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Assessing the efficiency level of the "poverty alleviation through agriculture project": A case study of fixed observation points in China

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In the modern era, development organizations and governments worldwide are undertaking various policies and projects to eradicate poverty. However, there is a lack of evidence that can trigger the efficiency level of those. Based on the survey data of the Ministry of Agriculture and Rural Affairs, which was acquired at rural fixed observation points across 31 provinces of China from 2012 to 2016, the study evaluates the overall efficiency, stage-specific efficiency, and indicator-based efficiency of "Poverty alleviation through agriculture projects of China". First of all, the entire process of agricultural poverty relief is divided into two stages: (i) agricultural production and (ii) social governance. Accordingly, the study proposes a two-stage theoretical analysis framework for agricultural poverty relief and decomposes the mechanisms; it also discusses the potential for improved efficiency levels in both agricultural production efficiency and social governance efficiency. Therefore, we utilize the two-stage dynamic data envelopment analysis (DEA) model to outline the findings. The outcomes showed the efficiency level of the projects can play an important role in addressing rural poverty in China. This study's major findings are summarized as follows: (i) the overall efficiency of the projects tends to be stable undauntedly. While agricultural production efficiency is the major cause and social governance efficiency in the second stage has been a minor cause for maintaining a relatively lower level of overall efficiency. (ii) There is significant room for improving the efficiency of certain input indicators (including total labor force, productive fixed assets, and education attainment of rural labor) and intermediate variables (i.e., income gap of village households). However, limited room has been found for certain output indicators (including the total output of grain, the poverty elimination index, and an aggregate index of social harmony). Thus, in China, poverty alleviation projects should be revitalized and targeted instead of concentrated. It is required to advance a long-term structure for rural poverty and promote the smooth transition of poverty alleviation projects and working criteria. Moreover, the government should strengthen the top-level design for addressing the relative poverty problem and incorporate it into the rural revitalization strategy.

KEYWORDS

poverty alleviation, agriculture, production, social governance, efficiency, dynamic data envelopment analysis

Introduction

The notion of poverty is primarily regarded as an obvious deprivation of sustainable development goals set by the united nations, especially for emerging nations it has been causing significant and persistent burdens (Adamkovič and Martončik, 2017; Maulu et al., 2021). In economics, it is considered a worldwide socioeconomic phenomenon that is generally studied from macroeconomic aspects and often involves multi-dimensional concepts (Bradshaw, 2007; Zhou and Che, 2021). In recent trends of poverty-related literature, there is a clearer understanding of the reality that market-driven economic expansion does not have to be incompatible with the reduction of poverty (Liu, 2018; Leng et al., 2021). In general, improving chances for sustainable and financially rewarding work (such as through entrepreneurship and laboring) is the most essential approach for socioeconomic development to assist the poor (Peng et al., 2021; Shen and Li, 2022). Conversely, several initiatives such as easy mortgage and financing options, improve risk-taking mechanisms and machinery supports which eventually can rectify the overall growth by availing allocates efficient resources allocation (Maja Gavrilovic, 2016; Guo and Liu, 2021). In this thrives poverty alleviation through agriculture becomes a prominent concept for the government, academia, and international and regional development organizations. Therefore, organizations like FAO and World Bank are predominantly highlighting the significance of agricultural interventions toward poverty alleviation (Charles, 2019; World Bank, 2021). According to the recent reports of the World Bank and Nations (Dah and Bassolet, 2021; World Bank and Nations, 2021), the rapid outward-oriented agricultural expansion has been linked to significant decreases in widespread poverty in several nations, particularly in East and Southeast Asia. According to Ellis and Freeman (Ellis and Freeman, 2005), the growth in agriculture further stimulates demand for other goods, acting as a growth multiplier in the rural economy and eventually reducing overall rural poverty. As a result, agricultural intervention is a critical first step toward alleviating regional poverty as a source of socioeconomic development (Shen, 2022). This is particularly so if the traded goods sector is more labor-intensive than the non-traded goods sector and if exports are more labor-intensive than import substitutes (assuming, of course, that the workers have some basic education and skills). Since China's reform and opening up, its per capita gross domestic product has continued to grow, the standard of living has greatly improved, and the absolute poverty-stricken population in the countryside has decreased significantly (Cheng et al., 2018; Miller et al., 2021). According to current poverty standards, China's rural poor population was 770 million in 1978, with a poverty incidence of 97.5%, but decreased to merely 5.51 million in 2019, with a poverty incidence of only 0.6% (Dong et al., 2021). President Xi Jinping announced China's victory against absolute poverty at the national commendation conference held in Beijing, on 25 February 2021 (Eryong and Xiuping, 2018). In the 20th National Congress of the Chinese Communist Party, President Xi committed that, the rural poor population will be lifted out of poverty by 2030, and existing poverty-stricken counties will all be delisted, thus eliminating overall regional poverty (Dong, 2022).

Various studies of poverty-stricken areas across the globe showed that a significant poverty level has a greater impact on unemployment and eventually hinders the development policies taken by the government (Bouwman et al., 2021; Zhu et al., 2022). Therefore, the relationship between agricultural interventions and availing better livelihoods for farmers and employment opportunities for rural households has been long examined worldwide (for example Hurst et al., 2005; Knickel et al., 2009; Martens et al., 2020). In a recent study, Wang et al. (2020) pointed out the existing need to direct attention toward the currently neglected issue of measuring efficiencies of poverty alleviation policies and projects, which has generally been overlooked in favor of assessing poverty from a solely economical or even macro economical perspective (see e.g., Kaidi et al., 2019; Ali et al., 2020; Zameer et al., 2020). Sole observations of economic expansion have been impeded in many situations, whereas inequalities have remained constant or to some extent even exacerbated (Bardhan, 1996; Liu et al., 2021a). Seemingly, various initiatives have been working to alleviate the tremendous limitations encountered by the poor, and enhancing their conditions can also aid macroeconomic expansion (Macfadyen et al., 2002; Mujuru et al., 2022). The situation may often contradict the conventional theory of economics with the equity-efficiency trade-off, as the efficiency rectifies different allocation costs, such as lower monetary incentives and overall competence (Kerr, 2002; Wongnaa et al., 2019). However, the impacts of governmental poverty relief programs on poverty alleviation have long been explored globally. For example, Fabiyi and Akande (Fabiyi and Akande, 2015) explored Nigerian rural women and found agricultural interventions can substantially help for fostering women empowerment and poverty relief. In a study of Bangladeshi rural farmers, Wei et al. (2021) indicated that the targeted poverty alleviation and food security programs administrated by the government significantly changed the socioeconomic conditions of rural households and help substantially to eliminate them from extreme poverty lines. Seemingly, Alemañ et al. (2019) depicted the major transitional effects of "poverty reduction through seaweed cultivation" among Latin American rural farmers.

Moreover, after the critical tasks of poverty elimination are completed, China's poverty status will change remarkably (Li et al., 2018). The key to poverty relief lies in agricultural and rural economic growth, thus attaching importance to the agricultural sector is a prerequisite for continuous poverty relief (Wu et al., 2018). Thus, poverty-relief projects will be refocused to address relative poverty and will be carried out in a normal rather than centralized manner. Hence, it is necessary to develop a long-term mechanism for reducing relative poverty and promoting the smooth transformation of the poverty relief strategy and work system (Wu et al., 2019; Bai et al., 2021). The Chinese government is also taking several policies such as China declaring that "the National Strategic Plan on Rural Revitalization *Via* Agriculture" will be prolonged till 2030. President and General Secretary of the Communist Party of China, Xi Jinping, gave important instructions to the National Spring Agricultural Production Work conference held in February 2020: "The more we face risks and challenges, the more we need to stabilize agriculture, and the more we need to ensure the security of food and important subsidiary toward poverty alleviation". Those highlights the integrity of China's long-term agenda toward the reform of agricultural development in quality, efficiency, and impetus and improving the innovativeness, competitiveness, and total factor productivity of agriculture continuously. Thus, it depicted the importance of examining whether the poverty alleviation projects efficiently help reduce poverty sustainably. However, the existing studies mainly explored the impacts of poverty alleviation and the linkage of core agriculture factors such as income stability, production factors, factor and resources endowments using different indicators in an isolated manner [Such as Cai and Xia (2018), Gassner et al. (2019) and Bird et al. (2022)]. While these factors are substantially interrelated and demand an integrated assessment within a single framework (Maulu et al., 2021; Sgroi and Marino, 2022).

Therefore, the prime goal of the study is to evaluate the efficiency level of China's poverty alleviation through agriculture projects in terms of agricultural production efficiency and social governance efficiency. We explore the probable efficiency improvement opportunities and summarize the experience and practical views of the projects. More specifically, the study evaluates the overall efficiency, stage-specific efficiency, and indicator-based efficiency of agricultural poverty relief in China. Seemingly, we redefined the social governance efficiency according to the local prospects, education attainment, and income gap are used as input variables, and the aggregate index of social harmony is used as an output variable. The empirical framework of the study is supported by the data collected by the Ministry of Agriculture and Rural Affairs, acquired at rural fixed observation points across 31 provinces of China from 2012 to 2016.

