.764***	6.082***	5.764***
	(19.83)	(19.98)	(17.74)	(21.01)	(10.24)	(18.66)	(19.64)	(11.86)
Regional fixed effects	YES	YES	YES	YES	YES	YES	YES	YES
Time fixed effects	YES	YES	YES	YES	YES	YES	YES	YES
N	251	262	261	252	256	257	342	171
R^2	0.737	0.710	0.706	0.670	0.700	0.745	0.658	0.658

Note: *, ** and *** indicate 10%, 5% and 1% significant levels, respectively; t-statistics in parentheses.

effective in improving the environment of poverty-stricken counties on the Qinghai-Tibetan plateau region. Since areas with better ecological endowments coincide with poorer areas, in order to accurately estimate the causal effect of poverty eradication policy implementation on county ecological quality, it is necessary to exclude endogeneity due to omitted variables, reverse causality and interference from other factors, and reduce the interference of endogeneity in the identification of disturbance causality. Therefore, this paper adopts the difference-in-differences (DID) model (Alari et al., 2021; Wang and Li, 2019) and refers to the model settings of Chen and Xu, on the basis of controlling for regional and year fixed effects (Chen et al., 2020; Xu et al., 2021), eliminating the differences in natural, geographic and economic conditions that do not change over time between the two groups before and after the policy intervention and external shocks from the national level (Athey and Imbens, 2006; Davies et al., 2008; Hawkins and Baum, 2016), in order to exclude other factors from interfering as much as possible, and finally obtain the following model 1). For robustness testing, this paper uses a series of methods such as propensity score matching method, changing time intervals, changing variable measures, changing model settings, and lagging variables to test the robustness of the results.

$$RSEI\_Index_{it} = \beta_0 + \beta_1 Treat \cdot T + \beta_2 control_{ir} + \eta_t + \mu_i + \varepsilon_{it} \quad (1)$$

where the subscript i represents the county and t represents the time. $RSEI\_Index_{it}$ is the explanatory variable measuring the environmental quality of the county, and the subscripts i and t represent the *ith* county and the year. *Treat* is used to distinguish the treatment group from the control group, T is used to distinguish before and after the policy implementation, and the cross product term $Treat{\cdot}T$ is the core explanatory variable in this paper. $Treat{\cdot}T = 1$ if it occurs after the policy and the county is a poverty-stricken county, that is, out of poverty in 2019, otherwise $Treat{\cdot}T = 0$. Control represents a series of control variables. η_t controls for time-level characteristics that do not vary with region, such as changes in macroeconomic situation;μ_i controls for region-level characteristics that do not vary with time; and ε_{it} denotes a random disturbance term. The coefficient β_1 indicates the impact of the poverty alleviation policy on the ecological environment quality of poverty-stricken counties, and is the core parameter of interest in this paper.

3.2 Data settings

Explained variable: The environmental quality level *RSEI_Index* is the explanatory variable, and the logarithmic value of Remote Sensing Ecological Index (RSEI) ($ln(RSEIit*100+1)$) of each county in the Qinghai-Tibet Plateau region is selected to measure the environmental quality level of counties in the Qinghai-Tibet Plateau region. The remote sensing ecological index data were obtained from the National Earth System Science Data Center of China by projection conversion, resampling and cropping.

Core explanatory variables: The cross-product term $Treat{\cdot}T$ is the core explanatory variable, representing whether the poverty-stricken counties implement the poverty alleviation policy. Among them, *Treat* is the policy dummy variable, which is assigned as 1 if the sample county is a national-level poverty-stricken county in the Qinghai-Tibet Plateau region that will be out of poverty in 2019, and 0 otherwise; T is the experimental period dummy variable, which is assigned as 1 after 2015 (including 2015) and 0 before 2015. The coefficient estimate β_1 of the cross-product term $Treat{\cdot}T$ is the DID estimator, which represents the net impact of the policy on county environmental quality, $Treat{\cdot}T$ is assigned a value of 1 when and only when the i_{th} county is a national-level poverty-stricken county in the Qinghai-Tibet Plateau region that escapes poverty in 2019 and $t \geq 2015$, and 0 otherwise.

Control variables: Regional environmental quality levels are influenced by a variety of factors, and drawing on relevant research practices, the following variables are controlled for in this paper.1) Per capita income level (*lnPGDP*): economic growth and other factors have caused an increase in carbon dioxide emissions, which has put great pressure on environmental quality (Liu et al., 2020). Academics usually use gross domestic product (*GDP*), gross national product (*GNP*), and *per capita* income level to measure the economic status of a country or region, while *per capita* regional GDP is more representative of economic growth than, for example, regional GDP (Dedecek and Dudzich, 2022; Guio et al., 2015). Therefore, in this paper, the logarithm of the *per capita* regional GDP (yuan) of each county is used to indicate the level of *per capita* income. 2) Share of tertiary industries (*Third*). The ratio of gross value of tertiary industry (million yuan) to gross regional product (million yuan) is used to express this indicator (He et al., 2018). 3) Population density (*pd*): population density is the ratio of the total population of each county at the end of the year to the area of the jurisdiction (Aarstad et al., 2016; Shah et al., 2020), which characterizes the degree of population concentration; the higher the population density, the higher the degree of concentration of enterprises and public service facilities around it, and the more serious air pollution emissions, which is not conducive to pollution control (Frank and Enngelke, 2005; Schweitzer and Zhou, 2010). 4) Economic performance index (*EPI*). It has been suggested that the pursuit of economic performance motivates local governments to devote themselves to areas that can bring promotion, crowding out resource inputs for environmental protection and weakening local environmental control standards, thus undermining the environmental quality of the region (Jiao et al., 2011; X. Wang et al., 2020; Wang and Lei, 2020), so with reference to Zhangchose GDP growth rate as an economic performance indicator (Zhang, 2020). 5)

Industrialization level (*second*): the level of industrialization and environmental quality are interrelated, and the evolution of industrial structure has a significant impact on the ecological and environmental quality in China (Xu et al., 2022), so the ratio of gross secondary industry product (million yuan) to gross regional product (million yuan) was used to represent this indicator (Lin and Zhu, 2019). 6) Enterprise density (*ID*). The spatial concentration of a large number of industrial enterprises leads to an increase in the total amount of industrial pollutants discharged in the region and an increase in the degree of environmental damage (Li H et al., 2020; Panda and Siva Nagendra, 2018), and is therefore measured by the ratio of the number of industrial enterprises above the scale to the area of the jurisdiction (Lin et al., 2022). 7) Vegetation index (*NDVI*): in this paper, the normalized difference vegetation index (NDVI) is used to measure the level of urban greening, which may have both positive and negative effects on air quality; on the one hand, green areas as carbon sinks can play a role in purifying the air, and on the other hand, excessive investment in urban green areas may crowd out environmental protection expenditures in other areas (Yu et al., 2022).

3.3 Data description and descriptive statistic

This paper assesses the policy effects of poverty alleviation policy by using panel data of 57 districts and counties (county-level cities) in the Qinghai-Tibet Plateau region from 2011 to 2019. Considering that Poverty-stricken counties in the Qinghai-Tibet Plateau region were removed from the list of national-level Poverty-stricken counties one after another in 2016–2018, the sample does not include counties that were removed from poverty in 2016–2018. Our principles for selecting the control group include: The control group should not have implemented the poverty alleviation policy and will not be subject to policy intervention, and the trend of ecological environment level of the experimental and control groups before the policy should be the same, i.e., they meet the requirement of parallel trend test. Based on the above principles, we summarized the factors affecting the quality of regional ecological environment based on previous studies, mainly including environmental factors (temperature, precipitation, air pressure, altitude, etc.), geographical factors (topography, vegetation cover, etc.) and socio-economic factors (population density, economic level, industrial structure, etc.) (Ahmed et al., 2019; Cui et al., 2022; De Carvalho and Szlafsztein, 2019; Hua et al., 2020; Liu et al., 2017). Therefore, non-poverty-stricken counties with consistent environmental and geographical conditions should be selected as the control group. If the study expands the scope of sample selection by choosing counties outside the Tibetan Plateau region, it will make the estimation results disturbed by other environmental, socio-economic and policy factors, thus violating our sample selection principle. Therefore, we excluded non-Qinghai-Tibetan Plateau areas and counties with only some areas on the Qinghai-Tibetan Plateau, and selected six counties, including Gulang County and Haixi Mongolian-Tibetan Autonomous Prefecture, as control groups. Therefore, in this paper, the 51 Poverty-stricken counties that successfully escaped from poverty in 2019 are selected as the treatment group, and the sample of districts and counties (county-level cities) in the remaining sample is taken as the control sample, using the national implementation of poverty alleviation policy in 2015 as the external policy shock point. The relevant data were obtained from the China County (City) Social and Economic Statistical Yearbook, the China County Statistical Yearbook, and the district and county statistical bulletins in previous years. Normalized Difference Vegetation Index (NDVI) data were obtained from the 15 days maximum synthetic data published by the Global In-ventor Modeling and Mapping Studies (GIMMS3g) of NASA (https://ecocast.arc.nasa.gov/data/pub/gimms/). The definitions and descriptive statistics of each variable are shown in Table 1.

