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The impact of rural living environment improvement programs on the subjective well-being of rural residents in China

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Increasing people's subjective well-being (SWB) remains a critical challenge for all countries. However, few studies have been dedicated to examining the influence of environmental governance programs on SWB, especially in developing and non-democratic societies. This paper aims to fill this void by taking the Rural Living Environment Improvement (RLEI) program in China—the largest rural living environment governance program in history, as an example to understand the role of environmental governance programs in SWB in the world's biggest developing and non-democratic country. Based on 3747 individual samples from the China Labor-force Dynamics Survey database, we found that RLEI can significantly improve rural residents' SWB. This effect remains significant after using the propensity score matching method and the instrumental variable approach to address potential selection bias and endogenous problems. The indirect analysis shows that RLEI can increase rural residents' SWB mainly through improving their income, consumption expenditure, and health. Compared with rural sewage and livestock manure RLEI programs, rural waste RLEI program has a greater enhanced impact on rural residents' SWB. The monetary value of RLEI based on the life satisfaction approach shows that the resulting improvement in rural residents' SWB created by RLEI is almost equivalent to the effect of household income. While the monetary value of rural sewage, livestock manure, and rural waste RLEI program is equivalent to 1.2, 3.67, and 1.1 times the effect of household income. Heterogeneity analysis indicates that RLEI has a greater positive impact on SWB for junior and old-aged, low-educated, Midwestern and Northeastern, and working rural residents.

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Introduction

Subjective well-being (SWB), a common measurement of individuals' happiness (Ng, 1996), has been broadly employed to assess the quality of government policy or public goods provision (Jebb et al., 2018; Jin et al., 2020). The third goal in the 2030 Sustainable Development Goals is "good health and well-being", which intends to enhance the SWB of each person worldwide (Tang et al., 2021). However, increasing people's SWB poses a critical challenge for every nation (Graham et al., 2017), especially in developing countries with increasing economic growth, such as China (Wang et al., 2021a).

Since the 1950s, SWB has become a worldwide academic topic and numerous studies have investigated how to improve people's SWB (Omri et al., 2022). Existing related literature has confirmed that human SWB is influenced by two aspects. The first aspect is socio-demographic individual factors, including income (Killingsworth, 2021; Pouwels et al., 2008), education (Cuñado and de Gracia, 2012), age (Knight et al., 2022), health (Blanchflower and Oswald, 2008), employment (Ashwin et al., 2021), and marital status (Li et al., 2021a). The second aspect is macro contextual factors, such as social security (Prenovitz, 2021), social media use (Schemer et al., 2021), ecosystem services (Wang et al., 2021b), species diversity (Methorst et al., 2021), city size (Dang et al., 2020), and income gap (Wang et al., 2021a). Especially, as environmental issues have gained growing prominence, the impact of environmental pollution on individuals' SWB has garnered escalating attention from academics (Jin et al., 2020). Sufficient empirical analysis has demonstrated a negative association between environmental pollution and residents' SWB (Guo et al., 2021). For example, Li and Zhou (2020) revealed that air pollution had a detrimental result on the residents' SWB. Xu et al., (2022) evidenced that severe air pollution is related to a decline in individuals' SWB. However, there has been comparatively limited research dedicated to examining the effect of environmental governance programs on SWB improvement, especially the influence of rural environmental governance programs on the SWB of rural residents. In actuality, as a result of increasing industrialization and urbanization, rural environmental pollution has emerged as one of the most pressing environmental problems in recent years worldwide, especially in China. According to the data from "The Bulletin of the Second National Pollution Source Census", a significant contributor to water pollution in China is rural environmental pollution, which accounts for 49.8%, 46.5%, and 67.2% of the total national Chemical Oxygen Demand (COD), Total Nitrogen (TN) and Total Phosphorus (TP) emissions. This severe rural environmental pollution has lowered agricultural productivity, devastated local ecosystems, and enhanced health risks to rural communities, all of which have harmed the environment and human well-being in China. To mitigate rural environmental pollution, the Chinese central government has made significant financial commitments and sustained efforts. One of which is the Rural Living Environment Improvement Program (RLEI). RLEI is an ambitious rural revitalization program launched by China in 2018. It is the largest rural living environment improvement government program in history, including 600 million rural residents in China. The key policy interventions involved in RLEI include residential waste treatment, wastewater disposal, toilet revolution, and village appearance improvement (Wang et al., 2021c). The Chinese government has implemented numerous policies to conduct RLEI. For example, the Chinese "Central No. 1 Document" has proposed to carry out RLEI for 15 consecutive years from 2008 to 2022. A three-year and a further five-year action plan for RLEI have been implemented in 2018 and 2021, respectively. It is estimated that every year 6 billion yuan is invested in RLEI in China (Zhao et al., 2019). Theoretically, the enormous efforts and investments in RLEI can provide rural areas with a tidy environment and sufficient infrastructure, which is beneficial to SWB enhancement (Hu and Wang, 2020). However, it is still unknown empirically if this massive investment in RLEI will enhance people's SWB. This question is worth investigating as it can help us understand the mechanism behind RLEI from the perspective of rural residents' SWB. Furthermore, it can provide suggestions on how to optimize the environmental governance programs and perfect other rural revitalization programs to further improve rural residents' SWB.

This study aims to address this knowledge gap by exploring whether a large-scale environmental governance program, RLEI, can contribute to people's SWB in the context of China—the world's largest developing and non-democratic country. We want to address the following research questions: Does RLEI improve rural residents' SWB? If RLEI indeed contributes to an increase in rural residents' SWB, what is its monetary value? Are the effects of RLEI on SWB heterogeneous across different contexts? And what are the mechanisms through which RLEI enhances SWB?

We make four distinct contributions to the existing literature and practice. Firstly, our study offers the first rigorous quantitative estimation, to the best of our understanding, of the influence of the rural environmental governance programs on rural residents' SWB. Existing research either considers the overall influence of environmental governance programs on SWB (Guo et al., 2020; Omri et al., 2022; Xu et al., 2022) or focuses on the effects of urban environmental governance programs on SWB (Chen et al., 2022). Limited research has been conducted to explore the impact of rural environmental governance programs on the SWB of rural residents, despite the severe issue of rural environmental pollution in China. In addition, compared to urban residents, rural residents' welfare losses from environmental pollution are larger due to their low income and education (Pan and Chen, 2021). We intend to solve this knowledge gap by exploring whether a large-scale rural environment improvement program—RLEI can contribute to rural residents' SWB.

Second, our paper contributes to and extends the existing literature on environmental governance programs by examining how rural environmental governance programs implemented in China impact the SWB. We examine the influence of environmental governance programs on the rural residents' SWB in China—the largest developing and non-democratic country in the world. In the developed and democratic context, research has shown that SWB is positively associated with governance programs (Coppel and Wustemann 2017). For example, Willmore (2013) pointed out in theory that SWB is associated with the quality of government programs. Nevertheless, there has been limited focus on investigating whether, and in what ways, environmental governance programs can influence SWB in developing and non-democratic societies. In reality, compared with developed and democratic countries, environmental governance programs may be decisive in enhancing people's SWB in developing and non-democratic societies due to prevalent market failures in these countries. This line of investigation is vital since it is an essential precondition of democratic theory that the environmental governance program can influence SWB. Our paper complements this knowledge by revealing that environmental governance programs can also have a significant positive influence on SWB in an authoritarian regime.

Third, our paper contributes to understanding how RLEI influences rural residents' SWB. We propose and test that the positive impact of RLEI on SWB is mainly through improving rural residents' income, consumption expenditure, and health. Investigating these underlying mechanisms can provide a clearer path for the Chinese government to further perfect

Table 1 Policies related to RLEI at the national level from 2014 to 2022.

Name of policy	Implemented Year	Main contents of the policy
Guidance on improving rural human settlement	2014	Focusing on the treatment of rural garbage and sewage
The overall program of ecological civilization system reform	2015	Strengthen the construction of rural sewage and garbage treatment
Thirteenth Five-Year Plan Outline	2015	Promote the construction of sewage and garbage collection and treatment facilities
Thirteenth Five-Year Plan for Ecological Environmental Protection	2016	Actively promote the extension of rural sewage and garbage treatment facilities
Rural Revitalization Strategy	2018	Pay more attention to rural garbage, sewage treatment, and village appearance improvement
Three-year action plan for rural settlement improvement	2018	Establish a diverse rural waste collection and disposal system
Five-year action plan for rural settlement improvement and upgrading (2021-2025)	2021	Focusing on rural toilets, domestic sewage, garbage treatment, and village appearance improvement
Opinions on the key work of comprehensive promotion of rural revitalization in 2022	2022	Promote rural toilet conversion, water supply, and sewage treatment to meet the actual needs of rural residents

Source: Organized by the author.

relative environmental government programs to improve people's SWB.