The major contributions of the study are as follows. First, the entire process of agricultural poverty relief is divided into the agricultural production and social governance stages. A novel rural revitalization model triggering the overall efficiency and stage-specific efficiency of poverty alleviation through agriculture projects has been proposed and tested based on village-level data. This would be the major contribution of the study. Second, a two-stage dynamic SBM-DEA model with undesirable output is applied to the study of agricultural production efficiency and social governance efficiency which would provide a more comprehensive outcome. Third, to the best of our knowledge, the study will serve as the first attempt to integrate several crucial factors of poverty alleviation such as social governance, education attainment, disposable income, and income gap in a single framework. The study will be crucial for governmental bodies and development partner organizations as it eventually provides in-depth policy suggestions for promoting the comprehensive revitalization of China's rural areas and fosters references for rural development in developing countries.

Materials and methods

The theoretical and analytical framework

In this study, the entire process of agricultural poverty relief is divided into two stages, an agricultural production stage and a social governance stage. Whereas agricultural production efficiency is evaluated in the first stage, and social governance efficiency is evaluated in the second stage. Overall efficiency is equal to the weighted average of both. In the first stage, the total labor force, sown area of farm crops, and productive fixed assets are used as input variables, and the total output of grain is an output variable as suggested by Thongdara et al. (2012) and Liu et al. (2021b). While according to the study by Ellis and Freeman (2004), disposable income per village household and the income gap of village households are used as intermediate variables. At the social governance stage, education attainment of rural labor is used as an input variable and the aggregate index of social harmony and the poverty elimination index are used as output variables, as suggested by Huang et al. (2021a). The study used an aggregate index of social harmony as an undesirable output variable because the degree of social harmony can explore the external impacts of poverty more comprehensively as suggested by Pan et al. (2021b). Moreover, Social governance efficiency in the second stage covers two aspects: (1) poverty elimination effectiveness in poor areas, measured in terms of non-poor population; and (2) social harmony and stability, measured in terms of the aggregate index of social harmony. Moreover, productive fixed assets are not only an input variable in the first stage but also an inter-period variable for the two-stage dynamic SBM-DEA model, to connect different periods. Figure 1 shows the theoretical analysis framework for two-stage agricultural poverty relief.

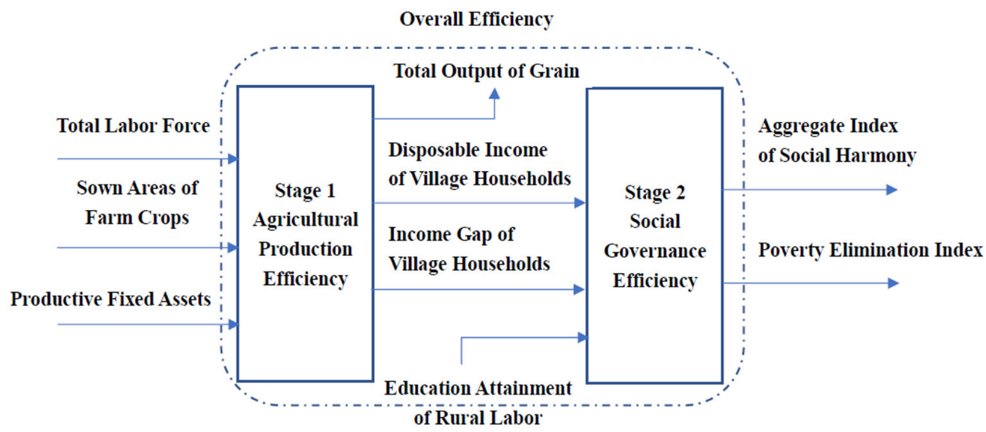

FIGURE 1
Theoretical analysis framework for two-stage agricultural poverty relief.

Methodology

The study utilized Data Envelopment Analysis (DEA) for crafting its findings. The DEA method is a linear programming model which is popularly used in social sciences and expressed as a ratio of output to input (Pan et al., 2021a). The study utilized a combination of a two-stage dynamic Slacks-Based Measure (SBM) model for performing the Data Envelopment Analysis (DEA). That is based on panel data that connects the linear programming problems of each period and does not require parameter estimation in the calculation process (Kao, 2018; Kuang et al., 2020). The primary reasons behind choosing the methodology are as follows: the conventional DEA model is used to measure the relative efficiency of multi-input and multi-output decision-making units (DMUs) (Charnes et al., 1978). However, it only considers input and output but omits the internal structure of DMUs (Chen et al., 2010). Existing studies [such as Tone and Tsutsui (2010, 2014), and Guo et al. (2017)] criticized the issue of internal structure and are widely referred to as a "black box," and possessed a certain level of difficulty to understand the critical factors when the framework incorporates input and output characteristics. In social sciences and behavioral studies, each of many problems or events comprises multiple stages or departments, which are linked to each other and have specific input and output variables, as well as linking variables interlinked with other stages or departments. Therefore, it is necessary to construct a multi-stage or multi-department network for assessing the situations. Färe et al. (2007) were the first who use network DEA to address the "black box" problem in the production process, which was ignored by the traditional DEA model. Tone and Tsutsui (2009) proposed a weighted SBM network and DEA model to explore the linkage between different stages or departments of the DMU, where the stages or departments were regarded as sub-DMUs and the SBM model was used to find the optimal solution.

Although network DEA has resolved the "black box" problem, it is restricted to only one stage, therefore Tone and Tsutsui (2010) proposed the dynamic SBM (DSBM) model, in which carry-over was used as a variable of linkage between different stages. Based on dynamic DEA combined with network DEA, Tone and Tsutsui (2014) evaluated the overall and internal variation of DMUs in the long term. This combined model can not only measure the overall efficiency of a DMU across the whole observation period but also perform further analysis and observe the dynamic variation in the DMU's overall and stage-specific efficiency. Chen et al. (2019) amended the dynamic network DEA model proposed by Tone and Tsutsui (2010), specifically considering undesirable output and referring to the amended model as the improved dynamic network model with undesirable output. Therefore, the improved two-stage dynamic SBM-DEA model has been selected in the study. Figure 2 shows the two-stage dynamic DEA model framework.

The selection of the model is mainly based on the following points: first, the theoretical analysis framework of the study divides the research problem into two stages (i) agricultural production and (ii) social governance. The traditional DEA model omits the internal structure of the model and cannot decompose and measure the total efficiency. Therefore, we use a two-stage dynamic SBM model to decompose and carry the research process more robustly as suggested by Huang et al. (2021b). Second, the static model based on cross-sectional data cannot see the dynamic efficiency changes between DMUs. This paper introduces a dynamic model to analyze the efficiency changes between periods. Third, there are often undesirable output indicators in most forms of measuring efficiency analysis (Zhuang et al., 2021; Sgroi, 2022). Therefore, the study considers undesired outputs in the core model to provide

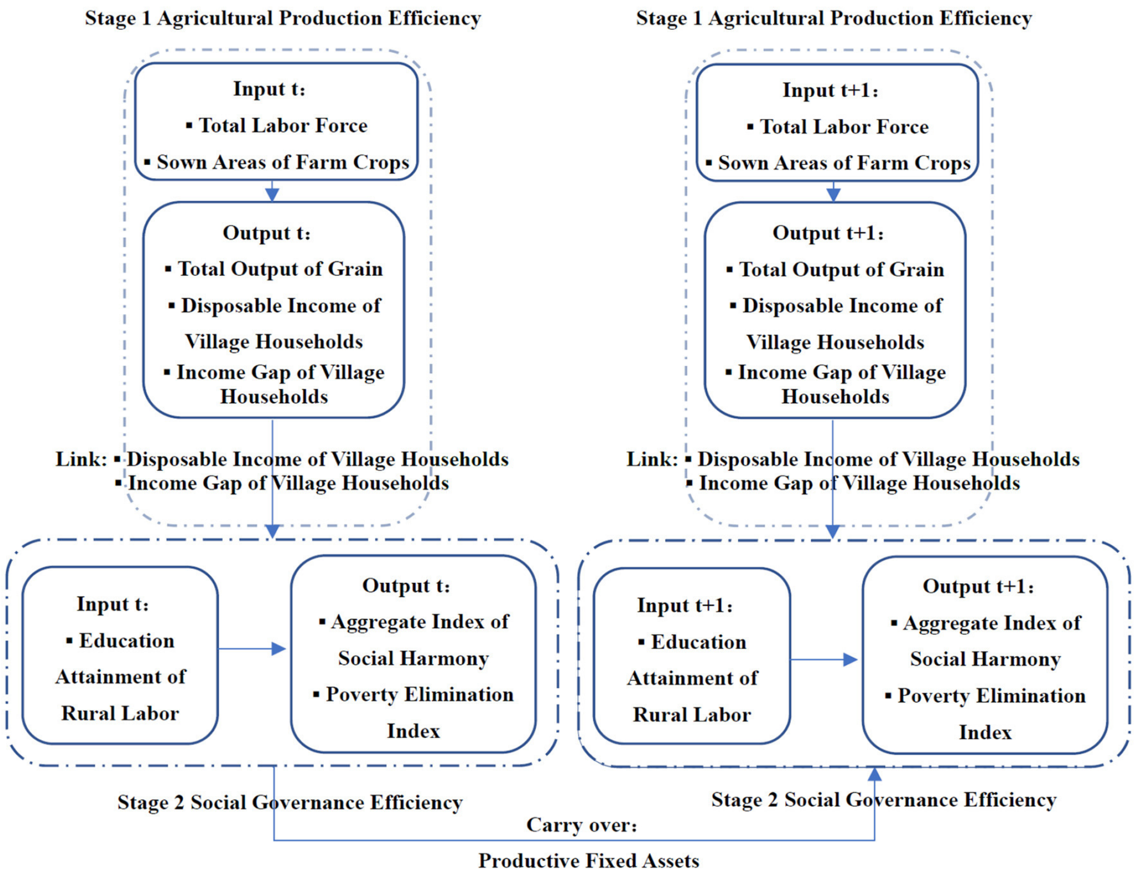

FIGURE 2
Two-stage dynamic SBM-DEA model frameworks with consideration of undesirable output.