4 Results and discussion

4.1 Analysis of benchmark model results

Table 2 reports the results of testing the impact of the poverty alleviation policy on the regional environmental quality level using the difference-in-differences method. Model 1) is the baseline model without any control variables, and control variables such as the *Third, lnPGDP, EPI, second, ID, pd,* and *NDVI* are added sequentially from the model (2) to model (8). In the process of adding the control variables in turn, the coefficients of the core explanatory variables *RSEI_Index* always remain significantly positive and the coefficient values do not change significantly, which reflects the robustness of the model estimation results to a certain extent.

In terms of the core explanatory variables that are of most interest in this paper, their regression coefficients are consistently positive at the 1% significance level, indicating that the operation of China's poverty alleviation policy significantly contributes to the improvement of the environment in the Tibetan Plateau region and that China's poverty alleviation policy has exerted the expected policy effect. The regression coefficient of the policy variable in the model (8) is 0.195, indicating that the poverty alleviation policy improves the ecological quality by 19.5%. This result implies that with the poverty alleviation policy, it significantly contributes to the improvement of the environment in the Tibetan Plateau region, allowing the pilot areas to achieve coordinated environmental and economic growth.

In terms of control variables, the regression coefficients of lnPGDP and ID are significantly negative at the 1% level, which is also largely consistent with the findings of previous scholars (Xu et al., 2022; Ward and Shively, 2012): economic and industrial

development will be detrimental to the local environment, especially in underdeveloped areas, the negative environmental impact of industrial development is more pronounced, and the higher the density of enterprises will bring about greater pollution. The regression results of other control variables are also basically consistent with the results of previous scholars (Zhou et al., 2013):The rise of secondary and tertiary industries has brought about improvements in the local environment, probably because of the popularity of the Nature Based Solutions (NBS) concept, and more and more companies and industries have started to transform to a sustainable economic development model. Therefore, along with the optimization of the local industrial structure, the economic growth has not caused negative impact on the local environment, and the rise of the economy has also increased the level of local financial resources, which can better protect and improve the environment. EPI has a catalytic effect on the environment, probably because the improved economy has eased the government's financial constraints, which has led to an increase in environmental protection inputs and expenditures and improved environmental quality.

4.2 Parallel trend test

Based on the above methods, we performed coefficient estimation and plotted parallel trends, and the results are shown in Figure 1. It can be seen that in the interval of 2013–2014 years, the estimated coefficients at 90% confidence interval are not significantly different from 0, indicating that there is no significant difference between the ecological and environmental quality levels of the treatment and control groups in the pre-poverty alleviation policy implementation period, which satisfies the parallel trend test; and in terms of dynamic effects, the policy effects in the current period and the first period of policy implementation are not significant, probably because there is a In terms of the dynamic effect, the effect of the policy is not significant in the current period and the first period of policy implementation, probably because there is a time lag in the implementation and execution of the policy, and it takes time to improve the environment, so the environmental improvement effect of the poverty alleviation policy is not significant, while from the second period, the estimated coefficient β_k starts to be significantly different from 0 and lasts until the fourth period, which indicates that the promotion effect of the poverty alleviation policy has a long-term effect and can significantly improve the comprehensive environmental quality level among counties.

4.3 Robustness tests

To further ensure the reliability of the study findings, this paper also performs a series of robustness tests using the DID model of Eq. 1 as the benchmark, the results are shown in Table 3.

4.3.1 Change the time interval

To identify whether the environmental improvement effect of the poverty alleviation policy varies with the length of the sample, this paper identifies the sensitivity of the policy to time changes by varying the regression time interval. This is done by taking the policy occurrence time of 2015 as the middle point, and selecting the samples of 1, 2, and 3 years before and after each regression, if the regression coefficient and significance do not change, it indicates that the estimation results of this paper are robust. The corresponding results are shown in columns (1), (2), and (3) of Table 4. By changing the time interval used for regression, the effect coefficients of the poverty alleviation policy are significantly positive, which still support the previous conclusion, thus proving that the conclusions of this paper are robust.

4.3.2 Replacing variable measurements

The main regression in this paper uses the annual mean value of the remote sensing ecological index as an annual indicator of regional ecological and environmental quality. Compared with the mean value, the public may be more sensitive to the maximum value of the environmental index. Based on this understanding, this paper adopts the annual maximum value of the remote sensing ecological index, which is treated according to the treatment of the explanatory variables in the main regression, as an indicator of the comprehensive ecological and environmental conditions, and the corresponding results are shown in column (4) of Table 4, indicating that the implementation of the poverty alleviation policy has indeed raised the maximum value of the environmental index. Specifically, in terms of the remote sensing ecological index maximum indicator, the implementation of the poverty alleviation policy raised the maximum value of the environmental index by about 11.8%.

4.3.2.1 Using the tobit model

Referring to Xiao, the results were re-tested using the Tobit model considering the Remote Sensing Ecological Index (RSEI) as a restricted variable (Xiao et al., 2021), and the corresponding results are shown in column (5) of Table 3, and the conclusions of this paper are robust.

4.3.2.2 Truncation processing

Robustness test based on sample size. To ensure the robustness of the regression results and to exclude the possible influence of outliers of the variables on the estimation results, the control variables below the 5% and above the 95% quantile are replaced by the 5% and 95% quantile, respectively, and the corresponding results are shown in column (6) of Table 3. The policy of poverty alleviation can significantly improve the level of environmental quality in the county, which proves that the estimation results are robust.

4.3.3 Change model settings

The control variables in model 1) contain regional economic indicators, which may have an inverse effect between them and the implementation of poverty alleviation policy. In order to reduce the potential endogeneity problem, all control variables are lagged by one period and regressed again, and the empirical results are shown in column (7) of Table 3. As can be seen, the sign and significance of the coefficients of the explanatory variables are basically consistent with the results of the benchmark regression, which again verifies the robustness of the conclusions of this paper.

4.3.4 Use propensity score matching (PSM) method

In order to prevent possible sample selection bias and solve the sample self-selection problem, we added the PSM method to further test the results. The PSM method is considered to be a good solution to endogeneity bias (Abadie and Cattaneo, 2018; Dhaliwal et al., 2016; Titus, 2007; Yao et al., 2010), and is therefore widely used in policy evaluation (Mojo et al., 2017; Titus, 2007; Yao et al., 2010). To address the endogeneity issue and more effectively identify the causal relationship between poverty alleviation policy and changes in ecological quality in poverty-stricken counties on the Qinghai-Tibet Plateau, this paper further employs the PSM-DID model to test the robustness of the solution. The rationale for PSM is to make the treatment and control groups "similar" and thus comparable to each other before DID estimation is performed. Therefore, in this paper, the one-to-one nearest neighbor matching method is chosen to match the sample cities to ensure a good consistency of the sample distribution between the treatment and control groups. The final estimation results are shown in column (8) of Table 3, and the findings of the benchmark study in this paper remain robust.

4.3.5 Lags the core explanatory variables

Lagged core explanatory variables are considered to be an effective method that can address endogeneity (Clemens et al., 2012; Green et al., 2005) and are widely used in economics, finance, and other disciplines (Cornett et al., 2007). This method has been adopted by various studies and recognized by many scholars (Cornett et al., 2007; Green et al., 2005). For example, Clemens argues that potential biases in reverse and simultaneous causality can be addressed by lagging core explanatory variables (Clemens et al., 2012), and Buch and Hayo also use this approach in their paper (Buch et al., 2012; Hayo et al., 2010), so this paper refers to existing studies and uses a 1-year lagged core explanatory variable treatment to address endogeneity disturbances. The final estimation results are shown in column (9) of Table 3, and the findings of the benchmark study in this paper remain robust.

4.4 Mechanism of action and pathway analysis

Both the above benchmark regressions and robustness tests indicate that the poverty alleviation policy has a significant improvement on the RSEI of counties in the Qinghai-Tibet Plateau region. In this section, the paper further explores the possible theoretical mechanisms behind this ameliorative effect. As analyzed in Section 2.2, the poverty alleviation policy positively affects the ecological quality of counties in the Qinghai-Tibet Plateau region through two channels: increasing the level of government public expenditure and alleviating government fiscal pressure. To further verify the existence of these effects, we use a two-stage mediated effects model to verify them (Fan et al., 2021).