Fourth, our paper contributes to estimating the monetary value of RLEI, which can provide a reference for formulating specific schemes, such as assessing the benefits of RLEI improvement, ensuring the effective allocation and rational utilization of resources, and encouraging the Chinese government to continue supporting RLEI. It is challenging to quantify the monetary value of a public good like RLEI, given its inherent non-excludability and non-rivalrous nature. Thus, we adopt the life satisfaction approach (LSA) to calculate the RLEI's monetary value based on the relationship between rural residents' SWB and RLEI. Estimating RLEI's monetary value can provide a reference for formulating specific schemes, such as assessing the benefits of RLEI improvement, ensuring the effective allocation and rational utilization of resources, and encouraging the Chinese government to continue supporting RLEI.

The rest of the paper can be categorized into five sections. Section 2 proposes our theoretical analysis. Section 3 explains the data and method. Section 4 depicts the direct impacts of RLEI on rural resident's SWB, the indirect impacts of RLEI on rural resident's SWB, the impacts of different RLEI measures on rural resident's SWB, the monetary value of RLEI, the robustness tests, and the heterogeneity analysis. Section 5 provides conclusions and corresponding policy recommendations.

Theoretical analysis and research hypotheses

The direct impact of RLEI on rural residents' SWB. Improving people's SWB is the final target of government administration (Song et al., 2019). RLEI is one of the main government governances in rural China and can significantly improve rural residents' SWB.

First, RLEI is the most direct and effective way to upgrade the rural living environment and alleviate rural environmental pollution, thus enhancing people's SWB (Levinson, 2012). The Chinese central government has proposed a variety of policies regarding RLEI to fulfill the increasing demand of rural residents for an improved environment. Table 1 lists the specific policies and measures related to RLEI at the national level from 2014 to 2022. We can see that RLEI paid much attention to the regulation of rural domestic sewage, domestic waste, and livestock manure. With the application of these actions, the investments in the establishment of domestic sewage and waste management capacities have seen a continuous increase from 2014 to 2020 (see Fig. 1). Consequently, under these substantial investments, the quality of the rural environment, including the water, air, and soil quality, has improved dramatically in recent years in rural China (Li et al., 2021b). A substantial body of evidence from previous literature has verified that environmental quality enhancement can significantly improve residents' SWB. On the one hand, better environmental quality can reduce the likelihood of cardiorespiratory deaths, hospitalizations, and respiratory illnesses caused by environmental pollution, thereby increasing peoples' SWB (Orru et al., 2016). On the other hand, environmental quality improvement can enhance peoples' moods by reducing their stress, fear, and depression arising from environmental pollution, thereby increasing their SWB (Dratva et al., 2010).

Second, RLEI can improve rural residents' psychological satisfaction through fulfillment and engagement, thereby enhancing their SWB. On the one hand, rural residents' aspirations for a better living environment can be effectively satisfied through RLEI. RLEI is conducted in the whole village, which means that all rural residents in the village can benefit from RLEI, thus reducing their perception of inequality and improving their SWB (Lee, 2019). On the other hand, RLEI encourages all rural residents to participate, thus enabling them to gain a sense of self-efficacy, social competence, and civic responsibility, which can have positive impacts on their SWB (Csikszentmihalyi, 2000).

The indirect impact of RLEI on rural residents' SWB. Grounded on the utility theory and the related literature of Li et al., (2020), we introduce the utility model in classical economics to analyze the indirect impact of RLEI on rural residents' SWB. Figure 2 depicts the specific conceptual framework. Specifically, we assume that rural residents' SWB utility $\boldsymbol{U}$ derive from the utilization set of RLEI $\boldsymbol{X}$ with public good characteristics and other goods $\boldsymbol{Y}$ with private good characteristics. The reason we treat RLEI as a public good is that it is costly for each rural resident to provide RLEI, and the government providing RLEI can reduce this cost (Li et al., 2020). Supposing that rural residents demand a better RLEI when the government provides RLEI, the cost for rural residents to get a better RLEI decreases. Thus, the relative price of the public commodity $\boldsymbol{X}$ decreases, which will generate two effects—substitution effect and the income effect. The substitution effect indicates that rural residents' RLEI consumption expenditure will increase. However, as Oakland (1987) pointed out there is no price for public goods such as RLEI, and public goods' raised expenses are reflected in the cost of time. Therefore, in this study, we solely focus on the income effect that can be expressed by rural residents' income, consumption

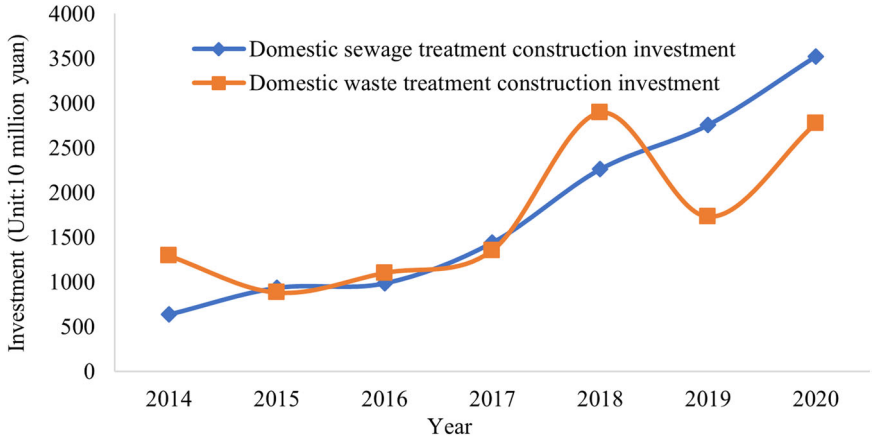

Fig. 1 The investment for village domestic sewage and waste treatment facilities construction. This figure shows the investment for village domestic sewage and waste treatment facilities construction in China 10 million yuan between 2014 and 2020. Source: China Urban and Rural Construction Statistical Yearbook, 2021.

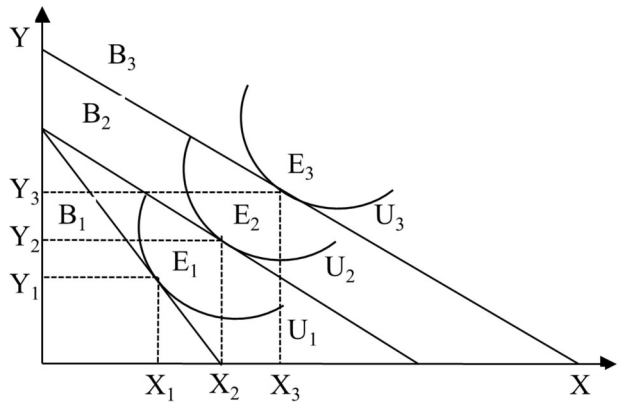

Fig. 2 Conceptual framework. This figure shows the conceptual framework explaining the impact mechanisms of RLEI on SWB. At a certain point of income, the undifferentiated curve is tangent to the budget line at point E1 when the amounts of the two goods are X_1 and Y_1 and rural residents' SWB utility is U (X_1, Y_1). Supposing that rural residents' demand a better RLEI when the government provides RLEI, the cost for rural residents to get a better RLEI decreases. Source: Organized by the author.

expenditure, and health (Fiorito and Kollintzas, 2004; Li et al., 2020). The specific explanations are as follows.

First, RLEI can increase rural residents' income and thus promote their SWB. On the one hand, rural residents' agricultural income can increase with the application of RLEI. This is because measures of RLEI, such as improving villages' architectural appearance and planting trees, can create additional jobs for rural residents to participate in, and thus rural residents can gain income from these jobs (Wang et al., 2021d). On the other hand, rural residents' non-agricultural income can also be enhanced due to environmental quality improvement under RLEI (Hu and Wang, 2020). For example, the improvement of the rural environment creates favorable conditions for the growth of rural tourism, enabling numerous rural residents to generate non-agricultural income from rural tourism development (Shen et al., 2021).

Second, RLEI can increase rural residents' consumption expenditure and thus promote their SWB. On the one hand, it is assumed that as government spending on RLEI increases, rural residents do not need to spend more money to obtain better RLEI. Such savings in public goods consumption allow people to indirectly increase their income and thus consume more private goods (Li et al., 2020). On the other hand, a better rural environment resulting from the implementation of RLEI will raise people's demand for a better quality of life, which in turn increases their private consumption (Fiorito and Kollintzas, 2004).