comprehensive efficiency outcomes. The empirical analysis of the study follows four steps. First, we analyze the overall results from the perspective of comprehensive efficiency and compare the efficiency differences between DMUs. Second, the efficiency of agricultural production and social governance has been measured, and then eventually measured the total efficiency of each stage. Third, the study compares and analyzes the dynamic changes in the efficiency of each year's decision-making units. Finally, we analyze the efficiency difference between the various indicators and draw research conclusions based on the empirical analysis.

Data sources

Considering that there may be a non-linear relationship between some variables and food imports, and the economic threshold model can more accurately explore this relationship between variables, the study adopted the theory and practice of "Threshold Auto-regression" proposed by Hansen (2011) and built the following single threshold panel model to explore whether each variable has a threshold value. Table 1 depicts the descriptive statistics of input and output variables.

Measurement model

The study assumes that there are n $DMUs$ $(j = 1, \ldots, n)$ and each DMU has k $(k = 1, ..., K)$ stages and T $(t = 1, ..., T)$ periods. For each DMU, the tth period and (t+1)th period are linked through carry-over. Assuming that m_k and r_k denotes the input and output of each stage (K), denotes the variable of the link from the k^{th} stage to h^{th} stage, and L_{hk} denotes the number of stages from the k^{th} stage to the h^{th} stage. The input, output, and intermediate indicators, and the inter-period link indicator (carry-over) are defined as follows.

Input and output indicators

Firstly, $x_{ijk}^{t} \in R_{+}(i = 1, ...m_k; j = 1, 2, ...n; k = 1, ..., K; t = 1, ...T)$ denotes the input i of DMU$_j$ at the kth stage of the tth period; $y_{rjkgood}^{t} \in R_{+}(r = 1, ...r_{1k}; j = 1, 2, ...n; k = 1, ..., K; t = 1, ...T)$ denotes the desirable output of at the kth stage of the tth period; $y_{rjkbad}^{t} \in R_{+}(r = 1, ...r_{2k}; j = 1, 2, ...n; k = 1, ..., K; t = 1, ...T)$ denotes the undesirable output of DMU$_j$ at the kth stage of the tth period.

Intermediate indicators (links)

First,$z_{jk_l}^{(t,(t+1))} \in R_{+}(j = 1, 2, ...n; l = 1, 2, ...L_k; t = 1, 2, ...T)$ denotes the inter-period link (carry-over) of DMU$_j$ at the kth stage of the tth period; L_k denotes the number of inter-period link indicators at the kth stage. As mentioned above, there are four types of carry-over. In this study, advisable carry-over is selected, thus the number of inter-period link indicators at the kth stage is equal to the advisable carry-over quantity at the kth stage $ngood_k$.

Second, $P^t = \left\{(\mathbf{x}_k^t, \mathbf{y}_{kgood}^t, \mathbf{y}_{kbad}^t, \mathbf{z}_{(kh)_l in}^t, \mathbf{z}_{k_l}^{(t,t+1)})\right\}$ $(t = 1, ..., T)$ (the production possibility set) is defined as follows:

$$\mathbf{x}_k^t \geq \sum_{j=1}^{n} \mathbf{x}_{jk}^t \lambda_{jk}^t \ (\forall k, \forall t)$$

$$\mathbf{y}_{kgood}^t \leq \sum_{j=1}^{n} \mathbf{y}_{jkgood}^t \lambda_{jk}^t \ (\forall k, \forall t)$$

$$\mathbf{y}_{kbad}^t \leq \sum_{j=1}^{n} \mathbf{y}_{jkbad}^t \lambda_{jk}^t \ (\forall k, \forall t)$$

$\mathbf{z}_{k_l}^{(t,t+1)} = \sum_{j=1}^{n} \mathbf{z}_{jk_l}^{(t,t+1)} \lambda_{jk}^t \ (\forall k, \forall k_l, \forall t = 1, ..., T - 1)$ $\mathbf{z}_{k_l}^{(t,t+1)} = \sum_{j=1}^{n} \mathbf{z}_{jk_l}^{(t,t+1)} \lambda_{jk}^t (\forall k, \forall k_l, \forall t = 1, ..., T-1)$ (carry-over of the tth period) $\mathbf{z}_{k_l}^{(t,t+1)} = \sum_{j=1}^{n} \mathbf{z}_{jk_l}^{(t,t+1)} \lambda_{jk}^{t+1} (\forall k, \forall k_l, \forall t = 1, ..., T - 1)$ (carry-over of the (t+1)th period) $\sum_{j=1}^{n} \lambda_{jk}^t = 1 (\forall k, \forall t), \lambda_{jk}^t \geq 0 (\forall j, \forall k, \forall t)$ (constant returns to scale).

Where $\lambda_k^t = \left\{\lambda_{jk}^t\right\} \in R_+^n$ denotes the weight vector at the Stage of $k(\forall k)$ the period $t\ (\forall t).(\left\{\lambda_k^t\right\}, \left\{\mathbf{s}_{ok}^{t-}\right\}, \left\{\mathbf{s}_{okgood}^{t+}\right\}, \left\{\mathbf{s}_{okgood}^{t-}\right\}, \left\{\mathbf{s}_{o(kh)in}^{t}\right\})$ is used as a variable to evaluate the overall efficiency of DMU$_o$ (o = 1,....,n) $\in P^t$. The input and output constraints are expressed as follows:

$$\mathbf{x}_{ok}^t = \mathbf{X}_k^t \lambda_k^t + \mathbf{s}_{ok}^{t-} (\forall k, \forall t) \tag{1}$$

$$\mathbf{y}_{okgood}^t = \mathbf{Y}_{kgood}^t \lambda_k^t - \mathbf{s}_{okgood}^{t+} (\forall k, \forall t) \tag{2}$$

$$\mathbf{y}_{okbad}^t = \mathbf{Y}_{kbad}^t \lambda_k^t + \mathbf{s}_{okbad}^{t-} \ (\forall k, \forall t) \tag{3}$$

$$e\lambda_k^t = 1 (\forall k, \forall t) \tag{4}$$

$$\lambda_k^t \geq 0,\ \mathbf{s}_{ok}^{t-} \geq 0,\ \mathbf{s}_{okgood}^{t+} \geq 0,\ \mathbf{s}_{okgood}^{t-} \geq 0,\ (\forall k, \forall t) \tag{5}$$

Where, $\mathbf{X}_k^t = (\mathbf{x}_{1k}^t, \mathbf{x}_{2k}^t, ...\mathbf{x}_{nk}^t) \in R^{m_k \times n}$ $\mathbf{Y}_{kgood}^t = (\mathbf{y}_{1kgood}^t, \mathbf{y}_{2kgood}^t, ...\mathbf{y}_{nkgood}^t) \in R^{r_{1k} \times n}$ $\mathbf{Y}_{kbad}^t = (\mathbf{y}_{1kbad}^t, \mathbf{y}_{2kbad}^t, ...\mathbf{y}_{nkbad}^t) \in R^{r_{2k} \times n}$ and are input and output matrices; $\mathbf{s}_{ko}^{t-}$, $\mathbf{s}_{okgood}^{t+}$ and $\mathbf{s}_{okgood}^{t-}$ are matrices of input, desirable output, and undesirable output, respectively. The intermediate variables as input constraints are as follows:

$$\mathbf{z}_{o(kh)in}^t = \mathbf{Z}_{(kh)in}^t \lambda_k^t + \mathbf{s}_{o(kh)in}^t \ ((kh)in = 1, ..., linkin_k) \tag{6}$$