The first stage is to test the driving effect of the poverty alleviation policy on the two main effects. A mediation model is constructed to test whether the policy variables act on the mediating variable effect is significant, see model 2). If β_1 is not significant, the test of mediating effect is stopped; otherwise, it means that the effect of policy variables on mediating variables is significant and the second stage is entered:

$$GPS_{it}\,(GFP_{it}) = \beta_0 + \beta_1 Treat \cdot T + \beta_2 control_{ir} + \eta_t + \mu_i + \varepsilon_{it} \tag{2}$$

The second stage is to verify the two main effects of the poverty alleviation policy on the RSEI in the Tibetan Plateau region by building an integrated model (3) based on the mediator model (2). If $\beta 2$ is insignificant, there is no mediating effect. Otherwise, there is a mediating effect whether $\beta 1$ is significant or not. If $\beta 1$ is not significant, it indicates that the mediating variable is the only transmission path for the policy variables to have an effect on RSEI in the counties of the Tibetan Plateau region. Otherwise, it indicates the existence of other transmission paths.

$$RSEI\_Index_{it} = \beta_0 + \beta_1 Treat \cdot T + \beta_2 GPS_{it}\,(GFP_{it}) + \beta_3 control_{ir} + \eta_t + \mu_i + \varepsilon_{it} \tag{3}$$

In model (3), *GPSit*, *GFPit* denote two mediating variables. *GPSit* represents the level of government public expenditure, and the logarithm of local government fiscal expenditure is used to measure the level of government public expenditure (GPS) with reference to Sheng's approach (Sheng et al., 2022). *GFPit* stands for Government Fiscal Pressure and, drawing on the practice of Reserve Bank, uses the local government fiscal vertical imbalance rate to measure government fiscal pressure (GFP) (Lin and Zhou., 2021b). The relevant data come from the "China County (City) Social and Economic Statistical Yearbook", "China County Statistical Yearbook" and district and county statistical bulletins in previous years.

The results of the above mechanism tests are shown in Table 4. We first test the mechanism of the level of government public spending. Columns (1) and (2) show that

the poverty alleviation policy can significantly increase the level of government public expenditure with or without adding control variables. Columns (3) and (4) test the effect of government public expenditure level on *RSEI_Indexit*.The coefficient of Treat-T is significantly positive and the coefficient of *GPSit* is always significantly positive, indicating that the increase of government public expenditure level can significantly improve the ecological environment quality of counties in Qinghai-Tibet Plateau region, therefore, combining the results of the four columns, we can conclude that:the implementation of the poverty alleviation policy improves the level of government public expenditure and finally enhances the *RSEI_Indexit*.

The remaining four columns test the mechanism of the government's level of financial stress. Columns (5) and (6) show that the poverty alleviation policy significantly alleviates government fiscal pressure with or without the addition of control variables. Columns (7) and (8) test the effect of government fiscal pressure on *RSEI_Indexit*.The coefficient of Treat-T is significantly positive and the coefficient of *GFPit* is always significantly negative, indicating that the alleviation of government financial pressure level can significantly improve the ecological environment quality of counties in the Tibetan Plateau region. Therefore, combining the results in columns (5) to (8), we can conclude that the implementation of the poverty alleviation policy eases the government's fiscal pressure and thus enhances the *RSEI_Indexit*.

4.5 Heterogeneity analysis

Since the heterogeneity of economic base, factor endowment structure, and geographic environment leads to differences in policy effects among different districts and counties, it is necessary to conduct heterogeneity analysis for the baseline regression results. This paper will examine the following three perspectives: (1) whether the policy effect is influenced by the size of the administrative area of the county; (2) whether the policy effect is influenced by the altitude of the county; (3) whether the policy effect is influenced by the level of advanced industrialization in the county; and (4) whether the policy environment improvement effect is influenced by the type of provincial ecological poverty alleviation policy, the results are shown in Table 5.

4.5.1 Administrative area

Since the size of the administrative region affects the difficulty of environmental management in the local counties and the environmental protection expenditure required to be occupied increases, this paper divides the large and small administrative region counties by the mean value of the administrative region of the county, and the results are shown in Table 5. It can be seen that the effect of the poverty alleviation policy on the small administrative region area is more significant and the improvement of the environmental quality of the large administrative region area is less, specifically, the policy on the small administrative regions brought 8.4% higher environmental improvement effect than that for large administrative regions. This may imply that for counties with larger administrative areas, higher-level and local governments need to invest more energy, money, and time in environmental management.

4.5.2 Elevation

Because altitude determines the topographic conditions of a region, high altitude areas are usually mountainous and plateau, which have strong restriction on the scale of local economy and industrial structure, thus the pollution effect of economic development will be higher, and altitude is also an important influencing factor for the diffusion of air pollutants (Jans et al., 2018; Xiao et al., 2021). Therefore, this paper divides high-altitude counties and low-altitude counties according to the mean elevation of the area in which the counties are located, and the results are shown in Table 5, which shows that the poverty alleviation policy can have better environmental enhancement effects in low-altitude areas, while the effects are relatively small in high-altitude areas, which reflects both that the environmental improvement work is more arduous and difficult in high-altitude, and that topographic terrain needs to be considered in regional industrial planning and spatial layout (Q. Li Q et al., 2020; Su et al., 2019).

4.5.3 Advanced industrialization

Both in the near and long term, the optimization and upgrading of industrial structure is important for the effective implementation of environmental policy (Li T et al., 2021). Therefore, in this paper, drawing on Zhou, the industrial structure hierarchy coefficient is used to indicate the industrial structure upgrading, the relative changes in share proportions are used to portray the evolutionary process of the three major industries (Zhou et al., 2020). The specific calculation formula is:

$$AISL_{kt} = y_{i,k,t} \cdot i \tag{4}$$

In Eq. 4, $y_{i,k,t}$ denotes the proportion of the i_{th} industry in the k-county area to the regional GDP in period t. This index reflects the evolution of the three major industries in the Poverty-stricken counties on the Qinghai-Tibet Plateau from the dominant position of the primary industry to the dominant position of the secondary industry and the tertiary industry, so the industrial structure level coefficient is used to measure the industrial structure upgrading, and the average value of the industrial structure level coefficient in counties in previous years is used as the grouping Based on this, the counties are divided into high industrial advanced counties and low industrial advanced counties, and the results are shown in Table 5, which shows that the poverty alleviation policy can have a better environmental upgrading effect in high industrial advanced

counties, while the effect is not significant in low industrial advanced counties. This indicates that the degree of industrial structure advanced will affect the effect of the policy on local environmental improvement, so it is necessary to increase the financial investment in regions with backward industrial structure and promote the upgrading of local industrial structure to achieve the purpose of effectively improving the level of environmental quality.