Third, RLEI can increase rural residents' health and thus promote their SWB. In the direct aspect, RLEI will significantly improve the local environmental condition and thus alleviate pollution. A better living environment is beneficial to rural residents' physical health, which enhances their SWB (Tong et al., 2022). Additionally, RLEI can ease rural residents' fear of environmental pollution, making it easier for them to access natural spaces and landscapes (Mackerron and Mourato, 2009). These improvements help mitigate rural residents' depression, improve their mental health, and thus enhance their SWB (Tang et al., 2023). In the indirect aspect, on the one hand, good physical and mental health leads to higher productivity and more income, which in turn increases peoples' SWB (Charlery et al., 2016). On the other hand, good physical and mental health makes rural residents spend less money on their bodies, which in turn increases their SWB (Zhang et al., 2021).

Therefore, we put forward Hypotheses 1 that RLEI has a positive effect on rural residents' SWB, and Hypothesis 2 that the positive impact of RLEI on rural residents' SWB mainly through boosting rural residents' income, consumption expenditure, and health.

The impact of different types of RLEI on rural residents' SWB. As can be seen from Table 1, there are different types of RLEI, including the rural sewage environment improvement program (rural sewage), the rural livestock manure environment improvement program (livestock manure), and the rural waste environment improvement program (rural waste). Based on the status of different types of RLEI and the above three mechanisms —rural residents' income, consumption expenditure, and health, we propose Hypothesis 3 that compared to the rural sewage and livestock manure program, the rural waste program can exert a higher impact on rural residents' income, consumption expenditure, and health, and thus has a more significant effect on rural residents' SWB. The following provide thorough justifications.

First, compared to the rural sewage and livestock manure program, the rural waste program can contribute more to rural residents' income, and therefore has a higher positive impact on rural residents' SWB. This is because the rural waste program in China is often implemented in the whole rural area and needs a

large amount of labor input to collect the waste every day (Wang et al., 2021d), so it can provide many extra employment opportunities for rural residents within the village (Hu and Wang, 2020). In addition, rural waste products can be used for composting and recycling, which can also serve as revenues for some rural residents. However, the rural sewage program is often carried out by the local government and thus does not need much labor input from local rural residents. Therefore, it cannot offer extra job opportunities and can only benefit rural residents' income by improving the water and soil quality. For the livestock manure program, some rural residents may benefit from the commercialization of livestock manure products, such as fertilizers (Li et al., 2023a). Nevertheless, due to environmental protection, the livestock is primarily raised by large factories in certain areas of China, so the income gains from the livestock manure programs are mainly applicable to the areas characterized by massive livestock production, rather than being universally applicable to the entire demographic of rural residents (Byrne et al., 2020).

Second, compared to the rural sewage and livestock manure program, the rural waste program can have a higher impact on rural residents' consumption expenditure and thus has a more significant effect on rural residents' SWB. Following the same logic of the above-mentioned income gains from different kinds of RLEI, that is, the rural waste program requires daily involvement from rural residents in the whole village, while the rural sewage program predominantly involves one-time infrastructural interventions by the local government and the livestock manure program is often implemented in main livestock production areas (Shen et al., 2021). Therefore, rural residents' consumption expenditure will be more impacted by the rural waste program.

Third, compared to the rural sewage and livestock manure programs, rural waste management will contribute more to health improvement and thus have a more significant effect on rural residents' SWB. Effective rural waste programs can yield health benefits from many aspects, including air quality improvement, vector control, water pollution reduction, disease prevention, and sanitation enhancement (Yang, 2020). In contrast, the rural sewage program primarily promotes health through water quality improvement, while the livestock manure program is mainly associated with health improvements from water quality (Li et al., 2023b).

Methodology

Data collection. This paper takes the data from the China Labor-Force Dynamic Survey (CLDS), which includes the survey data from 2012, 2014, 2016, and 2018. CLDS, organized and implemented by Sun Yat-sen University, is the first nationwide tracking survey focusing on the labor force and has established a comprehensive database through biennial tracking surveys conducted in urban and rural areas across 29 provincial-level administrative regions[1] in China. Figure 3 shows the location of these 29 provinces. We can see that there are 34 provincial-level administrative regions in China, and CLDS covers 29 of them, showing that the CLDS data are nationally representative. Furthermore, we also provide information about the population and livestock productivity of the above 29 provinces to enrich evidence of the representative of our data (see Supplementary Table S1 online).

In this study, we use the CLDS dataset from two waves in 2016 and 2018 as our sample. This is because the questionnaires before 2016 did not cover the question related to our key variable, RLEI. These two waves collected data from 21,086 and 16,534 respondents aged 15 and over, respectively. After screening the variables, addressing outliers, and subsequently vertically integrating the datasets of two waves, we get unbalanced panel data covering 20 provincial-level administrative regions across the country containing a sample of 3747 rural residents.

Variables

Dependent variable: rural residents' SWB. This variable can be measured from the query in the CLDS questionnaire "Overall, do you think you are happy with your life?". The answer to this question ranges from 1 ("very unhappy") to 5 ("very happy").

Independent variable: village-level RLEI where the rural resident is located. Our independent variable is RLEI at the village level, rather than at the individual level. This is because the RLEI program in China is a place-based program that demands the entire village as a unit to implement coherently. So, when the village has conducted the RLEI program, all rural residents living in the village are involved in the RLEI program (Pan and Chen, 2021). Therefore, using RLEI at the village level can better reflect the well-being effect of the environmental governance programs and can also avoid individual self-reported measurement errors. RLEI in rural China includes the rural sewage program, rural waste program, and livestock manure program (Zheng et al., 2021), which can be reflected in the following three questions in the CLDS questionnaire.

1. "How is household sewage generally treated in your village?". The answer to this question is the following three: discharged anywhere; discharged in the home-built drainage facilities; and discharged in the village-built drainage facilities.
2. "What is the general way to treat household waste disposal in your village?". The answer to this question is the following two: dumped anywhere; dumped at the refuse collection point or collection bins in the village.
3. "How is livestock manure generally treated in your village?" The answer to this question is the following two: discharged anywhere; collected for fertilizer or biogas fuel.

We use the overall RLEI score in each village to measure RLEI. Specifically, we recode the answers to the above three questions to scores 0 and 1, and then obtain the overall RLEI scores (0 to 3), with higher scores representing better RLEI in villages. The detailed measurement of RLEI is shown in the following Table 2. Considering that the score of RLEI in some villages is 0, in order to weaken the impact of extreme values of RLEI scores from individual villages on the estimation results, we increment the RLEI scores by 1 and subsequently apply the natural logarithm function.

Control variables. Drawing from prior research, we account for six variables to reflect the affective factors of rural residents' SWB, which are gender, party member, marital status, household income, villages' transportation, and villages' expenditure on public goods.

1. Gender. The impact of gender on people's SWB is ambiguous. For instance, Knight et al., (2009) stated that men have more domestic and social responsibilities than women, resulting in lower SWB. However, Mroczek and Kolarz (1998) documented that men always feel better off than women.
2. Party member. The impact of party members on SWB is positive. On the one hand, being a party member can expand their social network and enhance social capital, which is beneficial to SWB enhancement (Appleton and Song, 2008). On the other hand, being a party member can bring an extra sense of honor and pride, which in turn increases people's SWB (Helliwell, 2003).

Fig. 3 The location of 29 provinces. This figure shows 29 provinces covered by the CLDS used in this paper. Source: Organized by the author.

Table 2 Indicators for RLEI measurement.

Variables	Definition	Mean	S.D	Min	Max
RLEI	RLEI scores (ranged from 0 to 3)	2.040	0.818	0	3
Rural sewage score	Score 0 when the sewage is discharged anywhere; score 1 when the sewage is discharged in the home-built or village-built drainage facilities	0.453	0.498	0	1
Rural waste score	Score 0 when waste is dumped anywhere; score 1 when waste is dumped at the refuse collection point or collection bins in the village	0.824	0.381	0	1
Livestock manure score	Score 0 when livestock manure is discharged anywhere; score 1 when livestock manure is collected for fertilizer or biogas fuel	0.763	0.425	0	1

3. Marital status: Being married significantly increases people's SWB (Knight et al., 2009). This is because married people can overcome life stresses more easily with the company of the other half and thus have higher SWB (Dang et al., 2020).
4. Household income. Household income is generally considered to have a positive relationship with people's SWB (Chen et al., 2022; Knight et al., 2022). Higher household income enables individuals and families to have greater financial resources, which helps them meet their basic needs and enhance their overall quality of life. It also provides access to better healthcare, education, housing, and other essential goods and services, which are known to contribute to higher SWB (Ashwin et al., 2021).
5. Transportation. The condition of hardened roads in the village is used to represent this variable. Existing studies have found that the availability of hardened roads in villages will contribute to the increase in rural residents' SWB (Li et al., 2023b). This is because having hardened roads in villages can make rural residents communicate better with other people, easier to search for better jobs, and make it more convenient to buy things they need, thereby enhancing their SWB (Das et al., 2020).
6. Villages' expenditure on public goods. The impact of this variable on people's SWB is ambiguous. Some studies found that public expenditure enhancement can be regarded as social welfare that relieves the economic burden of rural residents, such as villages' public expenditure for large irrigation facilities, which enhances rural residents' SWB (Li et al., 2020). However, other literature also shows that public expenditure has no impact on rural residents' SWB. This is because public expenditure in rural areas may often lack effective regulation, leading to its inefficiency in improving infrastructure, education, healthcare, etc.