Where $\mathbf{Z}_{(kh)in}^t = (\mathbf{z}_{1(kh)in}^t, \mathbf{z}_{2(kh)in}^t, ..., \mathbf{z}_{n_g(kh)in}^t,) \in R^{L(kh)in \times n}$; $\mathbf{s}_{o(kh)in}^t \in R^{L(kh)in}$ is a non-negative reduced value. The advisable carry-over constraints are as follows:

$$\sum_{j=1}^{n} z_{jk_lgood}^{(t,(t+1))} \lambda_{jk}^t = \sum_{j=1}^{n} z_{jk_l}^{(t,(t+1))} \lambda_{jk}^{t+1} \ (\forall k; \forall k_l; \ t = 1, \ldots, T-1) \tag{7}$$

$$z_{ok_lgood}^{(t,(t+1))} = \sum_{j=1}^{n} z_{jk_lgood}^{(t,(t+1))} \lambda_{jk}^t - s_{ok_lgood}^{(t,(t+1))} \ (l = 1, ..., ngood_k; \forall k; \forall t) \tag{8}$$

$$s_{ok_lgood}^{(t,(t+1))} \geq 0 \ (\forall k_l; \forall t). \tag{9}$$

Where, $s_{ok_lgood}^{(t,(t+1))}$ is a reduced value. The objective function is as follows:

$$\theta^* = \min \frac{\sum_{t=1}^{T} W^t \left[\sum_{k=1}^{K} w^k \left[1 - \frac{1}{m_k + linkin_k} \left(\sum_{i=1}^{m_k} \frac{s_{iok}^{t-}}{x_{iok}^t} + \sum_{(kh)_l=1}^{linkin_k} \frac{s_{o(kh)_l in}^t}{z_{o(kh)_l in}^t}\right)\right]\right]}{\sum_{t=1}^{T} W^t \left[\sum_{k=1}^{K} w^k \left[1 + \frac{1}{r_{1k} + r_{2k} + ngood_k} \left(\sum_{r=1}^{r_{1k}} \frac{s_{rokgood}^{t+}}{y_{rokgood}^t} + \sum_{r=1}^{r_{2k}} \frac{s_{rokbad}^{t-}}{y_{rokbad}^t} + \sum_{k_l}^{ngood_k} \frac{s_{ok_lgood}^{(t,t+1)}}{z_{ok_lgood}^{(t,(t+1))}}\right)\right]\right]} \tag{10}$$

Results

Theoretical and analytical framework analyzing the overall efficiency of agricultural poverty relief

Table 2 describes the overall efficiency and stage-specific efficiency from 2012 to 2016. Among the 32 villages, the overall efficiency of Yunnan01 was 1, demonstrating the highest overall efficiency. The overall efficiency of 13 villages (e.g., Heilongjiang06) was higher than 0.7, indicating good performance overall, while the overall efficiency of 11 villages (e.g., Shaanxi01) was lower than 0.5 [specifically, the overall efficiency of Shaanxi01 is the lowest (0.3421)]. In general, overall efficiency is substandard for most villages from 2012 to 2016 and differs significantly across the 32 villages.

Figure 3 shows the overall efficiency of agricultural poverty relief in 32 villages from 2012 to 2016. There are seven villages whose overall efficiency is higher than 1 in at least 2 years; specifically, the overall efficiency of Yunnan01 was always 1 over 5 consecutive years. Over the 5 years, the overall efficiency of 14 villages (e.g., Jilin01) tended to rise to undulate, and the overall efficiency of 18 villages (e.g., Heilongjiang05) tended to decline to undulate. The overall efficiency of four villages (e.g., Shaanxi01) was relatively low, indicating no obvious effectiveness in agricultural poverty relief. In general, the overall

TABLE 1 Descriptive statistics of input and output variables.

Input/output variable	Unit	Mean	Minimum	Maximum	Standard deviation
Total labor force	Person	1,376.07	238	4,355	961.47
Productive fixed assets	10,000 yuan	752.80	12.42	30,872.24	3,041.56
The sown area of farm crops	Mu	6,029.09	278	34,000	6,452.10
The total output of grain	Ton	7,240.36	295	83,407.05	10,452.97
Disposable income per village household	Yuan	31,733.01	8,416.89	82,955.13	11,645.33
Income gap of village households	/	6.16	1.49	19.74	3.65
Educational attainment of rural labor	Year	8.06	3	10	1.10
Poverty elimination index	Person	2,429.82	11	7,805	1,689.38
Aggregate index of social harmony	/	23.45	1	463	44.71

TABLE 2 Overall efficiency and stage-specific efficiency from 2012 to 2016.

DMU	Stage 1	Stage 2	Overall efficiency	DMU	Stage 1	Stage 2	Overall efficiency
Yunnan01	1.0000	1.0000	1.0000	Anhui02	0.5146	0.6583	0.5865
Heilongjiang06	0.9885	1.0000	0.9942	Hubei01	0.7478	0.4161	0.5819
Jilin03	0.9756	1.0000	0.9878	Gansu02	0.5192	0.6135	0.5664
Guangdong01	0.8786	1.0000	0.9393	Heilongjiang02	0.5203	0.5410	0.5307
Jilin01	1.0000	0.7962	0.8981	Gansu01	0.5900	0.4610	0.5255
Zhejiang02	1.0000	0.7782	0.8891	Henan01	0.4513	0.5476	0.4995
Jilin02	0.9601	0.7906	0.8754	Anhui05	0.2093	0.7778	0.4935
Zhejiang01	1.0000	0.5886	0.7943	Anhui07	0.2819	0.6939	0.4879
Shaanxi03	1.0000	0.5211	0.7606	Fujian03	0.2420	0.7092	0.4756
Heilongjiang04	1.0000	0.5188	0.7594	Anhui04	0.2670	0.6834	0.4752
Heilongjiang03	0.9253	0.5828	0.7540	Xinjiang01	0.2869	0.6283	0.4576
Fujian01	0.6121	0.8786	0.7454	Guangxi01	0.3316	0.5727	0.4522
Heilongjiang05	0.6924	0.7551	0.7238	Guizhou02	0.2620	0.6105	0.4362
Fujian02	0.6582	0.6285	0.6434	Shaanxi02	0.4812	0.3536	0.4174
Heilongjiang01	0.5196	0.7071	0.6134	Guizhou01	0.2787	0.4672	0.3729
Anhui06	0.8135	0.3648	0.5892	Shaanxi01	0.1195	0.5648	0.3421

efficiency of agricultural poverty relief tends to be stable and undulate from 2012 to 2016, implying the significant potential for improvement.

Analyzing agricultural production efficiency and social governance efficiency in different years

In this study, the overall efficiency of agricultural poverty relief is further decomposed into efficiency in two stages: agricultural production efficiency and social governance efficiency. In the first stage, the agricultural production efficiency of six villages (e.g., Heilongjiang04) all reach the efficiency frontiers; in the second stage, the social governance efficiency of four villages (e.g., Guangdong01) reaches the efficiency frontiers. In the first stage, there were 19 villages (e.g., Shaanxi02) whose agricultural production efficiency was lower than 0.5; in the second stage, there were five villages (e.g., Guizhou01) whose social governance efficiency was lower than 0.5. The low overall efficiency of eight villages (e.g., Xinjiang01) is mainly due to their low agricultural production efficiency at the first stage; the low overall efficiency of five villages (e.g., Guizhou01) is mainly due to their low social governance

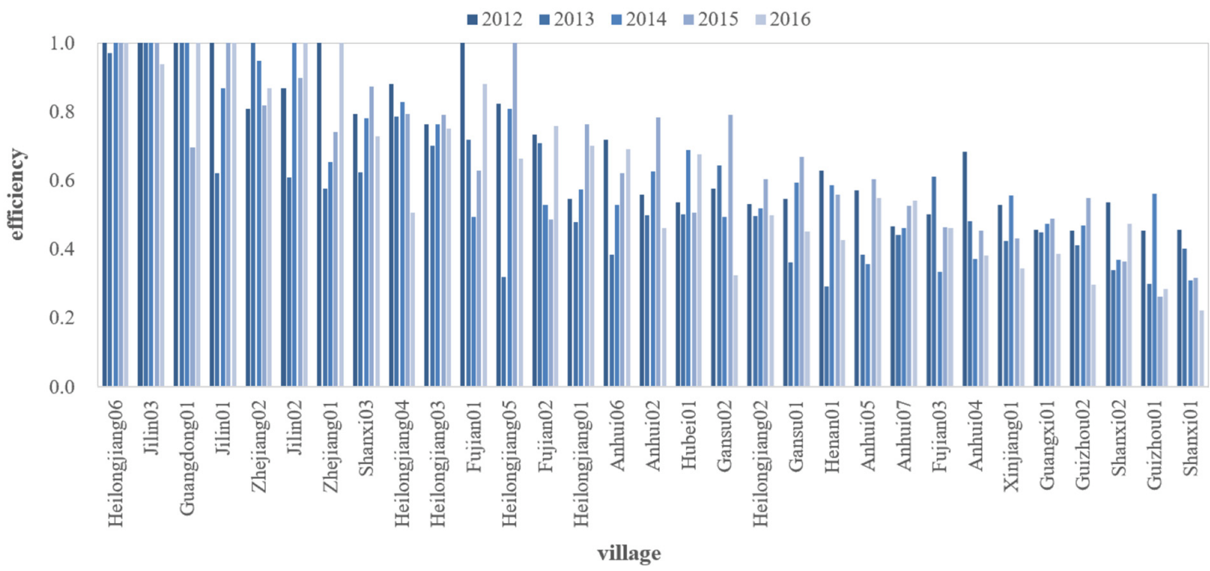

FIGURE 3
Overall efficiency from 2012 to 2016.