4.5.4 Types of ecological poverty alleviation policy

Based on poverty alleviation policy, local governments have introduced a series of different poverty alleviation policy based on local factors, resource endowments, and other conditions, such as ecological management, industrial poverty alleviation, and ecological compensation, and other related policy. Different ecological poverty alleviation policy will affect the behavior of local governments in environmental protection and will lead to different levels of policy effects, so this paper classifies the types of poverty alleviation into industrial poverty alleviation and ecological compensation based on the content of local poverty alleviation policy based on county and provincial and municipal annual bulletins, and the results are shown in Table 5, which shows that the degree of environmental improvement in counties that adopt industrial poverty alleviation is 22.2%, and the degree of environmental improvement in counties that adopt ecological compensation is 19.4%. It can be seen that the environmental improvement of counties that adopt industrial poverty alleviation is the most obvious, and the degree of environmental improvement of counties that adopt industrial poverty alleviation is 2.8% higher than that of ecological compensation counties. This may be due to the superiority of industrial poverty alleviation, which is a policy that can solve the root causes of poverty at the source, and can transform the "green mountains" in poor areas into "golden mountains", so that ecological advantages can be transformed into industrial advantages and economic advantages, instead of fishing for the environment. The way to get rid of poverty by destroying the environment (Chien et al., 2022; Lei et al., 2021). In fact, the industrial poverty eradication policy is more in line with the NBS development philosophy, constantly supported and utilized by nature, and aims to address poverty in a resource-efficient and adaptable way, while providing economic, social and environmental benefits to poor areas (Maes and Jacobs, 2015; Pan et al., 2021). The development of poverty-alleviation industries can accumulate funds for the development of other social projects. Moreover, the development of poverty alleviation industries can accumulate funds for the development of other social projects in rural areas, which objectively supports other poverty alleviation policy and contributes to the implementation of environmental protection policy (Lei et al., 2021; Shi et al., 2022; Zhang et al., 2022). Specifically, some scholars argue that some industrial poverty alleviation policy (F. B. Huang et al., 2022), such as photovoltaic poverty alleviation in developing countries, can promote sustainable development, improve the overall wellbeing of beneficiaries, and achieve the dual goals of poverty alleviation and green development, while some scholars argue that tourism can be developed to alleviate poverty by involving farmers in the development of local tourism industries and gaining income (Medina-Munoz et al., 2016), exploring the path to transform the "green mountains" in poverty-stricken areas into "silver mountains". Because the poor areas on the Qinghai-Tibet Plateau are in areas with harsh natural environment, poor basic conditions for economic development and fragile natural ecology, many areas are prone to natural disasters, which seriously affect economic and social development, but, on the other hand, most of these areas are scenic areas, not only with beautiful and unique natural scenery, but also with different ethnic customs because they are mostly inhabited by ethnic minorities, and of course, there are many Of course, many of these areas are also the upper reaches of large rivers and are in important national ecological function zones (restricted and prohibited development zones), which are crucial to the sustainable development of downstream areas and developed regions. These areas rely on natural and humanistic landscapes to develop tourism industry, which is to use this characteristic landscape product as a commodity to realize its economic value, and truly make "green water and green mountains are the silver mountain of gold" a reality. However, since poverty alleviation is a prerequisite for ecological improvement, ecological compensation policy has built-in poverty reduction measures, so when the economy of poor areas has not yet reached the poverty line, poverty reduction is still its main goal, and ecological improvement requirements are relaxed, so its environmental improvement effect is slightly weaker than that of industrial poverty alleviation policy. The choice of the type of poverty alleviation policy leads to different improvement effects, and this variation provides some reference value for other poor countries and regions in terms of what kind of poverty alleviation approach to adopt.

5 Conclusions and policy recommendations

It is of great theoretical and practical significance to accurately grasp the policy effects of poverty alleviation policies on the ecological environment, in order to further promote the coordinated growth of economic and ecological environment quality, and to provide lessons for the development of other poor areas. In this paper, using the poverty alleviation policy as a quasi-natural experiment and based on the panel data of poverty-stricken counties in the Qinghai-Tibet Plateau region from 2011 to 2019, the theoretical mechanism and impact effects of the poverty alleviation policy on the improvement of the ecological environment quality are examined in depth using the difference-in-differences model. The

findings of this paper include: first, the poverty alleviation policy significantly improves the quality of the ecological environment in the Qinghai-Tibet Plateau region; second, the main transmission mechanism comes from the implementation of the poverty alleviation policy, which raises the level of public spending and relieves government fiscal pressure, which in turn improves the quality of the local ecological environment. Third, further heterogeneity analysis results show that: 1) The adoption of different types of ecological poverty alleviation policy has obvious differences in the effect of ecological environment improvement in counties, and each county needs to choose the most suitable way to get rid of poverty according to its natural endowment and actual needs. 2) The more advanced the industrial structure, the more obvious the improvement of ecological environment quality, which indicates that the local government needs to increase capital investment and control, promote industrial upgrading, and realize the coordinated development of environment and economy. 3) Administrative area and altitude also affect the effect and degree of environmental improvement, so policy should not be applied across the board, but should be tailored to local conditions, and more investment and assistance should be provided to the hard-to-reach areas. In addition, a series of robustness tests were conducted in this paper, indicating that the measurement results are stable and reliable.

Essentially, behind the fact that economic growth may be detrimental to ecological environmental quality reflects the long-standing contradiction and conflict between economic development and ecological environmental protection. This paper assesses the environmental impacts of poverty eradication policies on poor regions and analyzes the related impact mechanisms, which can clarify whether poverty eradication policies can achieve their economic-environmental synergy and can provide corresponding references for the implementation and formulation of SDGs and NBS strategies in other poor regions. The findings of this paper have the following three policy implications: First, within the Poverty-stricken counties of the Qinghai-Tibet Plateau under the influence of the poverty alleviation policy, economic growth does not damage the quality of the local ecological environment, which implies that the contradiction and conflict between economic development and ecological environmental protection is not irreconcilable. This means that the contradiction and conflict between economic development and ecological protection are not irreconcilable. This shows that in poor areas of China, ecological environmental protection and economic development can be organically combined and complementary, and that the "win-win" situation of "both green water and green mountains and golden mountains" can be achieved, and the goal of continuously supported by and using nature can be realized. Second, for the improvement of ecological environment quality, the most important thing is financial security, to solve the financial pressure of the local government, otherwise, the county government may not be able to provide adequate supplies, and the intervention and coordination of the higher government can solve this problem, so we should increase the transfer payments and policy support to poor areas, to encourage the local government to generate income and development, to form a virtuous circle; Third, after the financial pressure is solved, the government Third, after the fiscal pressure is solved, the government should also "dare to spend money" and increase public spending. The government is the main force in improving public goods and the environment, so it can consider including environmental protection indicators in the local government assessment to encourage the government to increase investment; finally, it is necessary to reasonably and orderly guide the transfer of labor to secondary and tertiary industries, encourage the low-carbon transformation of enterprises and promote the upgrading of local industrial structure, combine local natural endowments and actual needs, and choose the right type of poverty alleviation policy, so as to achieve poverty In this paper, we have proposed a scientific and systematic approach to the development of poverty alleviation policy in the region. In summary, this paper scientifically and systematically evaluates the effects of poverty alleviation policy, which can provide useful experiences and references for other poverty countries and regions to realize economic development and ecological environmental protection at the same time.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found here: National Earth System Science Data Center of China.

Author contributions

Conceptualization, writing—review and editing, RR; methodology and formal analysis, ZN; data curation and writing—original draft preparation, LH; project administration, TL. All authors have read and agreed to the published version of the manuscript.

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Conflict of 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.

Publisher's note

References

Aarstad, J., Kvitastein, O., and Jakobsen, S. (2016). Related and unrelated variety as regional drivers of enterprise productivity and innovation: A multilevel study. *Res. Policy* 45, 844–856. doi:10.1016/j.respol.2016.01.013

Abadie, A., and Cattaneo, M. D. (2018). *Econometric methods for program evaluation*. Editors P. Aghion and H. Rey (Reprinted), 10, 465.

Ahmed, S., Griffin, T. S., Kraner, D., Schaffner, M. K., Sharma, D., Hazel, M., et al. (2019). Environmental factors variably impact tea secondary metabolites in the context of climate change. *Front. Plant Sci.* 10, 939. doi:10.3389/fpls.2019.00939

Alari, A., Schwarz, L., Zabrocki, L., Le Nir, G., Chaix, B., and Benmarhnia, T. (2021). The effects of an air quality alert program on premature mortality: A difference-in-differences evaluation in the region of Paris. *Environ. Int.* 156, 106583. doi:10.1016/j.envint.2021.106583

Alix-Garcia, J., McIntosh, C., Sims, K. R. E., and Welch, J. R. (2013). The ecological footprint of poverty alleviation: Evidence from Mexico's oportunidades program. *Rev. Econ. Statistics* 95 (2), 417–435. doi:10.1162/REST_a_00349

Assessment, M. (2005). *Ecosystems and human well-being: Policy responses: Findings of the responses working group*. Bibliovault OAI Repository, the University of Chicago Press.

Athey, S., and Imbens, G. W. (2006). Identification and inference in nonlinear difference-in-differences models. *Econometrica* 74 (2), 431–497. doi:10.1111/j.1468-0262.2006.00668.x

Barbier, E. B. (2014). Climate change mitigation policies and poverty. *WIREs Clim. Change* 5 (4), 483–491. doi:10.1002/wcc.281

Blackman, A., and Kildegaard, A. (2003). Clean technological change in developing-country industrial clusters: mexican leather tanning. *Environ. Econ. Policy Stud.* 12, 115–132. doi:10.1007/s10018-010-0164-7

Brashares, J. S., Arcese, Peter, Sam, M. K., Coppolillo, P. B., Sinclair, A. R., and Balmford, A. (2004). Bushmeat hunting, wildlife declines, and fish supply in west Africa. *Science* 306, 1180–1183. doi:10.1126/science.1102425

Brooks, J. S., Waylen, K. A., and Mulder, M. B. (2012). How national context, project design, and local community characteristics influence success in community-based conservation projects. *Proc. Natl. Acad. Sci. U. S. A.* 109 (52), 21265–21270. doi:10.1073/pnas.1207141110

Buch, C., Koch, C., and Koetter, M. (2012). Do banks benefit from internationalization? Revisiting the market power-risk nexus. *Rev. Financ.* 17, 1401–1435. doi:10.1093/rof/rfs033

Busso, M., Gregory, J., and Kline, P. (2013). Assessing the incidence and efficiency of a prominent place based policy. *Am. Econ. Rev.* 103 (2), 897–947. doi:10.1257/aer.103.2.897

Cao, H., Zhao, X. Q., Wang, S. P., Zhao, L., Duan, J. C., Zhang, Z. H., et al. (2015). Grazing intensifies degradation of a Tibetan plateau alpine meadow through plant-pest interaction. *Ecol. Evol.* 5 (12), 2478–2486. doi:10.1002/ece3.1537

Carlsson, F., and Gable, S. (2000). *Political and economic freedom and the environment: The case of co2 emissions*. Available at: https://www.semanticscholar.org/paper/Political-and-Economic-Freedom-and-the-Environment%3A-Carlsson-SusannaLundstr%C3%B6m/42f9d33a623f0ca38337e23aaca05f6f55722897.