Table 3 Indicators for mediation variables' measurement.

Variables	Definition	Mean	S.D	Min	Max
Income					
Agricultural income	Last year's individual agricultural income (in natural logarithms)	9.156	1.597	3.912	13.592
Non-agricultural income	Individual total income (including agricultural income, wages, business income, etc) minus the agricultural income (in natural logarithms)	9.883	1.024	6.908	11.918
Consumption expenditure					
Travel consumption expenditure	Last year's household travel expenditure (in natural logarithms).	8.819	1.990	1.099	11.513
Gifts and gratuities consumption expenditure	Last year's household total gift and gratuity spending (in natural logarithms)	8.326	1.508	2.996	12.429
Health					
Physical health	Have you been hospitalized since July last year? 0 = Yes; 1 = No	0.014	0.121	0	1
Mental health	How often have you felt sad in the past week? 0 = Almost always (5–7 days); 1 = Always (3–4 days); 2 = Seldom (1–2days); 3 = None/mostly none (less than 1days)	2.530	0.710	0	3

Table 4 Descriptive statistics of variables.

Variables	Definition	Mean	S.D	Min	Max
Dependent variable					
Rural residents' SWB	1 = very unhappy; 2 = relatively unhappy; 3 = so-so; 4 = relatively happy; 5 = very happy	3.632	0.927	1	5
Independent variable					
LnRLEI	Adding 1 to RLEI scores and taking the natural logarithm	1.068	0.315	0	1.386
LnRural sewage program	Adding 1 to rural sewage program scores and taking the natural logarithm	0.314	0.345	0	0.693
LnRural waste program	Adding 1 to rural waste program scores and taking the natural logarithm	0.571	0.263	0	0.693
LnLivestock manure program	Adding 1 to rural livestock manure scores and taking the natural logarithm	0.529	0.295	0	0.693
Control variables					
Gender	0 = female; 1 = male	0.504	0.500	0	1
Marital status	0 = unmarried; 1 = married	0.842	0.365	0	1
Party member	0 = other; 1 = party member	0.037	0.189	0	1
Household income	The approximate total household income last year (in natural logarithms).	10.199	1.261	0.693	13.816
Transportation	Condition of hardened roads in villages 0 = no; 1 = Yes	0.526	0.224	0	1
Village's expenditure on public goods	The village's total expenditure on public services and public affairs was in millions of yuan last year (in natural logarithms).	3.810	2.954	0.182	12.620

Consequently, it fails to significantly enhance the quality of life and rural residents' SWB (Wang et al., 2021a).

Mediation variables. As outlined in the theoretical framework section above, RLEI affects rural residents' SWB mainly by improving their income, consumption expenditure, and health. Furthermore, we also differentiate these mediation variables to get a detailed test result. In terms of rural residents' income, we focus on agricultural income and non-agricultural income. Regarding consumption expenditure, we emphasize travel, gifts, and gratuities consumption expenditure, which are two kinds of consumption expenditure that are highly related to rural residents' SWB in China. As for health, our attention is given to both physical and mental health. The detailed measurement of mediation is shown in the following Table 3.

Descriptive statistics. Table 4 offers the descriptive statistics of the above variables. The following result explains that rural residents' average SWB in China is 3.632, indicating most Chinese rural people feel relatively happy. The average LnRLEI score in China is 1.068, implying that most rural villages in China have implemented RLEI. The proportion of males in the sample is about 50.40%. The party members make up 3.7% of the total. Married rural residents account for 84.2% of the total, the natural logarithm of household income in 2017 is 10.199 (the corresponding amount is 39388.42 yuan), 52.6% of villages have hardened roads and the natural logarithm of village' expenditure on public goods is 3.810. The above numbers agree with the basic conditions in rural China. The descriptive statistics result indicates that the sample in our study can represent the basic situation of rural residents nationwide.

Model

The direct impact regression: the Ordered Probit model. Since the dependent variable "rural residents' SWB" is measured as a discrete ordered response variable, we adopt the Ordered Probit model to conduct regression, which can be shown in Eq. (1):

$$SWB^{*}_{iIt} = \alpha + \beta_1 \ln\mathrm{RLEI}_{It} + \gamma X_{itI} + v_I + \delta_t + \varepsilon_{itI} \quad (1)$$

Where SWB^{*}_{iIt} is a latent variable for measuring ith rural residents' SWB in village I in year t, which has a quantitative relationship with SWB_{iIt} (as shown in Eq. (2)). $RLEI_{It}$ represents village I implements RLEI in year t. The coefficient β_1 measures the influence of RLEI on the SWB of rural residents and its symbols indicate the direction of influence. v_I and δ_t denote village and temporal dummy variables to control for unobservable village-section and time-section-specific effects, respectively. α, X_{itI}, and ε_{itI} denote constant term, a series of control variables,

and random disturbance terms, respectively.

$$SWB_{iIt} = \begin{cases} 1.\, if\, SWB^*_{iIt} \le C_1 \\ 2.\, if\, C_1 < SWB^*_{iIt} \le C_2 \\ 3.\, if\, C_2 < SWB^*_{iIt} \le C_3 \\ 4.\, if\, C_3 < SWB^*_{iIt} \le C_4 \\ 5.\, if\, C_4 < SWB^*_{iIt} \end{cases} \quad (2)$$

Where SWB_{iIt} indicates the ith rural residents' SWB in village I in year t. From C_1 to C_4 are unknown cut points. If SWB_{iIt} is below the cut-point C_1, the rural residents feel "very unhappy". If SWB_{iIt} is between C_1 and C_2, the rural residents feel "relatively unhappy". If SWB_{iIt} is greater than the cut-point C_4, the rural residents feel "very happy".

The indirect impact regression. In order to test the mediating effect of mediate variables on the relationship between RLEI and rural residents' SWB that the theoretical framework analyzed above, we refer to the literature of Li et al., (2023b), which introduces the interaction term between mediating variables and RLEI ($lnRLEI_{It} \times M_{itI}$) into the function (2) and establish the following hybrid function (3):

$$SWB_{iIt} = \beta_2 + \beta_3 \mathrm{lnRLEI}_{It} + \beta_4 \mathrm{lnRLEI}_{It} \times M_{itI} + \beta_5 M_{itI} + \beta_6 X_{itI} + \varepsilon_{itI} + \nu_I + \delta_t \quad (3)$$

Where M_{itI} are mediation variables, including rural residents' agricultural and non-agricultural income, travel, gifts and gratuities consumption expenditure, and physical and mental health. The coefficient of the interaction term β_4 indicates whether mediation variables play an indirect role in the impact of RLEI on rural residents' SWB.

Monetary value calculation of RLEI: LSA. We use LSA to calculate the monetary value of RLEI. LSA is an emerging evaluative methodology to quantify the monetary valuation of goods with public characteristics, such as air pollution (Wang et al., 2021d), airport noise (Van Praag and Baarsma, 2005), and water disasters (Luechinger and Raschky, 2009). Its primary objective is to estimate the correlation between the residents' SWB and latent psychological statistical variables that pose challenges in direct observation (Zhao and Xia, 2021).

We assume that individuals behave rationally to maximize their utility. In this context, rural residents' SWB is considered as a measure of utility. Based on this assumption, at the equilibrium point, we can calculate the monetary value of RLEI by estimating the marginal effect derived from an increase in RLEI on rural residents' SWB, which is equal to the marginal effect derived from an increase in household income on rural residents' SWB, as shown in Eq. (4):

$$MRS = -\frac{\Delta household\ income}{\Delta RLEI} = \frac{\partial SWB/\partial household\ income}{\partial SWB/\partial RLEI} \quad (4)$$

Where $\partial SWB/\partial household\ income$ represents the marginal effect of household income on rural residents' SWB and $\partial SWB/\partial RHS$ is the marginal effect of RLEI on rural residents' SWB.