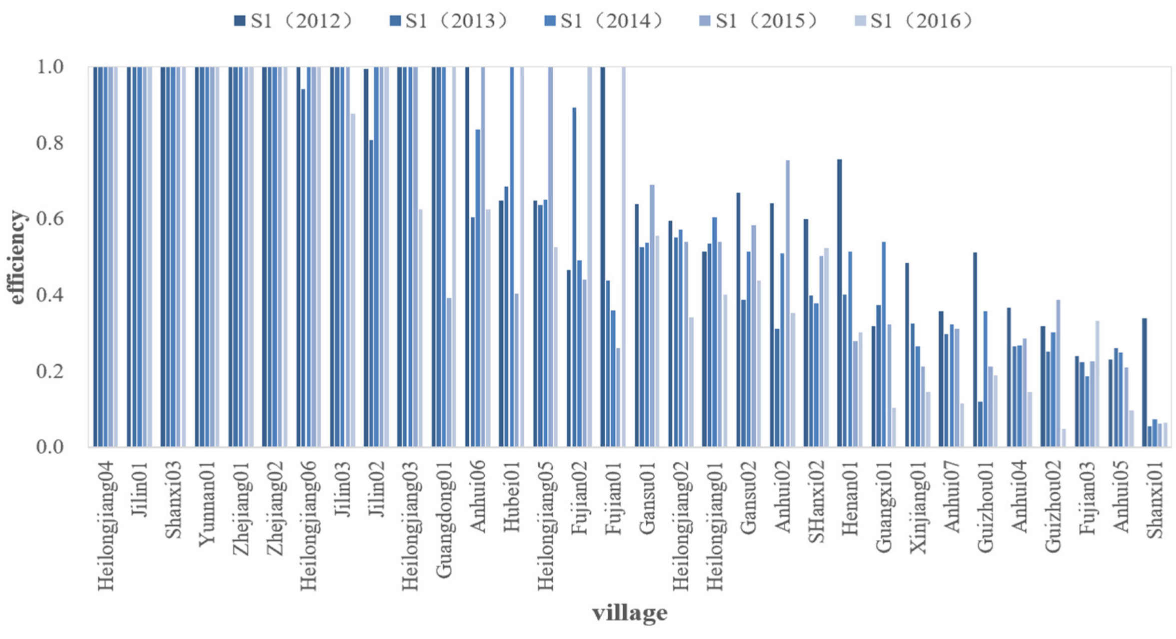

FIGURE 4
Agricultural production efficiency at the first stage, from 2012 to 2016.

efficiency at the second stage. Overall, there is a slight difference in efficiency between the two stages. Specifically, the efficiency values in the second stage were slightly higher than those in the first stage.

Here, Figures 4, 5 show the agricultural production efficiency and social governance efficiency of 32 villages, respectively, from 2012 to 2016. The agricultural production efficiency of ten villages (e.g., Anhui06) tended to decline and undulate, that of Xinjiang01 continues to decline, and that of six villages (e.g., Anhui07) was always lower than 0.4 over the 5 years, showing no obvious improvement across the years. The social governance efficiency of eight villages (e.g., Jilin01) tended to increase undulated, that of ten villages (e.g., Heilongjiang05) tended to decline undulated, and that of

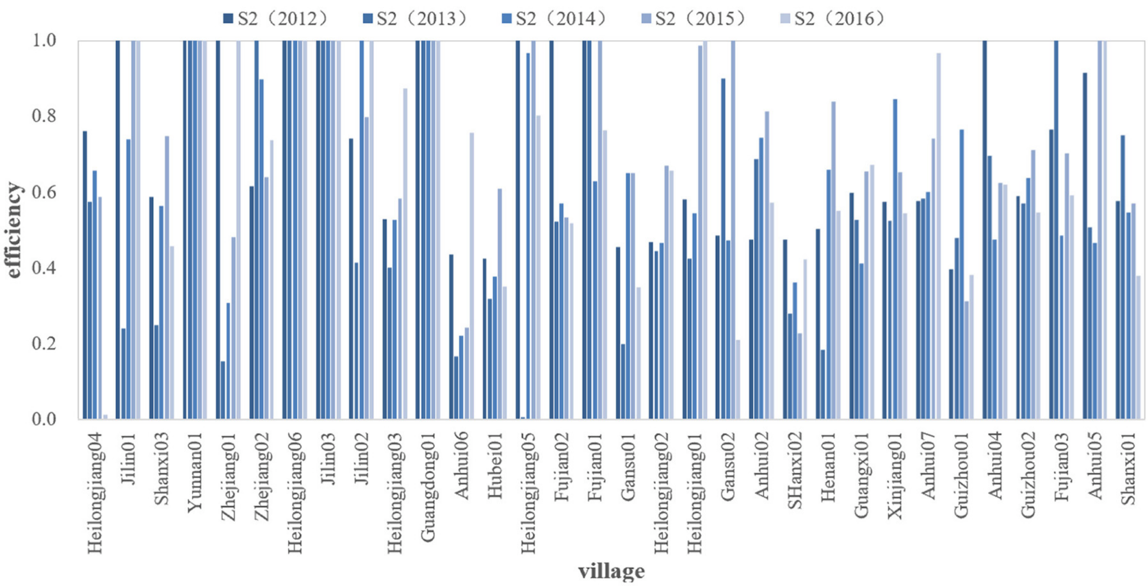

FIGURE 5
Social governance efficiency in the second stage, from 2012 to 2016.

Shaanxi02 was always lower than 0.5 over the 5 years. Overall, agricultural production efficiency in the first stage is the primary cause of the low overall efficiency of agricultural poverty relief; social governance efficiency in the second stage is a minor cause. In the whole process of agricultural poverty relief, there is significant potential for improvement in both agricultural production efficiency at the first stage and social governance efficiency in the second stage, particularly at the first stage. Moreover, agricultural production efficiency at the first stage does not vary significantly across different years, whereas social governance efficiency at the second stage does.

Comparison between agricultural production efficiency and social governance efficiency

For the 32 villages, the average agricultural production efficiency and average social governance efficiency are respectively 0.6290 and 0.6628. To further analyze the potential for improvement in agricultural production and social governance efficiency, the specific values of the 32 villages were compared with the average values (as described in Table 3).

Analyzing the efficiency of input and output indicators

Table 3 describes the average efficiency of the input, intermediate, and output variables of the 32 villages. Regarding input variables, there are six villages whose efficiency of the total labor force is 1, reaching efficiency frontiers; the remaining 26 villages all have the potential for improvement. There are 16 villages (e.g., Guangxi01) whose efficiency of the total labor force is below the average (0.6962); specifically, Guangxi04 has the lowest efficiency of the total labor force (0.2230). There is labor redundancy in agricultural production, thus it is necessary to reduce the agricultural labor force to improve agricultural production efficiency. Regarding the sown areas of farm crops, there are 15 villages (e.g., Yunnan01) that reach efficiency frontiers, and the remaining 17 villages all have some potential for improvement; overall, the efficiency of sown areas of farm crops is relatively high. There are 11 villages (e.g., Yunnan01) whose efficiency of productive fixed assets is 1, reaching efficiency frontiers. The remaining 21 villages all have some potential for improvement. Specifically, it is necessary to raise the utilization rate of productive fixed assets, thus improving agricultural production efficiency. Regarding the educational attainment of rural labor, there are four villages (e.g., Zhejiang02) that reach efficiency frontiers, and the 28 remaining villages have the potential for improvement to varying degrees. The average educational attainment of rural laborers is 8.06. Regional social governance can be improved by increasing the average educational attainment of rural laborers.

Regarding output variables, there are seven villages (e.g., Yunnan01) whose total output of grain reaches efficiency frontiers; the remaining 25 villages have the potential for improvement to varying degrees. There are 17 villages (e.g., Anhui05) with below-average efficiency in the total output of grain; Anhui05 also has the lowest efficiency in the total

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TABLE 3 Average efficiency of input and output indicators in 5 years (2012 to 2016).