Cavendish, W. (2000). Empirical regularities in the poverty-environment relationship of rural households: Evidence from Zimbabwe. *World Dev.* 28 (11), 1979–2003. doi:10.1016/S0305-750X(00)00066-8

Chen, J., Wang, L., and Li, Y. (2020). Natural resources, urbanization and regional innovation capabilities. *Resour. Policy* 66, 101643. doi:10.1016/j.resourpol.2020.101643

Chen, S., Ou, J., and He, L. (2021). The environmental and health impacts of poverty alleviation in China: From a consumption-based perspective. *Sustainability* 13 (4), 1784. doi:10.3390/su13041784

Chien, F., Chau, K. Y., and Zhang, Y. (2022). Retracted article: Research on the coordinated development of environmental protection and industry in poverty alleviation under uncertainty. *Econ. Research-Ekonomska Istraz.* 35 (1), 1–18. doi:10.1080/1331677X.2020.1845968

Clemens, M., Radelet, S., Bhavnani, R., and Bazzi, S. (2012). Counting chickens when they hatch: Timing and the effects of aid on growth. *Econ. J.* 122, 590–617. doi:10.1111/j.1468-0297.2011.02482.x

Comim, F., Kumar, P., and Sirven, N. (2009). Poverty and environment links: An illustration from Africa. *J. Int. Dev.* 21, 447–469. doi:10.1002/jid.1562

Cornett, M. M., Marcus, A. J., Saunders, A., and Tehranian, H. (2007). The impact of institutional ownership on corporate operating performance. *J. Bank. Finance* 31 (6), 1771–1794. doi:10.1016/j.jbankfin.2006.08.006

Cristina, B., and Guido, P. (2011). How are growth and productivity in private firms affected by public subsidy? Evidence from a regional policy. *Regional Sci. Urban Econ.* 41 (3), 253–265. doi:10.1016/j.regsciurbeco.2011.01.005

Cui, J., Zhu, M., Liang, Y., Qin, G., Li, J., and Liu, Y. (2022). Land use/land cover change and their driving factors in the yellow river basin of shandong province based on Google Earth engine from 2000 to 2020. *ISPRS Int. J. Geo-Inf.* 11 (3), 163. doi:10.3390/ijgi11030163

Dasgupta, S., Deichmann, U., Meisner, C., and Wheeler, D. (2005). Where is the poverty–environment nexus? Evidence from Cambodia, Lao pdr, and vietnam. *World Dev.* 33 (4), 617–638. doi:10.1016/j.worlddev.2004.10.003

Davies, R., Kristjánsdóttir, H., and Ionascu, D. (2008). Estimating the impact of time-invariant variables on fdi with fixed effects. *Rev. World Econ.* 144, 381–407. doi:10.1007/s10290-008-0153-0

Davies, T. E., Fazey, I., Cresswell, W., and Pettorelli, N. (2014). Missing the trees for the wood: Why we are failing to see success in pro-poor conservation. *Anim. Conserv.* 17 (4), 303–312. doi:10.1111/acv.12094

De Carvalho, R. M., and Szlafsztein, C. F. (2019). Urban vegetation loss and ecosystem services: The influence on climate regulation and noise and air pollution. *Environ. Pollut.* 245, 844–852. doi:10.1016/j.envpol.2018.10.114

Dedecek, R., and Dudzich, V. (2022). Exploring the limitations of gdp per capita as an indicator of economic development: A cross-country perspective. *Rev. Econ. Perspect.* 22 (3), 193–217. doi:10.2478/revecp-2022-0009

Deng, Q., Li, E., and Yang, Y. (2022). Politics, policies and rural poverty alleviation outcomes: Evidence from lankao county, China. *Habitat Int.* 127, 102631. doi:10.1016/j.habitatint.2022.102631

Dhaliwal, D., Judd, J. S., Serfling, M., and Shaikh, S. (2016). Customer concentration risk and the cost of equity capital. *J. Account. Econ.* 61 (1), 23–48. doi:10.1016/j.jacceco.2015.03.005

Dong, S., Shang, Z., Gao, J., and Boone, R. B. (2020). Enhancing sustainability of grassland ecosystems through ecological restoration and grazing management in an era of climate change on qinghai-Tibetan plateau. *Agric. Ecosyst. Environ.* 287, 106684. doi:10.1016/j.agee.2019.106684

Dunlop, T., and Corbera, E. (2016). Incentivizing REDD+: How developing countries are laying the groundwork for benefit-sharing. *Environ. Sci. Policy* 63, 44–54. doi:10.1016/j.envsci.2016.04.018

Fan, H., Tao, S., and Hashmi, S. (2021). Does the construction of a water ecological civilization city improve green total factor productivity? Evidence from a quasi-natural experiment in China. *Int. J. Environ. Res. Public Health* 18, 11829. doi:10.3390/ijerph182211829

Frank, L., and Engelke, P. (2005). Multiple impacts of the built environment on public health: Walkable places and the exposure to air pollution. *Int. Regional Sci. Rev.* 28, 193–216. doi:10.1177/0160017604273853

Fu, R., Jin, G., Chen, J. Y., and Ye, Y. Y. (2021). The effects of poverty alleviation investment on carbon emissions in China based on the multiregional input-output model. *Technol. Forecast. Soc. Change* 162, 120344. doi:10.1016/j.techfore.2020.120344

Fuenfgelt, J., and Schulze, G. G. (2016). Endogenous environmental policy for small open economies with transboundary pollution. *Econ. Model.* 57, 294–310. doi:10.1016/j.econmod.2016.03.021

Ghanem, D., and Zhang, J. (2014). Effortless perfection:' do Chinese cities manipulate air pollution data? *J. Environ. Econ. Manag.* 68 (2), 203–225. doi:10.1016/j.jeem.2014.05.003

Giua, M. (2017). Spatial discontinuity for the impact assessment of the eu regional policy: The case of Italian objective 1 regions. *J. Regional Sci.* 57 (1), 109–131. doi:10.1111/jors.12300

Gong, C., Zhang, J., and Liu, H. (2020). Do industrial pollution activities in China respond to ecological fiscal transfers? Evidence from payments to national key ecological function zones. *J. Environ. Plan. Manag.* 64, 1184–1203. doi:10.1080/09640568.2020.1813695

Gray, L., and Moseley, W. (2005). A geographical perspective on poverty-environment interactions. *Geogr. J.* 171, 9–23. doi:10.1111/j.1475-4959.2005.00146.x

Gray, W. B., and Shadbegian, R. J. (2003). Plant vintage, technology, and environmental regulation. *J. Environ. Econ. Manag.* 46 (3), 384–402. doi:10.1016/S0095-0696(03)00031-7

Green, R., Malpezzi, S., and Mayo, S. (2005). Metropolitan-specific estimates of the price elasticity of supply of housing, and their sources. *Am. Econ. Rev.* 95, 334–339. doi:10.1257/000282805774670077

Guild, J. (2020). The political and institutional constraints on green finance in Indonesia. *J. Sustain. Finance Invest.* 10, 157–170. doi:10.1080/20430795.2019.1706312

Guio, A., Marlier, E., and Atkinson, A. (2015). Monitoring the evolution of income poverty and real incomes over time. *CASE* 188.