Correcting selective bias: PSM. If villages' decision on RLEI implementation is random, regressions can be performed directly by using the above Ordered Probit model. However, villages' decisions on RLEI implementation may be self-selected rather than random. That is, villages can self-select whether to implement RLEI or not. For example, Pan et al., (2020) contended that rural waste management is non-random, in that wealthier villages have more rural waste management facilities. Therefore, we apply the PSM method to correct this selection bias problem. PSM approach can mitigate self-selection biases within the comparison of treatment groups, enabling a rigorous evaluation of the effectiveness of RLEI (Reddy and Sasidharan, 2024).

The operation of PSM consists of the following two steps:

First, we utilize the logit model to estimate the predicted probability of RLEI implementation in a village, which is reflected in the following equation:

$$P(X_{It}) = \Pr(RLEI_{It} = 1|X_{It}) = \frac{\exp(\delta X_{It})}{1 + \exp(\delta X_{It})} \quad (5)$$

Where $P(X_{It})$ represents the propensity score of RLEI. X_{It} represents a vector of observed covariates that affect the implementation of RLEI which by the psestimate command aims to select a linear or quadratic function of covariates. $\frac{\exp(\delta X_{It})}{1+\exp(\delta X_{It})}$ is the cumulative distribution function; δ is the corresponding parameter to be estimated. In addition, we employ the overlap test to confirm the validity of PSM (Caliendo and Kopeinig, 2008).

Second, we calculate the average treatment effect on treated (ATT) by applying nearest-neighbor matching, radius matching, and kernel matching methods. ATT reflects the average difference in rural residents' SWB with and without RLEI, which can be computed as follows:

$$\tau^{PSM}_{ATT} = E\left(SWB_{1it}\middle|RLEI_{It} = 1, P(X_{It})\right) - E\left(SWB_{0it}\middle|RLEI_{It} = 0, P(X_{It})\right) \quad (6)$$

Where $E\{\cdot\}$ is the expectation operator, SWB_{1it} is the potential rural residents' SWB under RLEI implementation, while SWB_{0it} is the potential rural residents' SWB under no implementation of RLEI. $RLEI_{It} = \{0, 1\}$ indicates whether village I implements RLEI. If $RLEI_{It} = 1$, the villages go with the treatment group. If $RLEI_{It} = 0$, the villages go with the control group. We further use the balance test to verify the matching quality.

Endogeneity test: IV approach. Therefore, we apply the IV method to address the above endogeneity issues. Since both RLEI and rural residents' SWB are discrete variables, the IV approach grounded on continuous variables might not be appropriate (Zhang et al., 2022). Therefore, according to the study of Gu et al., (2019), we adopt the IV-Oprobit method to solve endogeneity issues, which is set as follows:

$$\mathrm{lnRLEI}_{It} = \alpha_2 + \beta_2 \mathrm{lnAvg\_RLEI}_{\mathrm{It}} + \gamma_2 \mathrm{m}_1 + \rho_1 \quad (7)$$

$$SWB_{iIt} = \alpha_3 + \beta_3 \widehat{RLEI}_{It} + \gamma_3 m_2 + \kappa_1 \quad (8)$$

Where $\mathrm{lnAvg\_RLEI}_{\mathrm{It}}$ represents the IV. We use the average RLEI score of other villages in the province excluding the village itself as our IV. $\widehat{RLEI}_{It}$ is the fitted values of $RLEI_{It}$. α and β are the parameters to be estimated. γ, ρ_1, and κ_1 are the vector of estimated coefficients and the random perturbation terms, respectively. The remaining variables remain unchanged from Eqs. (1) and (2).

Empirical estimation results

In this part, we first explore the influence of RLEI on rural residents' SWB grounded on the Ordered Probit method and then explore the indirect impact of RLEI on rural residents' SWB. Additionally, we analyze the impact of the three different RLEI measures on rural residents' SWB; we also estimate the monetary value of RLEI, rural sewage, rural waste, and livestock manure RLEI program; then we use an empirical framework combining PSM and IV techniques to overcome the potential endogeneity problems between RLEI and rural residents' SWB. Furthermore,

Table 5 The direct impact of RLEI on rural residents' SWB.

Variables	Coefficients	Marginal effects				
		Very unhappy	Relatively unhappy	So-so	Relatively happy	Very happy
	(1)	(2)	(3)	(4)	(5)	(6)
LnRLEI	0.154** (0.070)	−0.006** (0.003)	−0.012** (0.005)	−0.031** (0.014)	0.013** (0.006)	0.035** (0.016)
Gender	0.022 (0.043)	−0.001 (0.002)	−0.002 (0.003)	−0.004 (0.009)	0.002 (0.004)	0.005 (0.010)
Marital status	0.148*** (0.033)	−0.006*** (0.001)	−0.011*** (0.003)	−0.030*** (0.006)	0.013*** (0.003)	0.034*** (0.007)
Party member	0.142* (0.082)	−0.005* (0.003)	−0.011* (0.006)	−0.028* (0.016)	0.012* (0.007)	0.032* (0.019)
Household income	0.119*** (0.018)	−0.005*** (0.001)	−0.009*** (0.001)	−0.024*** (0.003)	0.010*** (0.002)	0.027*** (0.004)
Transportation	0.175** (0.082)	−0.007** (0.003)	−0.013** (0.006)	−0.035** (0.016)	0.015** (0.007)	0.040** (0.019)
Village's expenditure on public goods	0.013* (0.008)	−0.000* (0.000)	−0.001* (0.001)	−0.003* (0.002)	0.001* (0.001)	0.003* (0.002)
Observations	3747	3747	3747	3747	3747	3747
Village dummy variable	Yes	Yes	Yes	Yes	Yes	Yes
Year dummy variable	Yes	Yes	Yes	Yes	Yes	Yes

Robust standard errors are reported in coefficients' parentheses. Delt-method standard errors are reported in marginal effects' parentheses. *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

we run four robustness tests to improve the rationality of our findings. Finally, we look into the heterogeneous effects of RLEI on rural residents' SWB.

The direct impact of RLEI on rural residents' SWB. Table 5 displays the influence of RLEI on rural residents' SWB. Column (1) shows that the coefficient of RLEI is significantly positive at the 5% level, indicating that RLEI can significantly increase rural residents' SWB, supporting our Hypothesis 1. Since SWB is a discrete ordered variable, we then calculate the marginal effects of each independent variable, as shown in columns (2) to (6). The results show that the marginal effects of RLEI are −0.006 for "very unhappy" (SWB = 1), −0.012 for "relatively unhappy" (SWB = 2), -0.031 for "so-so" (SWB = 3), 0.013 for "relatively happy" (SWB = 4), and 0.035 for "very happy" (SWB = 5), indicating that when the overall RLEI score in each village increases by one standard deviation (0.315) from the mean (1.068), the probability of "very unhappy" decreases by 0.189% (0.189% = 0.006 (the marginal effect of very unhappy) × 0.315 (one standard deviation)), "relatively unhappy" decreases by 0.378%, and "so-so" decreases by 0.976%, respectively. In contrast, the probability of "relatively happy" and "very happy" increases by 0.409% and 1.103%, respectively.

Concerning the control variables, the results mostly follow the findings of previous existing literature. Marriage is positively related to rural residents' SWB, which is in harmony with an earlier study by Dang et al., (2020). Rural residents who are party members have higher SWB, which conforms to the study of Helliwell (2003). Household income has a significant positive influence on rural residents' SWB, which verifies the findings of Chen et al., (2022). Villages' transportation significantly increases rural residents' SWB. This outcome corresponds to the result of Li et al., (2023b). We also detect a positive relationship between the villages' expenditure on public goods and rural residents' SWB, which proves the findings of Guo and Zhang (2021).

The indirect impact of RLEI on rural residents' SWB. Table 6 presents the indirect impact results of RLEI on rural residents' SWB based on function (3) in the model section. Columns (1)-(6) document that the coefficients of the interaction term between the six mediation variables and RLEI (β_4) all are significant and positive, indicating that RLEI can promote rural residents' SWB by increasing rural residents' income, consumption expenditure, and health, which proves our Hypothesis 2.

Different types of RLEI programs and rural residents' SWB. Furthermore, we conduct an analysis of the influence of three types of RLEI programs on rural residents' SWB. Table 7 shows the results. Compared to rural sewage and livestock manure RLEI programs, the rural waste RLEI program has a larger influence on rural residents' SWB. This confirms Hypothesis 3.