DMU	Input variable				Intermediate variable		Output variable		
	Labor force	Sown area	Educational attainment	Fixed assets	Disposable income per village household	Income gap	Total output of grain	Non-poor population	Public order
Yunnan01	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Heilongjiang06	0.9804	0.9956	1.0000	1.0000	1.0000	1.0000	0.9860	1.0000	1.0000
Jilin03	0.9935	1.0000	1.0000	1.0000	1.0000	1.0000	0.9449	1.0000	1.0000
Zhejiang02	1.0000	1.0000	0.9053	1.0000	1.0000	1.0000	1.0000	0.7176	0.9780
Jilin02	0.8958	1.0000	0.8631	0.9963	1.0000	0.9942	0.9803	0.7698	0.8207
Jilin01	1.0000	1.0000	0.9286	1.0000	1.0000	1.0000	1.0000	0.7662	0.9554
Guangdong01	0.8521	0.9675	1.0000	1.0000	1.0000	1.0000	0.8485	1.0000	1.0000
Shaanxi03	1.0000	1.0000	0.8020	1.0000	1.0000	1.0000	1.0000	0.4534	0.8449
Heilongjiang03	0.9583	1.0000	0.6066	1.0000	1.0000	1.0000	0.8814	0.5850	0.7430
Zhejiang01	1.0000	1.0000	0.9816	1.0000	1.0000	1.0000	1.0000	0.5180	0.9711
Henan01	0.6423	0.8274	0.7618	0.5259	0.9402	0.4063	0.6941	0.8300	0.7006
Heilongjiang01	0.6080	0.8557	0.8066	0.8692	0.9285	0.8424	0.4447	0.7981	0.8004
Fujian02	0.6135	1.0000	0.7884	0.9360	1.0000	1.0000	0.5876	0.7246	0.3781
Fujian01	0.4975	1.0000	0.9255	1.0000	0.9908	1.0000	0.5208	1.0000	0.7288
Anhui06	0.9611	0.7626	0.7776	0.9729	1.0000	0.8980	0.7240	0.3188	0.8684
Hubei01	0.8128	0.9120	0.5164	0.9713	1.0000	0.8949	0.7585	0.4280	0.7098
Gansu01	0.6420	0.9412	0.4848	0.8791	0.9394	0.6232	0.4908	0.5197	0.8671
Gansu02	0.7025	0.8429	0.7727	0.8980	1.0000	0.7862	0.3248	0.6070	0.9954
Anhui02	0.4909	0.7904	0.7418	0.9557	0.9238	0.6095	0.5356	0.8362	0.9395
Heilongjiang02	0.3802	0.9785	0.5825	0.9334	0.9576	0.6129	0.3596	0.9924	0.3356
Guizhou01	0.6404	0.8641	0.6202	0.4798	0.9532	0.5450	0.2689	0.6481	0.4550
Anhui07	0.3395	0.8980	0.7932	0.6957	0.9212	0.6903	0.2294	0.9548	0.7263
Shaanxi02	0.8286	0.9869	0.7289	0.9485	1.0000	0.4591	0.2038	0.3711	0.8518
Guangxi01	0.2230	0.9388	0.5217	0.7908	0.9841	0.7068	0.2846	1.0000	0.3990
Guizhou02	0.4143	1.0000	0.4868	0.6385	0.9605	0.9369	0.2118	0.9732	0.4295
Anhui04	0.2344	1.0000	0.6547	0.6849	0.9675	0.7346	0.1925	1.0000	0.6696
Xinjiang01	0.5971	1.0000	0.6305	0.7248	0.9893	0.8651	0.1480	0.9230	0.4212
Fujian03	0.4244	0.9352	0.8826	0.8481	0.9623	0.8657	0.1277	0.9196	0.5138
Anhui05	0.2882	1.0000	0.8494	0.7801	0.8648	0.7196	0.1174	1.0000	0.9398
Shaanxi01	0.4986	0.8257	0.5883	0.3986	0.9430	0.6097	0.1234	0.8626	0.6925
Heilongjiang04	1.0000	1.0000	0.6405	1.0000	1.0000	1.0000	1.0000	0.7237	0.5613
Heilongjiang05	0.7579	0.5442	0.8616	0.8911	1.0000	0.9707	1.0000	0.8007	0.9651

output of labor (0.1174). Agricultural production efficiency can be improved to some extent by increasing the output of grain. Regarding the poverty elimination effect, eight villages (e.g., Yunnan01) reach efficiency frontiers, and the remaining 24 villages have potential for improvement to varying degrees. Regarding undesirable output variables, there are four villages (i.e., Yunnan01, Heilongjiang06, Jilin03, and Guangdong01) whose aggregate index of social harmony reaches efficiency frontiers, and the remaining 28 villages have room for improvement to varying degrees. Moreover, there are 15 villages (e.g., Heilongjiang02) with below-average efficiency in the aggregate index of social harmony. The efficiency of the two output variables in the second stage shows that remarkable achievements have been made in poverty relief and social harmony and stability, but the aggregate index of social harmony has more potential for improvement.

Regarding disposable income per village household, 17 villages reach efficiency frontiers, while the remaining 15 villages have the potential for improvement to varying degrees. Regarding the income gap of village households, 12 villages reached efficiency frontiers; the remaining 20 villages have some potential for improvement. For the 32 villages, the efficiency of disposable income per village household is appreciable, while the efficiency of the income gap of village households has significant potential for improvement. Thus, to improve social governance efficiency, it is necessary to reduce the income gap of village households. Table 3 Average efficiency of input and output indicators in 5 years (2012 to 2016).

Discussion

It is beneficial to draw some emphasis on the outcomes produced by the study and synthesize those with the existing literature. However, China's success in reducing poverty across the board is unevenly dispersed throughout the country (Zameer et al., 2020). Like most other emerging countries Chinese poverty alleviation may possess uneven development trends and the efficiency level is also random which is mostly characterized by factor endowment, distributions of labor and natural resources, local governments support, and sociodemographic notions. Interestingly, the potential success of alleviating poverty through agriculture projects is dependent upon the simultaneous development of several interrelated mechanisms from production factors *via* labor and resource allocations through household income and gaps of income to social harmony aggressions and managing undesired outcomes (Ellis and Freeman, 2004; Thongdara et al., 2012; Huang et al., 2021a). Therefore, we divided the whole process of agricultural poverty reduction into two stages, namely the agricultural production stage and the social governance stage, and include the desirable and undesirable outcomes in an integrated manner.

In general comprehensive efficiency value of China's agricultural poverty reduction shows a relatively stable trend in the fluctuations. The agricultural production efficiency value has a large improvement space, and the social governance efficiency value has a small space for improvement. The outcome is parallel with the study of Zhou et al. (2019) and Peng et al. (2021). The study believes that in the first-stage value of agricultural production efficiency is significantly lower than the value of poverty reduction efficiency in the second stage, and there is still much room for improvement in agricultural production efficiency. In the study of China's Targeted Poverty Alleviation Policies from 2013 to 2019, Li and Li (2021) also found similar findings. The study found in the future, due to the rapid development of the agricultural scale, mechanization, and smart agriculture in China, there will be a lot of room for improvement in agricultural production efficiency. After evaluating the notion of anti-poverty policy efficiencies and the problem of agricultural poverty reduction in China based on the Chinese rural statistical data of 28 provinces, municipalities, and autonomous regions from 2013 to 2017, Yang et al. (2021) also outlined parallel assumptions. Interestingly, Zameer et al. (2020) found China's poverty alleviation trends have much room for increasing greater social harmony and social obligation is relatively weak. The current study also found limited room for probable expansions concerning the output of grain, the poverty elimination index, and an aggregate index of social harmony which is slightly different from some studies. The study found grain productivity will lead to an increase in farmers' disposable income and reduce the income gaps which eventually fosters better performance of poverty alleviation. While ins a study of poverty relief and grassland dilapidation in Inner Mongolia Briske et al. (2015) had quite different outcomes as they outline maximization of livestock revenue reduces household income and creates a burden for the household to get rid of poverty.

Conclusion

Like most other developing countries Chinese government is also fostering various poverty alleviation projects. However, among them "Poverty alleviation through agriculture projects" has drawn much more focal attention toward policy dimensions and empirical setup. While the existing literature mainly lacks an evaluation of the level of efficiencies of these particular types of projects. Moreover, how and to what extent the projects foster and perform in alleviating poverty at the village level has not been fully grasped by other studies. Therefore, the study has been designed to fulfill those gaps by using the data from rural fixed observation points across 31 provinces of China from 2012 to 2016. For doing so, we have adopted a two-stage dynamic Slacks-Based Measure (SBM) model for performing the Data Envelopment Analysis (DEA). The study depicted the following outcomes: the overall efficiency of agricultural poverty relief across the 32 villages tended to be stable and undulate. Agricultural production efficiency in the first stage is the primary cause of the low overall efficiency of agricultural poverty relief, and social governance efficiency in the second stage is its secondary cause. Throughout the entire process of agricultural poverty relief, there is significant potential for improvement in both agricultural production efficiency at the first stage and social governance efficiency in the second stage, particularly at the first stage. Agricultural poverty relief provides an important pathway to addressing rural poverty in China. Specifically, we can achieve the goal of agricultural poverty relief by improving the conditions of agricultural production and operation and enhancing the potential of rural social governance at the grassroots level. It is necessary to improve agricultural production efficiency in particular. Among the 32 villages, agricultural production efficiency in the first stage differs significantly from social governance efficiency in the second stage. Village-based agricultural production efficiency does not vary significantly across different years, whereas village-based social governance efficiency does.