Guo, Y., and Liu, Y. (2021). Poverty alleviation through land assetization and its implications for rural revitalization in China. *Land Use Policy* 105, 105418. doi:10.1016/j.landusepol.2021.105418

Gupta, J., and Vegelin, C. (2016). Sustainable development goals and inclusive development. *Int. Environ. Agreements.* 16 (3), 433–448. doi:10.1007/s10784-016-9323-z

Haider, L. J., Boonstra, W. J., Peterson, G. D., and Schluter, M. (2018). Traps and sustainable development in rural areas: A review. *World Dev.* 101, 311–321. doi:10.1016/j.worlddev.2017.05.038

Hawkins, S. S., and Baum, C. F. (2016). Invited commentary: An interdisciplinary approach for policy evaluation. *Am. J. Epidemiol.* 183 (6), 539–541. doi:10.1093/aje/kwv237

Hayes, T., Murtinho, F., Wolff, H., and Cleveland, C. J. (2015). An institutional analysis of payment for environmental services on collectively managed lands in Ecuador

Hayo, B., Kutan, A. M., and Neuenkirch, M. (2010). The impact of u.s. Central bank communication on European and Pacific equity markets. *Econ. Lett.* 108 (2), 172–174. doi:10.1016/j.econlet.2010.05.006

He, C., Zhang, T., and Rui, W. (2012). Air quality in urban China. *Eurasian Geogr. Econ.* 53, 750–771. doi:10.2747/1539-7216.53.6.750

He, L., Wu, M., Wang, D., and Zhong, Z. (2018). A study of the influence of regional environmental expenditure on air quality in China: The effectiveness of environmental policy. *Environ. Sci. Pollut. Res.* 25, 7454–7468. doi:10.1007/s11356-017-1033-8

Hou, L., Chen, Q., Huang, J., He, Y., Rose, N., Rozelle, S., et al. (2021). Grassland ecological compensation policy in China improves grassland quality and increases herders' income. *Nat. Commun.* 12, 4683–4692. doi:10.1038/s41467-021-24942-8

Hou, Y., Yin, G., and Chen, Y. (2022). Environmental regulation, financial pressure and industrial ecological efficiency of resource-based cities in China: Spatiotemporal characteristics and impact mechanism. *Int. J. Environ. Res. PUBLIC HEALTH* 19 (17), 11079. doi:10.3390/ijerph191711079

Howe, C., Suich, H., Gardingen, P. V., Rahman, A., and Mace, G. M. (2013). Elucidating the pathways between climate change, ecosystem services and poverty alleviation. *Curr. Opin. Environ. Sustain.* 5 (1), 102–107. doi:10.1016/j.cosust.2013.02.004

Hua, L., Zhang, H., Liu, X., Yang, X., Duan, H., Tieniu, W., et al. (2020). Climate comfort evaluation of national 5a touristattractions in the mainland of China based on universal thermal climate index. *Adv. Meteorology* 2020, 1–8. doi:10.1155/2020/4256164

Huang, F. B., Li, W. J., Jin, S., Yue, M., Shuai, C. M., Cheng, X., et al. (2022). Impact pathways of photovoltaic poverty alleviation in China: Evidence from a systematic review. *Sustain. Prod. Consum.* 29, 705–717. doi:10.1016/j.spc.2021.11.015

Huang, Y. (2022). The impact of government official assessment on ecological poverty alleviation: Evidence from Chinese listed companies. *Int. J. Environ. Res. PUBLIC HEALTH* 19 (6), 3470. doi:10.3390/ijerph19063470

Hui, C., Shen, F., Tong, L., Zhang, J., and Liu, B. (2022). Fiscal pressure and air pollution in resource-dependent cities: Evidence from China. *Front. Environ. Sci.* 10, 908490. doi:10.3389/fenvs.2022.908490

Jans, J., Johansson, P., and Nilsson, J. P. (2018). Economic status, air quality, and child health: Evidence from inversion episodes. *J. Health Econ.* 61, 220–232. doi:10.1016/j.jhealeco.2018.08.002

JenniferAlix-Garcia, C., Katharine, R., et al. (2013). The ecological footprint of poverty alleviation: Evidence from Mexico's oportunidades program." in *Review of economics & statistics*.

Jia, R., Kudamatsu, M., and Seim, D. (2014). Political selection in China: The complementary roles of connections and performance. *SSRN J.* 13, 801. doi:10.2139/ssrn.2468801

Jiang, C., Zhang, L. B., and Tang, Z. P. (2017). Multi-temporal scale changes of streamflow and sediment discharge in the headwaters of yellow river and yangtze river on the Tibetan plateau, China. *Ecol. Eng.* 102, 240–254. doi:10.1016/j.ecoleng.2017.01.029

Jiang, Y., Zhang, L., Li, Y., Lin, J., Li, J., Zhou, G., et al. (2021). Evaluation of county-level poverty alleviation progress by deep learning and satellite observations. *Big Earth Data* 5 (4), 576–592. doi:10.1080/20964471.2021.1967259

Jiao, H., Alon, I., and Cui, Y. (2011). Environmental dynamism, innovation, and dynamic capabilities: The case of China. *J. Enterprising Communities* 5, 131–144. doi:10.1108/17506201111131550

Leffel, B., Tavasoli, N., Liddle, B., Henderson, K., and Kiernan, S. (2022). Metropolitan air pollution abatement and industrial growth: Global urban panel analysis of pm10, pm2.5, no2 and so2. *Environ. Sociol.* 8 (1), 94–107. doi:10.1080/23251042.2021.1975349

Lei, M., Yuan, X., and Yao, X. (2021). Synthesize dual goals: A study on China's ecological poverty alleviation system. *J. Integr. Agric.* 20 (4), 1042–1059. doi:10.1016/S2095-3119(21)63635-3

Li, H, H., Lu, J., and Li, B. (2020). Does pollution-intensive industrial agglomeration increase residents' health expenditure? *Sustain. Cities Soc.* 56, 102092. doi:10.1016/j.scs.2020.102092

Li, Q, Q., Shi, X., and Wu, Q. (2020). Exploring suitable topographical factor conditions for vegetation growth in wanhuigou catchment on the loess plateau, China: A new perspective for ecological protection and restoration. *Ecol. Eng.* 158, 106053. doi:10.1016/j.ecoleng.2020.106053

Li, R. Q, R. Q., Shan, Y. L., Bi, J., Liu, M. M., Ma, Z. W., Wang, J. N., et al. (2021). Balance between poverty alleviation and air pollutant reduction in China. *Environ. Res. Lett.* 16 (9), 094019. doi:10.1088/1748-9326/ac19db

Li, T, T., Ma, J., and Mo, B. (2021). Does environmental policy affect green total factor productivity? Quasi-natural experiment based on China's air pollution control and prevention action plan. *Int. J. Environ. Res. PUBLIC HEALTH* 18 (15), 8216. doi:10.3390/ijerph18158216

Lin, B., and Zhou, Y. (2021a). Does fiscal decentralization improve energy and environmental performance? New perspective on vertical fiscal imbalance. *Appl. Energy* 302, 117495. doi:10.1016/j.apenergy.2021.117495

Lin, B., and Zhou, Y. (2021b). How does vertical fiscal imbalance affect the upgrading of industrial structure? Empirical evidence from China. *Technol. Forecast. Soc. Change* 170, 120886. doi:10.1016/j.techfore.2021.120886

Lin, B., and Zhu, J. (2019). Fiscal spending and green economic growth: Evidence from China. *Energy Econ.* 83, 264–271. doi:10.1016/j.eneco.2019.07.010

Lin, Q., Luo, X., Lin, G., Yang, T., and Su, W. (2022). Impact of relocation and reconstruction policies on the upgrading of urban industrial structure in old industrial districts. *Front. Environ. Sci.* 10, 2993. doi:10.3389/fenvs.2022.1002993

Liu, H., Fang, C., Zhang, X., Wang, Z., Bao, C., and Li, F. (2017). The effect of natural and anthropogenic factors on haze pollution in Chinese cities: A spatial econometrics approach. *J. Clean. Prod.* 165, 323–333. doi:10.1016/j.jclepro.2017.07.127

Liu, K., Qiao, Y. R., Shi, T., and Zhou, Q. (2021). Study on coupling coordination and spatiotemporal heterogeneity between economic development and ecological environment of cities along the yellow river basin. *Environ. Sci. Pollut. Res.* 28 (6), 6898–6912. doi:10.1007/s11356-020-11051-0

Liu, L., Di, B., and Zhang, M. (2020). The tradeoff between ecological protection and economic growth in China's county development: Evidence from the soil and water conservation projects during 2011-2015. *Resour. Conservation Recycl.* 156, 104745. doi:10.1016/j.resconrec.2020.104745

Liu, Y., Wang, J., and Deng, X. (2008). Rocky land desertification and its driving forces in the karst areas of rural guangxi, southwest China. *J. Mt. Sci.* 5, 350–357. doi:10.1007/s11629-008-0217-6