Table 8 presents the indirect impact results of three different types of RLEI on rural residents' SWB. Columns (1)-(6) document that the coefficient of rural sewage program, rural waste program, and livestock manure program interaction term (β_4) all have a significant impact on rural residents' SWB. It proves that three different types of RLEI can promote the rural residents' SWB through the rural residents' income, consumption expenditure, and health, which also proves our Hypothesis 3.

The monetary value of RLEI. The baseline results have demonstrated that RLEI can enhance rural residents' SWB. We then employ the LSA method to further assess the monetary value of RLEI. The advantage of LSA lies in its direct measurement of the monetary value of RLEI from the SWB perspective, rather than directly asking rural residents about their price towards the RLEI (Giovanis, 2019).

According to the study of Wang et al., (2021d), LSA usually takes the marginal effect at the mean. Since the mean value of SWB is 3.632 (see Table 4), we take the marginal effect of the Ordered probit at SWB = 4 to calculate the monetary value of RLEI. According to the result of Table 5, the marginal effect of RLEI on rural residents' SWB is 0.013, and the marginal effect of household income on rural residents' SWB is 0.010. This indicates that to maximize the utility of rural residents' SWB, an increase in rural residents' SWB due to a 1% increase of RLEI is equivalent to an increase of 130% (0.013 ÷ 0.010 = 1.3) in household income. Using the same method and based on the findings from Table 7, this paper further calculates the monetary value of the three different types of RLEI. The results show that an increase in rural residents' SWB resulting from a 1% increase in rural sewage, rural waste, and livestock manure RLEI program is equivalent to an increase of 120% (0.012 ÷ 0.010 = 1.20), 367% (0.033 ÷ 0.009 = 3.67), and 110% (0.011 ÷ 0.010 = 1.10) in household income, respectively. We can conclude that the rural waste RLEI program has the highest monetary value compared to rural sewage and livestock manure.

Table 6 The indirect impact of RLEI on rural residents' SWB.

Variables	Income		Consumption expenditure		Health	
	Agricultural income (1)	Non-agricultural income (2)	Travel consumption expenditure (3)	Gifts and gratuities expenditure (4)	Physical health (5)	Mental health (6)
Rural residents' SWB	0.637* (0.378)	0.048** (0.016)	0.008* (0.004)	0.033*** (0.010)	0.563*** (0.173)	0.156*** (0.048)
R^2	0.010	0.022	0.039	0.016	0.013	0.015
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2278	3072	588	1490	1949	1949
Village dummy variable	Yes	Yes	Yes	Yes	Yes	Yes
Year dummy variable	Yes	Yes	Yes	Yes	Yes	Yes

Robust standard errors are reported in parentheses.*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

Correcting selective bias using the PSM method. In this section, we employ the PSM method to correct potential selection bias. Before estimating ATT from PSM, we should ensure the validity of the PSM method and the quality of the matching. First, we run the overlap test to examine the PSM's validity. The results are shown in Fig. 4. We can find that the propensity score intervals for the matched RLEI and no-RLEI groups largely overlapped each other, indicating the condition of the overlap assumption is satisfied. Second, we conduct the balancing test to investigate the matching quality. The results are shown in Table 9. We should compare the pseudo-R^2, chi-square, the mean of standardized bias values, the median of standardized bias values, and the B-value before and after the matching procedure. If the matching is effective, then the above indicators should have a lower value than before the matching (Caliendo and Kopeinig, 2008). The results in Table 9 indicate that PSM significantly weakens the systematic disparities between the matched RELI and non-RELI groups and the matching process succeeded.

After passing the overlap test and the balancing test, we calculate the PSM estimation results acquired from different matching methods, which are presented in Table 10. The result indicates that RLEI has a significant positive influence on rural residents' SWB under all three matching methods. This outcome is along with the baseline result, which suggests that RLEI still contributes to rural residents' SWB enhancement after reducing the observable systematic differences between samples.

Endogeneity test using the IV approach. Although the above baseline analysis finds that RLEI significantly promotes rural residents' SWB. However, considering the possibility of endogenous issues such as missing variables and mutual causality that may bias the estimation results, this paper additionally uses the IV-Oprobit to examine the endogeneity problem. Specifically, we use $lnAvg\_RLEI_I$ denoted by the average RLEI score of other villages in the province excluding the village itself as our IV. The reasons for selecting this variable as the IV are as follows. First, the $lnAvg\_RLEI_I$ scores already exclude the village itself, which means that it will not impact the rural residents' SWB in that village. $lnAvg\_RLEI_I$ is not directly related to rural residents' SWB through the influence of other explanatory variables and meets the exogenous requirements of IV. Secondly, $lnAvg\_RLEI_I$ is related to RLEI, which is the government's implementation of the solution to the environmental problem in each village. Provinces with better RLEI may have more experience in governance, and therefore can effectively promote RLEI in the village, and is in accordance with the correlation requirements of IV. Thus, $lnAvg\_RLEI_I$ can be a suitable IV that satisfies the exogenous and excluding criteria. We also show the validity test results of our IV in Column (1) of Table 11. We can find that the auxiliary estimation parameter (atanhrho_12) is significant at the 1% level, implying that RLEI is an endogenous independent variable. Furthermore, the F-statistic significantly exceeds the threshold of 10, indicating a strong IV and fulfilling the validity requirement of the IV.

Table 11 demonstrates the outcomes of the IV-Oprobit model. Column (1) of the first stage result shows that our IV variable $lnAvg\_RLEI_I$ is significantly positively correlated with RLEI at the 1% level, satisfying the IV correlation condition. Column (2) of the second stage result shows that RLEI significantly positively impacts rural residents' SWB at 1%, suggesting that after addressing the issues of endogeneity and missing unobservable variables, the influence of RLEI on enhancing rural residents' SWB is still significant.

Robustness tests. To confirm the robustness of the previous empirical findings, this paper performs a train of robustness tests, which includes the following four: changing the regression method, reassigning the value of rural residents' SWB, replacing SWB with life satisfaction as a new dependent variable, and deleting the sample of migrant households.

First, we change the regression method. Apart from the Ordered Probit model used in the baseline regression, this paper also adopts the Ordered Logit and OLS models to verify the robustness of the results. These two methods' outcomes are shown in Columns (1)–(2) of Table 12. We can discover that the coefficients of RLEI in both methods are invariably significantly positive, which are along the lines of the benchmark results.

Second, we reassign the value of rural residents' SWB. The measurement error issues might be caused by the measurement of rural residents' SWB, which is judged by their subjective evaluation. For example, due to dissimilar cognitive levels, different rural residents may have inconsistent definitions of "so-so" (SWB = 3), which leads to bias when they choose between "relatively unhappy" (SWB = 2) and "so-so" (SWB = 3) or "relatively happy" (SWB = 4) and "so-so" (SWB = 3), and thus rural residents' reported SWB might be lower or higher (Stefkovics and Sik, 2022). Therefore, we refer to the method proposed by Gao (2012) to reassign the value of rural residents' SWB. Specifically, if rural residents under-report their SWB, then "very unhappy" and "relatively unhappy" are assigned to 0, "so-so", "relatively happy" and "very happy" are assigned to 1. Otherwise, if rural residents over-report their SWB, then "very

Table 7 The impact of three types of RLEI programs on rural residents' SWB.

Variables	Coefficients			Marginal effects				
				Very unhappy	Relatively unhappy	So-so	Relatively happy	Very happy
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Rural sewage	0.145** (0.064)			−0.006** (0.002)	−0.011** (0.005)	−0.029** (0.013)	0.012** (0.006)	0.033** (0.015)
Household income	0.116*** (0.018)			−0.004*** (0.001)	−0.009*** (0.001)	−0.023*** (0.003)	0.010*** (0.002)	0.026*** (0.004)
Rural waste		0.388*** (0.088)		−0.015*** (0.004)	−0.029*** (0.007)	−0.077*** (0.017)	0.033*** (0.007)	0.088*** (0.019)
Household income		0.110*** (0.018)		−0.004*** (0.001)	−0.008*** (0.001)	−0.022*** (0.003)	0.009*** (0.002)	0.025*** (0.004)
Livestock manure			0.125* (0.072)	−0.005* (0.003)	−0.010* (0.006)	−0.025* (0.014)	0.011* (0.006)	0.029* (0.016)
Household income			0.117*** (0.018)	−0.004*** (0.001)	−0.009*** (0.001)	−0.023*** (0.003)	0.010*** (0.002)	0.027*** (0.004)
Control variables	Yes	Yes	Yes	-	-	-	-	-
Observations	3604	3700	2906	-	-	-	-	-
Village dummy variable	Yes	Yes	Yes	-	-	-	-	-
Year dummy variable	Yes	Yes	Yes	-	-	-	-	-

Robust standard errors are reported in coefficients' parentheses. Delt-method standard errors are reported in marginal effects' parentheses. *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

Table 8 The indirect impact of three different types of RLEI on rural residents' SWB.