Regarding specific indicators, the efficiency of two input indicators (total labor force and productive fixed assets) at the first stage is poor, implying the significant potential for improvement; though the efficiency value of sown areas of farm crops is appreciable. Therefore, it is necessary to reduce the labor force of agricultural production, raise the utilization rate of productive fixed assets, develop modern agriculture, and improve agricultural production efficiency. Among the input indicators in the second stage, the efficiency of educational attainment of rural labor is poor, implying the significant potential for improvement. Therefore, it is necessary to improve the educational attainment of rural labor, thus facilitating poverty relief and social harmony. Among the output indicators in the second stage, the efficiency of the total output of grain has some potential for improvement. A high-yield, high-quality, and low-consumption agricultural production system can be created by improving agricultural production efficiency in the first stage. The analysis of the efficiency of output indicators at the second stage shows that remarkable achievements have been made in poverty relief and social harmony and stability, but the aggregate index of social harmony has more potential for improvement. The analysis of intermediate indicators shows that the efficiency of disposable income per village household is appreciable, while the efficiency of the income gap of village households has significant potential for improvement. To improve social governance efficiency, it is necessary to reduce the income gap of village households. The income gap affects not only the progress in poverty relief but also rural social harmony.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

Author contributions

Conceptualization and methodology: SY and AS. Software and resources: AS. Formal analysis and visualization: GY. Data curation: SY. Writing—original draft preparation, investigation, supervision, and funding acquisition: LL. Writing—review and editing and validation: SY, AS, and LL. Project administration: GY and AS. 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.

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References

Adamkovič, M., and Martončik, M. (2017). A review of consequences of poverty on economic decision-making: a hypothesized model of a cognitive mechanism. *Front. Psychol.* 8, 1784. doi: 10.3389/fpsyg.2017.01784

Alemañ, A. E., Robledo, D., and Hayashi, L. (2019). Development of seaweed cultivation in Latin America: current trends and future prospects. *Phycologia* 58, 462–471. doi: 10.1080/00318884.2019.1640996

Ali, Z., Ullah, I., Nazir, N., Asif, M., and Azeem, M. (2020). Social and financial efficiency: Institutional characteristics of the partner organizations of Pakistan Poverty Alleviation Fund. *PLoS ONE* 15, e0244444. doi: 10.1371/journal.pone.0244444

Bai, B., Xiong, S., Ma, X., and Tian, Y. (2021). Effectiveness evaluation of photovoltaic poverty alleviation project in China: From a capital perspective. *J. Clean. Prod.* 284, 124684. doi: 10.1016/j.jclepro.2020.124684

Bardhan, P. (1996). Efficiency, equity and poverty alleviation: policy issues in less developed countries. *Econ. J.* 106, 1344–1356. doi: 10.2307/2235526

Bird, K., Chabé-Ferret, B., and Simons, A. (2022). Linking human capabilities with livelihood strategies to speed poverty reduction: evidence from Rwanda. *World Dev.* 151, 105728. doi: 10.1016/j.worlddev.2021.105728

Bouwman, T. I., Andersson, J. A., and Giller, K. E. (2021). Herbicide induced hunger? Conservation agriculture, ganyu labour and rural poverty in Central Malawi. *J. Dev. Stud.* 57, 244–263. doi: 10.1080/00220388.2020.1786062

Bradshaw, T. K. (2007). Theories of poverty and anti-poverty programs in community development. *Commun. Dev.* 38, 7–25. doi: 10.1080/15575330709490182

Briske, D. D., Zhao, M., Han, G., Xiu, C., Kemp, D. R., Willms, W., et al. (2015). Strategies to alleviate poverty and grassland degradation in Inner Mongolia: Intensification vs production efficiency of livestock systems. *J. Environ. Manage.* 152, 177–182. doi: 10.1016/j.jenvman.2014.07.036

Cai, Y., and Xia, C. (2018). Interpretive structural analysis of interrelationships among the elements of characteristic agriculture development in Chinese rural poverty alleviation. *Sustainability* 10, 786. doi: 10.3390/su10030786

Charles, A. (2019). *Addressing the Climate Change and Poverty Nexus: A Coordinated Approach in the Context of the 2030 Agenda and the Paris Agreement*. Rome, Italy: FAO Available online at: https://www.fao.org/publications/card/en/c/CA6968EN/ (accessed May 5, 2022).

Charnes, A., Cooper, W. W., and Rhodes, E. (1978). Measuring the efficiency of decision making units. *Eur. J. Operat. Res.* 2, 429–444. doi: 10.1016/0377-2217(78)90138-8

Chen, H., Liu, J., Li, Y., Chiu, Y.-H., and Lin, T.-Y. (2019). A two-stage dynamic undesirable data envelopment analysis model focused on media reports and the impact on energy and health efficiency. *Int. J. Environ. Res. Public Health* 16, 1535. doi: 10.3390/ijerph16091535

Chen, Y., Du, J., David Sherman, H., and Zhu, J. (2010). DEA model with shared resources and efficiency decomposition. *Eur. J. Operat. Res.* 207, 339–349. doi: 10.1016/j.ejor.2010.03.031

Cheng, X., Shuai, C., Liu, J., Wang, J., Liu, Y., Li, W., et al. (2018). Modelling environment and poverty factors for sustainable agriculture in the three gorges reservoir regions of China. *Land Degrad. Dev.* 29, 3940–3953. doi: 10.1002/ldr.3143

Dah, O., and Bassolet, T. B. (2021). Agricultural infrastructure public financing towards rural poverty alleviation: evidence from West African Economic and Monetary Union (WAEMU) States. *SN Bus. Econ.* 1, 39. doi: 10.1007/s43546-021-00044-x

Dong, G. (2022). The political background of a pattern transformation in the Chinese system of science and technology during the 20th century. *Cult. Sci.* 5, 16–32. doi: 10.1177/20966083221094150

Dong, Y., Jin, G., Deng, X., and Wu, F. (2021). Multidimensional measurement of poverty and its spatio-temporal dynamics in China from the perspective of development geography. *J. Geogr. Sci.* 31, 130–148. doi: 10.1007/s11442-021-1836-x

Ellis, F., and Freeman, H. A. (2004). Rural livelihoods and poverty reduction strategies in four African countries. *J. Dev. Stud.* 40, 1–30. doi: 10.1080/00220380410001673175

Ellis, F., and Freeman, H. A. (eds.) (2005). *Rural Livelihoods and Poverty Reduction Policies*. London: Routledge. doi: 10.4324/9780203006214

Eryong, X., and Xiuping, Z. (2018). Education and anti-poverty: policy theory and strategy of poverty alleviation through education in China. *Educ. Phil. Theory* 50, 1101–1112. doi: 10.1080/00131857.2018.1438889

Fabiyi, E., and Akande, K. (2015). Economic empowerment for rural women in Nigeria: poverty alleviation through agriculture. *J. Agric. Sci.* 7, p236. doi: 10.5539/jas.v7n9p236

Färe, R., Grosskopf, S., and Whittaker, G. (2007). "Network DEA," in *Modeling Data Irregularities and Structural Complexities in Data Envelopment Analysis*, eds J. Zhu and W. D. Cook (Boston, MA: Springer US) 209–240.

Gassner, A., Harris, D., Mausch, K., Terheggen, A., Lopes, C., Finlayson, R., et al. (2019). Poverty eradication and food security through agriculture in Africa: Rethinking objectives and entry points. *Outlook Agric.* 48, 309–315. doi: 10.1177/0030727019888513

Guo, X., Lu, C.-C., Lee, J.-H., and Chiu, Y.-H. (2017). Applying the dynamic DEA model to evaluate the energy efficiency of OECD countries and China. *Energy* 134, 392–399. doi: 10.1016/j.energy.2017.06.040

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

Hansen, B. E. (2011). Threshold autoregression in economics. *Stat. Interface* 4, 123–127. doi: 10.4310/SII.2011.v4.n2.a4

Huang, Y., Huang, B., Song, J., Xu, X., Chen, X., Zhang, Z., et al. (2021a). Social impact assessment of photovoltaic poverty alleviation program in China. *J. Clean. Prod.* 290, 125208. doi: 10.1016/j.jclepro.2020.125208

Huang, Y., Huang, X., Xie, M., Cheng, W., and Shu, Q. (2021b). A study on the effects of regional differences on agricultural water resource utilization efficiency using super-efficiency SBM model. *Sci. Rep.* 11, 9953. doi: 10.1038/s41598-021-89293-2

Hurst, P., Termine, P., and Karl, M. (2005). *Agricultural Workers and Their Contribution to Sustainable Agriculture and Rural Development*. Rome, Italy: FAO. Available online at: https://agris.fao.org/agris-search/search.do?recordID=GB2013203664 (accessed April 7, 2021).