López, R., Galinato, G. I., and Islam, A. (2011). Fiscal spending and the environment: Theory and empirics. *J. Environ. Econ. Manag.* 62 (2), 180–198. doi:10.1016/j.jeem.2011.03.001

Luo, X., Qin, J., Wan, Q., and Jin, G. (2021). Expenditure fluctuation and consumption loss: Rural spatial poverty in China. *Technol. Econ. Dev. Econ.* 27 (6), 1357–1382. doi:10.3846/tede.2021.15374

Maes, J., and Jacobs, S. (2015). Nature-based solutions for europe's sustainable development. *Conserv. Lett.* 10, 121–124. in press. doi:10.1111/conl.12216

Mafi-Gholami, D., and Baharlouii, M. (2019). Monitoring long-term mangrove shoreline changes along the northern coasts of the Persian gulf and the Oman sea. *Emerg. Sci. J.* 3, 88. doi:10.28991/esj-2019-01172

Mahmood, R., Jia, S., Lv, A., and Zhu, W. (2020). A preliminary assessment of environmental flow in the three rivers' source region, qinghai Tibetan plateau, China and suggestions. *Ecol. Eng.* 144, 105709. doi:10.1016/j.ecoleng.2019.105709

Malerba, D. (2020). Poverty alleviation and local environmental degradation: An empirical analysis in Colombia. *World Dev.* 127, 104776. doi:10.1016/j.worlddev.2019.104776

Medina-Munoz, D. R., Medina-Munoz, R. D., and Gutierrez-Perez, F. J. (2016). The impacts of tourism on poverty alleviation: An integrated research framework. *J. Sustain. Tour.* 24 (2), 270–298. doi:10.1080/09669582.2015.1049611

Meijaard, E., Santika, T., Wilson, K. A., Budiharta, S., and Struebig, M. J. (2020). Toward improved impact evaluation of community forest management in Indonesia. *Conserv. Sci. Pract.*

Mojo, D., Fischer, C., and Degefa, T. (2017). The determinants and economic impacts of membership in coffee farmer cooperatives: Recent evidence from rural Ethiopia. *J. Rural Stud.* 50, 84–94. doi:10.1016/j.jrurstud.2016.12.010

Ouyang, J., Zhang, K., Wen, B., and Lu, Y. (2020). Top-down and bottom-up approaches to environmental governance in China: Evidence from the river chief system (rcs). *Int. J. Environ. Res. Public Health* 17, 7058. doi:10.3390/ijerph17197058

Pan, H., Page, J., Cong, C., Barthel, S., and Kalantari, Z. (2021). How ecosystems services drive urban growth: Integrating nature-based solutions. *Anthropocene* 35, 100297. doi:10.1016/j.ancene.2021.100297

Panda, S., and Siva Nagendra, S. M. (2018). Chemical and morphological characterization of respirable suspended particulate matter (pm 10) and associated heath risk at a critically polluted industrial cluster. *Atmos. Pollut. Res.* 9, 791–803. doi:10.1016/j.apr.2018.01.011

Park, A., Wang, S., and Wu, G. (2002). Regional poverty targeting in China. *J. Public Econ.* 86 (1), 123–153. doi:10.1016/S0047-2727(01)00108-6

Pereira, C. (2008). Appropriating 'gender' and 'empowerment': The resignification of feminist ideas in Nigeria's neoliberal reform programme. *IDS Bull.* 39 (6), 42–50. doi:10.1111/j.1759-5436.2008.tb00510.x

Piotroski, J. D., and Zhang, T. (2014). Politicians and the ipo decision: The impact of impending political promotions on ipo activity in China. *J. Financial Econ.* 111 (1), 111–136. doi:10.1016/j.jfineco.2013.10.012

Porras, I., and Asquith, N. (2018). *Ecosystems, poverty alleviation and conditional transfers guidance for practitioners*. London: International Institute for Environment and Development.

Qi, J. W., Lu, Y. Y., Han, F., Ma, X. K., and Yang, Z. P. (2022). Spatial distribution characteristics of the rural tourism villages in the qinghai-Tibetan plateau and its influencing factors. *Int. J. Environ. Res. PUBLIC HEALTH* 19 (15), 9330. doi:10.3390/ijerph19159330

Qi, Y. J., and Li, W. J. (2021). A nested property right system of the commons: Perspective of resource system-units. *Environ. Sci. Policy* 115, 1–7. doi:10.1016/j.envsci.2020.10.009

Qi, Y., and Zhang, L. (2014). Local environmental enforcement constrained by central-local relations in China. *Env. Pol. Gov.* 24 (3), 216–232. doi:10.1002/eet.1640

Qin, C., and Zhang, W. (2022). Green, poverty reduction and spatial spillover: An analysis from 21 provinces of China. *Environ. Dev. Sustain.* 24, 13610–13629. doi:10.1007/s10668-021-02003-w

Rakatama, A., and Pandit, R. (2020). Reviewing social forestry schemes in Indonesia: Opportunities and challenges. *For. Policy Econ.* 111, 102052. doi:10.1016/j.forpol.2019.102052

Ravallion, M. (1990). On the coverage of public employment schemes for poverty alleviation. *J. Dev. Econ.* 34 (1), 57–79. doi:10.1016/0304-3878(90)90076-N

Samal, P. K., Palni, L., and Agrawal, D. K. (2003). Ecology, ecological poverty and sustainable development in central himalayan region of India. *Int. J. Sustain. Dev. World Ecol.* 10 (2), 157–168. doi:10.1080/13504500309469794

Schmidt, J. P., Moore, R., and Alber, M. (2014). Integrating ecosystem services and local government finances into land use planning: A case study from coastal Georgia. *Landsc. Urban Plan.* 122, 56–67. doi:10.1016/j.landurbplan.2013.11.008

Schweitzer, L., and Zhou, J. (2010). Neighborhood air quality, respiratory health, and vulnerable populations in compact and sprawled regions. *J. Am. Plan. Assoc.* 76, 363–371. doi:10.1080/01944363.2010.486623

Shah, M., Wang, N., Ullah, I., Akbar, A., Khan, K., and Bah, K. (2020). Does environment quality and public spending on environment promote life expectancy in China? Evidence from a nonlinear autoregressive distributed lag approach. *Int. J. Health Plann. Mgmt.* 36, 545–560. doi:10.1002/hpm.3100

Shao, L., Zhang, H., and Irfan, M. (2022). How public expenditure in recreational and cultural industry and socioeconomic status caused environmental sustainability in oecd countries? *Econ. Research-Ekonomska Istraz.* 35 (1), 4625–4642. doi:10.1080/1331677X.2021.2015614

Sheng, W., Wan, L., and Wang, C. (2022). The spillover effect of fiscal environmental protection spending on residents' medical and healthcare expenditure: Evidence from China. *Environ. Geochem. Health* 44, 2975–2986. doi:10.1007/s10653-021-01146-z

Shi, Y., Guan, Y., Li, L., and Huang, M. (2022). Empirical analysis on the impacts of carbon sink afforestation project on county industrial structural upgrading. *Alexandria Eng. J.* 61 (1), 207–216. doi:10.1016/j.aej.2021.04.091

Sinn, H. W. (2008). Public policies against global warming: A supply side approach. *Int. Tax. Public Finance* 15 (4), 360–394. doi:10.1007/s10797-008-9082-z

Skutsch, M., Balderas Torres, A., and Carrillo Fuentes, J. C. (2017). Policy for pro-poor distribution of redd+ benefits in Mexico: How the legal and technical challenges are being addressed. *For. Policy Econ.* 75, 58–66. doi:10.1016/j.forpol.2016.11.014

Su, C., Umar, M., and Khan, Z. (2021). Does fiscal decentralization and eco-innovation promote renewable energy consumption? Analyzing the role of political risk. *Sci. Total Environ.* 751, 142220. doi:10.1016/j.scitotenv.2020.142220

Su, X., Han, W., Liu, G., Zhang, Y., and Lu, H. (2019). Substantial gaps between the protection of biodiversity hotspots in alpine grasslands and the effectiveness of protected areas on the qinghai-Tibetan plateau, China. *Agric. Ecosyst. Environ.* 278, 15–23. doi:10.1016/j.agee.2019.03.013

Tacconi, L., Jotzo, F., and Grafton, R. Q. (2008). Local causes, regional co-operation and global financing for environmental problems: The case of southeast Asian haze pollution. *Int. Environ. Agreements.* 8 (1), 1–16. doi:10.1007/s10784-007-9057-z

Titus, M. A. (2007). Detecting selection bias, using propensity score matching, and estimating treatment effects: An application to the private returns to a master's degree. *Res. High. Educ.* 48 (4), 487–521. doi:10.1007/s11162-006-9034-3