Categories	Variables	Income		Consumption expenditure		Health	
		Agricultural income (1)	Non-agricultural income (2)	Travel consumption expenditure (3)	Gifts and gratuities expenditure (4)	Physical health (5)	Mental health (6)
LnRural sewage	Rural residents' SWB	0.016* (0.009)	0.021* (0.012)	0.004* (0.002)	0.023** (0.011)	0.185** (0.101)	0.173** (0.080)
LnRural waste		0.035* (0.018)	0.048*** (0.014)	0.007* (0.004)	0.050*** (0.012)	0.209*** (0.025)	0.266*** (0.072)
Lnlivestock manure		0.028* (0.017)	0.009* (0.005)	0.006* (0.003)	0.001* (0.001)	0.200* (0.107)	0.086* (0.052)

Robust standard errors are reported in coefficients' parentheses. Delt-method standard errors are reported in marginal effects' parentheses. *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$. The year and village dummy variables and control variables are all controlled.

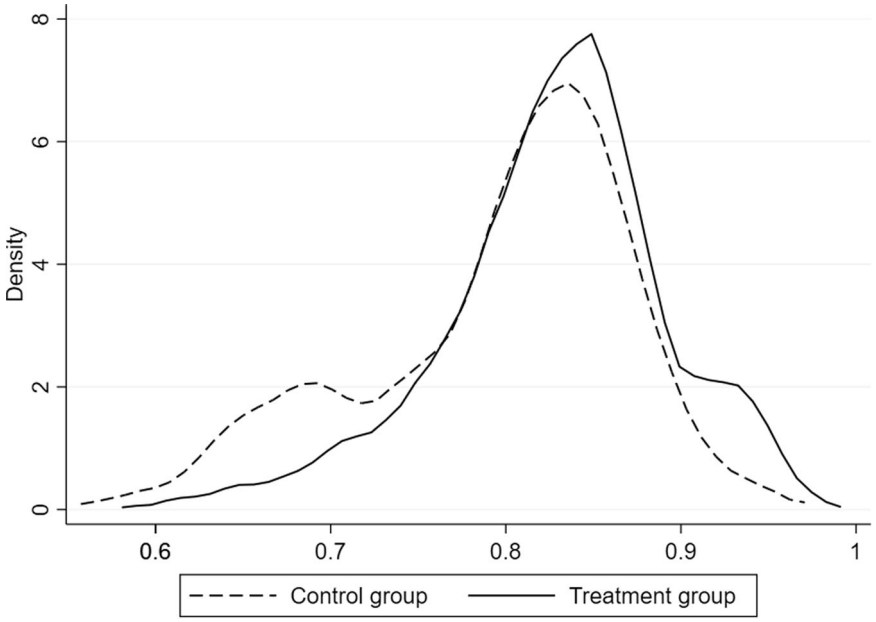

Fig. 4 The overlap assumption. This figure shows the result of the overlap test which is aimed to examine the PSM's validity. Source: Organized by the author.

Table 9 The balance tests before and after PSM.

Variable		Pseudo-R^2	LR test	P>chi 2	Mean of standardized bias (%)	Median of standardized bias (%)	B
RLEI	Before matching	0.193	180.75	0.109	47.300	30.800	145.700*
	After matching	0.009	14.410	0.000	30.800	23.600	21.800*

*$p < 0.1$. The year and village dummy variables are already controlled.

Table 10 ATT results of PSM.

Matching	Treatment group	Control group	ATT	S.D	T value
Nearest neighbor matching ($n = 2$)	3.707	3.075	0.632***	0.179	3.531
Radius matching (radius = 0.01)	3.707	3.050	0.657***	0.190	3.458
Kernel matching	3.707	3.036	0.671***	0.198	3.389

***$p < 0.01$. The year and village dummy variables are already controlled.

unhappy", "relatively unhappy", and "so-so" are assigned to 0, "relatively happy" and "very happy" are assigned to 1. The findings are shown in Columns (3)–(4) of Table 12. We can discover that the coefficients of RLEI are consistent with the main result, which is still significantly positive.

Third, we replace SWB with life satisfaction as a new dependent variable. According to previous literature, well-being can be expressed not only in terms of SWB but also in life satisfaction (Steptoe et al., 2015). Therefore, we apply life satisfaction as a new measurement of well-being for robustness testing. Life satisfaction can be measured from the following question in CLDS "Overall, are you satisfied with your life situation?". The answer ranges from 1 (very dissatisfied) to 5 (very satisfied). Column (5) of Table 12 further proves the robustness of the previous conclusion because the outcomes are in line with the baseline results after replacing rural residents' SWB with life satisfaction.

Fourth, we delete the sample of migrant households. Research findings indicate that rural residents who have migrated or are planning to migrate do not experience long-term benefits from RLEI, and their SWB remains relatively unaffected by RLEI's impacts (Luo et al., 2022). To avoid potential bias, we exclude rural residents who have plans to migrate or have already migrated within the next five years from the sample selection. The final sample only includes rural residents who have been living in rural areas for a significant period. This ensures a more accurate estimation of the results. We use the following question in CLDS to determine whether rural residents are planning to migrate or have already migrated in the next five years "In the next five years, do you plan to settle in the towns and cities?" The answer to this question is "1=Yes; 2=No; 3=Already settled in town". We delete the rural residents who select "1=Yes and 3=Already settled in town" from the sample. Column (6) of Table 12 shows that the coefficient on RLEI remains significantly positive after deleting the sample of migrant households. The result further validates the robustness of the benchmark regression.

Heterogeneity analysis. The results of benchmark regression estimation indicate that RLEI has a positive outcome on the SWB of rural residents, but this outcome does not consider its inherent variances. Therefore, this paper explores the heterogeneity of

Table 11 Endogeneity results based on the IV-Oprobit method.

Variable	1st-stage LnRLEI	2nd-stage Rural residents' SWB
	(1)	(2)
$lnAvg\_RLEI_i$	0.626***(0.016)	
LnRLEI		0.498***(0.134)
atanhrho_12	0.471***(0.123)	
1st-stage F-statistic	213.93	
Control variables	Yes	Yes
R^2/Pseudo R^2	0.333	0.394
Observations	2567	2723
Village dummy variable	Yes	Yes
Year dummy variable	Yes	Yes

Robust standard errors are reported in parentheses. ***$p < 0.01$.

RLEI affecting rural residents' SWB at three levels: region, age, and education levels.

Heterogeneity analysis with different regions. Affected by factors such as geographical features and resource levels, there will be differences in the strength of the implementation of RLEI in different regions (Hu and Wang, 2020; Van Dam et al., 2002). Thus, RLEI may not have the same effect on rural residents' SWB in different regions. Therefore, we further investigate the regional heterogeneity effects of RLEI on SWB. Analyzing this regional heterogeneity effect can let us distinguish between regions that facilitate SWB and others that do not, which helps provide information for the government to make policies for different regions. Specifically, we split the data into Eastern, Midwestern, and Northeastern areas according to the geographical location of each province.

Columns (1)–(3) of Table 13 present the heterogeneity findings across different regions. It shows that RLEI has significantly positive effects on rural residents' SWB in the Midwestern and Northeastern, which is in agreement with the baseline results. However, the effect of RLEI on rural residents' SWB in the Eastern regions is insignificant.

The possible reasons for this result are as follows. On the one hand, compared with the Midwestern and Northeastern regions, Eastern regions already have higher RLEI scores, that is, RLEI is rather widespread in Eastern regions. Our sample statistics data shows that the average RLEI score in Eastern regions is 2.18, which is much higher than that in Midwestern (2.00) and Northeastern (1.07) regions. Hence, the Eastern regions demonstrate a relatively limited potential for enhancing SWB, with the effect of RLEI being relatively weak (Liang et al., 2021). On the other hand, the RLEI scores in the Midwestern and Northeastern regions are still very low due to the weaker economic strength in these regions. RLEI provided as a public good can fill up the needs of rural residents in these areas and enhance their SWB (Hu and Wang, 2020).

Heterogeneity analysis with different ages. Age is an essential factor in influencing people's SWB (Knight et al., 2022). So, the impact of RLEI on rural residents' SWB may vary among people of different ages. Therefore, according to the method of Xu et al., (2022), we divide the rural residents into the "junior and old-aged group" (age<18 and age>60) and the "young and middle-aged group" (aged from 18-59).

Columns (4) and (5) of Table 13 present the heterogeneity findings across different ages. The results illustrate that the coefficient of RLEI is significantly positive in the junior and old-

Table 12 Robustness results.

Variables	Changing the regression method		Reassigning the value of rural residents' SWB		Replacing SWB with life satisfaction	Deleting the sample of migrant household
	OLS method	Ordered Logit method	Over-reported SWB	Under-reported SWB	Life satisfaction	
	(1)	(2)	(3)	(4)	(5)	(6)
LnRLEI	0.260* (0.148)	0.419* (0.296)	0.508* (0.280)	0.142* (0.084)	0.308* (0.169)	0.156*** (0.058)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
R^2/Pseudo R^2	0.014	0.010	0.069	0.026	0.009	0.009
Observations	2906	2906	2906	2906	2906	2284
Village dummy variable	Yes	Yes	Yes	Yes	Yes	Yes
Year dummy variable	Yes	Yes	Yes	Yes	Yes	Yes

Robust standard errors are reported in parentheses. *$p < 0.1$, ***$p < 0.01$.

Table 13 Heterogeneity results.

Rural residents' SWB	Region heterogeneity			Age heterogeneity		Education heterogeneity		Working status heterogeneity	
	Eastern	Midwestern	Northeastern	Junior and old-aged people	Young and middle-aged people	Low-educated	High-educated	Working	Non-working
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
LnRLEI	0.164	0.660**	0.121*	0.588*	0.222	0.164***	0.270	0.329*	0.284*
	(0.209)	(0.331)	(0.072)	(0.330)	(0.203)	(0.053)	(0.180)	(0.174)	(0.170)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pseudo R^2	0.015	0.024	0.011	0.037	0.012	0.054	0.013	0.010	0.197
Observations	1458	1442	845	816	2930	401	3346	2179	569
Villagedummy variable	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummy variable	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Robust standard errors are reported in parentheses. *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

aged group, indicating that RLEI can improve junior and old-aged people's SWB. However, the coefficient of RLEI is insignificant in the young and middle-aged group, meaning that RLEI has no impact on young and middle-aged people's SWB. This is in agreement with the discoveries of Appleton and Song (2008) and Liu et al., (2020), who pointed out that governmental policies have a less favorable effect on elders' SWB.

The following are the probable causes contributing to this outcome. On the one hand, with the massive rural migration in China, most young and middle-aged rural residents have migrated to cities, and they spend less time living in villages. Therefore, it is difficult for them to experience the changes in the rural environment brought by RLEI implementation, resulting in a less obvious SWB enhancement (Hu and Wang, 2020). On the other hand, junior and old-aged rural residents are generally in poor health, and the provision of RLEI can help them improve their health and thus is beneficial to their SWB improvement (Tong et al., 2022).

Heterogeneity analysis with different education levels. Education is also an important factor influencing people's SWB, so it is vital to assess the heterogeneity consequences of RLEI on rural residents' SWB across various education levels. We divide the sample into a low-education group and a high-education group. Specifically, rural residents with secondary and advanced education are defined as a highly educated group, while others are defined as a low-educated group.

Columns (6) and (7) of Table 13 give the results of the educational heterogeneity. This paper can discover that the coefficient of RLEI is significantly positive in the low-educated group, implying that RLEI can improve low-educated people's SWB. However, the coefficient of RLEI is insignificant in the highly educated group, revealing that RLEI has no impact on highly educated people's SWB. One likely explanation for this outcome is that compared with low-educated rural residents, high-educated rural residents often pursue their SWB more through self-worth realization rather than government program provision, which makes the effect of RLEI on their SWB less noticeable (Chen and Li, 2012).

Heterogeneity analysis with different working status. Job is also an important factor influencing people's SWB, so it is vital to assess the heterogeneity consequences of RLEI on rural residents' SWB across various working statuses (Ashwin et al., 2021). We divide the sample into the working rural residents' group and the non-working rural residents' group.

Columns (8) and (9) of Table 13 give the results of the working status heterogeneity. We can discover that the coefficient of RLEI is significantly positive in both working and non-working groups, implying that RLEI can improve the SWB of both working and non-working rural residents. However, the coefficient of RLEI is larger in the working group (0.329) than in the non-working group (0.284). One likely explanation for this outcome is that compared to non-working rural residents, working rural residents may have access to better job opportunities or positions through RLEI that require rich working experience (Hu and Wang, 2020). This may result in higher SWB among working rural residents.

Conclusion

Environmental governance programs are determined to people's SWB improvement. However, relatively little is known about whether and in what ways, environmental governance programs can influence SWB in developing and non-democratic societies (Chen et al., 2022; Xu et al., 2022). In this paper, we take RLEI in China—the largest rural living environment improvement

program in history, as an example to understand the character of environmental government programs in people's SWB to fill the literature gap. Our results indicate that: first, RLEI can significantly increase rural residents' SWB; according to the indirect analysis, rural residents' income, consumption expenditure, and health are the three main mechanisms that RLEI can have a promotion influence on rural residents' SWB; and the rural waste program has a greater impact on rural residents' SWB in parallel with the rural sewage and livestock manure programs. Various robustness analyses validate that the outcome is robust and reliable. Furthermore, the monetary value based on LSA shows that the improvement in rural residents' SWB resulting from RLEI is almost equivalent to the effect of household income. The monetary value of rural sewage, livestock manure, and rural waste RLEI program is 1.2 times, 3.67 times, and 1.1 times than those gained from household income, respectively. Second, heterogeneity analysis reveals the impact of RLEI on rural residents' SWB is greater for junior-aged, old-aged, low-educated, Midwestern and Northeastern, and working rural residents.

According to the above research conclusions and the existing development condition of RLEI in rural China, this paper recommends the subsequent recommendations. First, local government should persistently implement RLEI, thus promoting rural residents' SWB. At present, RLEI in rural China is still at a low level, and there is a large space for improvement. To this end, it is necessary to actively plan a new round of RLEI implementation and increase the investment in RLEI as much as possible. Especially, the governments in Midwestern and Northeastern China should maintain a stronger push for the RLEI implementation since RLEI has a greater impact on SWB in these two regions. Second, the future policy emphasis of RLEI should be on the rural sewage and livestock manure program to maximize rural residents' SWB since the impact of these two RLEI programs on rural residents' SWB is relatively low. For rural sewage programs, the government can allocate funds towards the construction and enhancement of sewage treatment plants and facilities in rural areas. For the livestock manure program, the government can prioritize investing in mechanized livestock manure treatment equipment and technologies to reduce the manual labor required in livestock manure management, which is a major obstacle in livestock manure treatment in China. Third, more efforts should be devoted to providing RLEI for people with junior and old age, with low education. Our heterogeneity analysis found that RLEI has a greater impact on SWB for junior-aged, old-aged, and low-educated rural residents. With the massive rural migration in China, these people spend more time living in villages and are more influenced by local environment quality (Pan and Chen, 2021), thus providing RLEI for these people has tremendous spillover effects on the enhancement of total people's SWB.

Despite the findings above, this study has potential limitations and analytical challenges concerning research data and methodology. Regarding research data, only using the two-panel data of CLDS2016 and CLDS2018 is not enough to establish a rigorous causal relationship between RLEI and rural residents' SWB. In terms of research methodology, although the study used PSM and IV methods to address endogeneity and enhance the reliability of the findings, precise causal identification remains elusive. Future studies could address these limitations by delving deeper into the findings by using the difference-in-difference method combined with longer years of longitudinal panel data or employing field experimental methods, such as randomized intervention experiments, to better identify the causal relationship between RLEI and rural residents' SWB.

Data availability

The data that support the findings of this study are available from the Center for Social Science Survey at Sun Yat-sen University in Guangzhou but restrictions apply to the availability of these data, which were used under licence for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of the Center for Social Science Survey at Sun Yat-sen University in Guangzhou.

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Note

1 *The 29 provinces are Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia, Liaoning, Jilin, Heilongjiang, Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Shandong, Henan, Hubei, Hunan, Guangdong, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang.*

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Author contributions

DP served as the first and corresponding author: conceptualization, formal analysis, project administration, funding acquisition, writing- original draft preparation, writing-reviewing & editing. YY served as the second author: software, methodology, data curation, writing - original draft. KJ served as the third author: validation, formal analysis, writing - review & editing.

Competing interests

The authors declare no competing interests.

Ethical approval

This article does not contain any studies with human participants performed by any of the authors.

Informed consent

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Additional information

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