Wang, D., Zhang, E., and Liao, H. (2022). Does fiscal decentralization affect regional high-quality development by changing peoples' livelihood expenditure preferences: Provincial evidence from China. *Land* 11 (9), 1407. doi:10.3390/land11091407

Wang, J., Wang, Y., Li, S. C., and Qin, D. H. (2016). Climate adaptation, institutional change, and sustainable livelihoods of herder communities in northern tibet. *E&S.* 21 (1), art5. doi:10.5751/ES-08170-210105

Wang, P., Lassoie, J. P., Morreale, S. J., and Dong, S. (2015). A critical review of socioeconomic and natural factors in ecological degradation on the qinghai-tibetan plateau, China. *Rangeland J.* 37 (1), 1–9. doi:10.1071/RJ14094

Wang, W. J., Zhao, X. Y., Cao, J. J., Li, H., and Zhang, Q. (2020). Barriers and requirements to climate change adaptation of mountainous rural communities in developing countries: The case of the eastern qinghai-Tibetan plateau of China. *Land Use Policy* 95, 104354. doi:10.1016/j.landusepol.2019.104354

Wang, X., and Lei, P. (2020). Does strict environmental regulation lead to incentive contradiction? — Evidence from China. *J. Environ. Manag.* 269, 110632. doi:10.1016/j.jenvman.2020.110632

Wang, Y., and Li, Y. (2019). Promotion of degraded land consolidation to rural poverty alleviation in the agro-pastoral transition zone of northern China. *Land Use Policy* 88, 104114. doi:10.1016/j.landusepol.2019.104114

Ward, P., and Shively, G. (2012). Vulnerability, income growth and climate change. *World Dev.* 40 (5), 916–927. doi:10.1016/j.worlddev.2011.11.015

Wen, H., and Lee, C. (2020). Impact of fiscal decentralization on firm environmental performance: Evidence from a county-level fiscal reform in China. *Environ. Sci. Pollut. Res.* 27, 36147–36159. doi:10.1007/s11356-020-09663-7

Westmore, B. (2018). Do government transfers reduce poverty in China? Micro evidence from five regions. *China Econ. Rev.* 51, 59–69. doi:10.1016/j.chieco.2018.05.009

Wiedmann, T., and Allen, C. (2021). City footprints and sdgs provide untapped potential for assessing city sustainability. *Nat. Commun.* 12 (1), 3758. doi:10.1038/s41467-021-23968-2

Wu, J., Hou, F., and Yu, W. (2021). The effect of carbon sink plantation projects on local economic growth: An empirical analysis of county-level panel data from guangdong province. *Sustainability* 13 (24), 13864. doi:10.3390/su132413864

Wu, J. S., Shen, Z. X., Shi, P. L., Zhou, Y. T., and Zhang, X. Z. (2014). Effects of grazing exclusion on plant functional group diversity of alpine grasslands along a

precipitation gradient on the northern Tibetan plateau. *Arct. Antarct. Alp. Res.* 46 (2), 419–429. doi:10.1657/1938-4246-46.2.419

Wu, L., and Jin, L. S. (2020). How eco-compensation contribute to poverty reduction: A perspective from different income group of rural households in guizhou, China. *J. Clean. Prod.* 275, 122962. doi:10.1016/j.jclepro.2020.122962

Xiao, Y., Tian, K., Huang, H., Wang, J., and Zhou, T. (2021). Coupling and coordination of socioeconomic and ecological environment in wenchuan earthquake disaster areas: Case study of severely affected counties in southwestern China. *Sustain. Cities Soc.* 71, 102958. doi:10.1016/j.scs.2021.102958

Xu, H., Pan, W., Xin, M., Pan, W. L., Hu, C., Dai, W. Q., et al. (2022). Study of the economic, environmental, and social factors affecting Chinese residents' health based on machine learning. *Front. Public Health* 10, 896635. doi:10.3389/fpubh.2022.896635

Xu, H., Qiu, L., Liu, B., Liu, B., Wang, H., and Lin, W. (2021). Does regional planning policy of yangtze river delta improve green technology innovation? Evidence from a quasi-natural experiment in China. *Environ. Sci. Pollut. Res.* 28 (44), 62321–62337. doi:10.1007/s11356-021-14946-8

Yang, R., Zhong, C., Yang, Z., and Wu, Q. (2022). Analysis on the effect of the targeted poverty alleviation policy on narrowing the urban-rural income gap: An empirical test based on 124 counties in yunnan province. *Sustainability* 14 (19), 12560. doi:10.3390/su141912560

Yao, L., Sun, Z., and Wang, Q. (2010). Estimation of average treatment effects based on parametric propensity score model. *J. Stat. Plan. Inference* 140 (3), 806–816. doi:10.1016/j.jspi.2009.09.009

Yu, M., Zhou, W., Zhao, X., Liang, X., Wang, Y., and Tang, G. (2022). Is urban greening an effective solution to enhance environmental comfort and improve air quality? *Environ. Sci. Technol.* 56 (9), 5390–5397. doi:10.1021/acs.est.1c07814

Zahra, S., Khan, D., and Nouman, M. (2022). Fiscal policy and environment: A long-run multivariate empirical analysis of ecological footprint in Pakistan. *Environ. Sci. Pollut. Res.* 29 (2), 2523–2538. doi:10.1007/s11356-021-15665-w

Zeng, G., Zhang, C., Li, S., and Sun, H. (2021). The dynamic impact of agricultural fiscal expenditures and gross agricultural output on poverty reduction: A var model analysis. *Sustainability* 13, 5766. doi:10.3390/su13115766

Zhang, P. (2020). Target interactions and target aspiration level adaptation: How do government leaders tackle the "environment-economy" nexus? *Public admin. Rev.* 81, 220–230. doi:10.1111/puar.13184

Zhang, X., Wang, Y., Yuan, X., and Yang, Y. (2022). Regional land ecological security evaluation and ecological poverty alleviation practice: A case study of yangxian county in shaanxi province, China. *J. Geogr. Sci.* 32 (4), 682–700. doi:10.1007/s11442-022-1967-8

Zhang, Y., and Feng, L. (2020). "The coupling relationship between economic poverty alleviation and ecological poverty alleviation in concentrated and contiguous poverty-stricken areas: Take yunnan province as an example," in IOP Conference Series: Earth and Environmental Science, 615 (1), 12018. doi:10.1088/1755-1315/615/1/012018

Zhang, Z., and Zhao, W. (2018). Research on financial pressure, poverty governance, and environmental pollution in China. *Sustainability* 10 (6), 1834. doi:10.3390/su10061834

Zhen, N., Fu, B., Lu, Y., and Wang, S. (2014). Poverty reduction, environmental protection and ecosystem services: A prospective theory for sustainable development. *Chin. Geogr. Sci.* 24 (1), 83–92. doi:10.1007/s11769-014-0658-5

Zhou, D., Zhang, X., and Wang, X. (2020). Research on coupling degree and coupling path between China's carbon emission efficiency and industrial structure upgrading. *Environ. Sci. Pollut. Res.* 27 (20), 25149–25162. doi:10.1007/s11356-020-08993-w

Zhou, L., and Tang, L. (2021). Environmental regulation and the growth of the total-factor carbon productivity of China's industries: Evidence from the implementation of action plan of air pollution prevention and control. *J. Environ. Manag.* 296, 113078. doi:10.1016/j.jenvman.2021.113078

Zhou, X., Zhang, J., and Li, J. (2013). Industrial structural transformation and carbon dioxide emissions in China. *Energy Policy* 57, 43–51. doi:10.1016/j.enpol.2012.07.017

Zhou, Y., Guo, L., and Liu, Y. (2019). Land consolidation boosting poverty alleviation in China: Theory and practice. *Land Use Policy* 82, 339–348. doi:10.1016/j.landusepol.2018.12.024

Zhu, M. C., Shen, L. Y., Tam, V., Liu, Z., Shu, T. H., and Luo, W. Z. (2020). A load-carrier perspective examination on the change of ecological environment carrying capacity during urbanization process in China. *Sci. Total Environ.* 714, 136843. doi:10.1016/j.scitotenv.2020.136843

Zhu, S., He, C., and Liu, Y. (2014). Going green or going away: Environmental regulation, economic geography and firms' strategies in China's pollution-intensive industries. *Geoforum* 55, 53–65. doi:10.1016/j.geoforum.2014.05.004

Zhu, Y., Liu, Z., Feng, S., and Lu, N. (2022). The role of fiscal expenditure on science and technology in carbon reduction: Evidence from provincial data in China. *Environ. Sci. Pollut. Res.* 29 (54), 82030–82044. doi:10.1007/s11356-022-21500-7