Kaidi, N., Mensi, S., and Ben Amor, M. (2019). Financial development, institutional quality and poverty reduction: worldwide evidence. *Soc. Indic. Res.* 141, 131–156. doi: 10.1007/s11205-018-1836-0

Kao, C. (2018). A classification of slacks-based efficiency measures in network data envelopment analysis with an analysis of the properties possessed. *Eur. J. Operat. Res.* 270, 1109–1121. doi: 10.1016/j.ejor.2018.04.036

Kerr, J. (2002). Watershed development, environmental services, and poverty alleviation in India. *World Dev.* 30, 1387–1400. doi: 10.1016/S0305-750X(02)00042-6

Knickel, K., Brunori, G., Rand, S., and Proost, J. (2009). Towards a better conceptual framework for innovation processes in agriculture and rural development: from linear models to systemic approaches. *J. Agric. Educ. Exten.* 15, 131–146. doi: 10.1080/13892240902909064

Kuang, B., Lu, X., Zhou, M., and Chen, D. (2020). Provincial cultivated land use efficiency in China: Empirical analysis based on the SBM-DEA model with carbon emissions considered. *Technol. Forecast. Soc. Change* 151, 119874. doi: 10.1016/j.techfore.2019.119874

Leng, G., Feng, X., and Qiu, H. (2021). Income effects of poverty alleviation relocation program on rural farmers in China. *J. Integr. Agric.* 20, 891–904. doi: 10.1016/S2095-3119(20)63583-3

Li, X., and Li, L. (2021). Evaluation of China's targeted poverty alleviation policies: a decomposition analysis based on the poverty reduction effects. *Sustainability* 13, 11691. doi: 10.3390/su132111691

Li, Y., Zhang, Q., Wang, G., McLellan, B., Liu, X. F., and Wang, L. (2018). A review of photovoltaic poverty alleviation projects in China: Current status, challenge and policy recommendations. *Renew. Sustain. Energy Rev.* 94, 214–223. doi: 10.1016/j.rser.2018.06.012

Liu, J., Huang, F., Wang, Z., and Shuai, C. (2021a). What is the anti-poverty effect of solar PV poverty alleviation projects? Evidence from rural China. *Energy* 218, 119498. doi: 10.1016/j.energy.2020.119498

Liu, M., Feng, X., Wang, S., and Zhong, Y. (2021b). Does poverty-alleviation-based industry development improve farmers' livelihood capital? *J. Integr. Agric.* 20, 915–926. doi: 10.1016/S2095-3119(20)63449-9

Liu, S. (2018). On the theoretical value and practical significance of the anti-poverty thought of socialism with Chinese characteristics. *Open J. Soc. Sci.* 6, 141–155. doi: 10.4236/jss.2018.611010

Macfadyen, G., Fao, R., and Corcoran, E. (2002). *Literature Review of Studies on Poverty in Fishing Communities and of Lessons Learned in Using the Sustainable Livelihoods Approach in Poverty Alleviation Strategies and Projects*. Rome (Italy):

FAO. Available online at: http://www.fao.org/docrep/005/y3914e/y3914e00.htm (accessed May 5, 2022).

Maja Gavrilovic, M. K. and P. P. (FAO) (2016). *Strengthening Coherence Between Agriculture and Social Protection to Combat Poverty and Hunger in Africa: Diagnostic Tool*. Rome, Italy: FAO. Available online at: https://www.fao.org/publications/card/en/c/dc7cdda7-4bb7-4d0f-99c4-96f2352e385d/ (accessed May 5, 2022).

Martens, K., Wolff, A., and Hanisch, M. (2020). Understanding social innovation processes in rural areas: empirical evidence from social enterprises in Germany. *Soc. Enterprise J.* 17, 220–239. doi: 10.1108/SEJ-12-2019-0093

Maulu, S., Hasimuna, O. J., Mutale, B., Mphande, J., and Siankwilimba, E. (2021). Enhancing the role of rural agricultural extension programs in poverty alleviation: a review. *Cogent Food Agric.* 7, 1886663. doi: 10.1080/23311932.2021.1886663

Miller, D. C., Mansourian, S., Gabay, M., Hajjar, R., Jagger, P., Kamoto, J. F. M., et al. (2021). Forests, trees and poverty alleviation: policy implications of current knowledge. *Forest Policy Econ.* 131, 102566. doi: 10.1016/j.forpol.2021.102566

Mujuru, N. M., Obi, A., Mishi, S., and Mdoda, L. (2022). Profit efficiency in family-owned crop farms in Eastern Cape Province of South Africa: a translog profit function approach. *Agric. and Food Secur.* 11, 20. doi: 10.1186/s40066-021-00345-2

Pan, W.-T., Zhuang, M.-E., Zhou, Y.-Y., and Yang, J.-J. (2021a). Research on sustainable development and efficiency of China's E-Agriculture based on a data envelopment analysis-Malmquist model. *Technol. Forecast. Soc. Change* 162, 120298. doi: 10.1016/j.techfore.2020.120298

Pan, Z., Zhang, Y., Zhou, C., and Zhou, Z. (2021b). Effects of individual and community-level environment components on the subjective well-being of poverty alleviation migrants: the case in Guizhou, China. *Int. J. Sustain. Dev. World Ecol.* 28, 622–631. doi: 10.1080/13504509.2021.1952659

Peng, C., Ma, B., and Zhang, C. (2021). Poverty alleviation through e-commerce: village involvement and demonstration policies in rural China. *J. Integr. Agric.* 20, 998–1011. doi: 10.1016/S2095-3119(20)63422-0

Sgroi, F. (2022). The circular economy for resilience of the agricultural landscape and promotion of the sustainable agriculture and food systems. *J. Agric. Food Res.* 8, 100307. doi: 10.1016/j.jafr.2022.100307

Sgroi, F., and Marino, G. (2022). Environmental and digital innovation in food: the role of digital food hubs in the creation of sustainable local agri-food systems. *Sci. Total Environ.* 810, 152257. doi: 10.1016/j.scitotenv.2021.152257

Shen, Y. (2022). "Poverty alleviation process in rural China," in *Rural Poverty, Growth, and Inequality in China*, ed Y. Shen (Singapore: Springer), 1–23.

Shen, Y., and Li, S. (2022). Eliminating poverty through development: the dynamic evolution of multidimensional poverty in rural China. *Econ. Polit. Stud.* 10, 85–104. doi: 10.1080/20954816.2022.2028992

Thongdara, R., Samarakoon, L., Shrestha, R. P., and Ranamukhaarachchi, S. L. (2012). Using GIS and spatial statistics to target poverty and improve poverty alleviation programs: a case study in Northeast Thailand. *Appl. Spatial Analysis* 5, 157–182. doi: 10.1007/s12061-011-9066-8

Tone, K., and Tsutsui, M. (2009). Network DEA: a slacks-based measure approach. *Eur. J. Operat. Res.* 197, 243–252. doi: 10.1016/j.ejor.2008.05.027

Tone, K., and Tsutsui, M. (2010). Dynamic DEA: a slacks-based measure approach. *Omega* 38, 145–156. doi: 10.1016/j.omega.2009.07.003

Tone, K., and Tsutsui, M. (2014). Dynamic DEA with network structure: a slacks-based measure approach. *Omega* 42, 124–131. doi: 10.1016/j.omega.2013.04.002

Wang, Z., Li, J., Liu, J., and Shuai, C. (2020). Is the photovoltaic poverty alleviation project the best way for the poor to escape poverty? –A DEA and GRA analysis of different projects in rural China. *Energy Policy* 137, 111105. doi: 10.1016/j.enpol.2019.111105

Wei, W., Sarker, T., Roy, R., Sarkar, A., and Rabbany, M. G. (2021). Women's empowerment and their experience to food security in rural Bangladesh. *Sociol. Health and Illness* 43, 971–994. doi: 10.1111/1467-9566.13273

Wongnaa, C. A., Awunyo-Vitor, D., Mensah, A., and Adams, F. (2019). Profit efficiency among maize farmers and implications for poverty alleviation and food security in Ghana. *Scientific African* 6, e00206. doi: 10.1016/j.sciaf.2019.e00206

World Bank (2021). *Agricultural Productivity, Diversification and Gender: Background Report to Sri Lanka Poverty Assessment*. Washington, DC: World Bank. Available online at: https://openknowledge.worldbank.org/handle/10986/36536 (accessed May 5, 2022).

World Bank and Nations (2021). *A Blueprint for Strengthening Food System Resilience in West Africa: Regional Priority Intervention Areas.* Washington, DC: World Bank. Available online at: https://openknowledge.worldbank.org/handle/10986/35618 (accessed May 5, 2022).

Wu, Y., Ke, Y., Wang, J., Li, L., and Lin, X. (2019). Risk assessment in photovoltaic poverty alleviation projects in China under intuitionistic fuzzy environment. *J. Clean. Prod.* 219, 587–600. doi: 10.1016/j.jclepro.2019.02.117

Wu, Y., Ke, Y., Zhang, T., Liu, F., and Wang, J. (2018). Performance efficiency assessment of photovoltaic poverty alleviation projects in China: a three-phase data envelopment analysis model. *Energy* 159, 599–610. doi: 10.1016/j.energy.2018.06.187

Yang, G., Wang, Y., Chang, H., and Chen, Q. (2021). Evaluating anti-poverty policy efficiencies in China: meta-frontier analysis using the two-stage data envelopment analysis model. *China Agric. Econ. Rev.* 14, 416–442. doi: 10.1108/CAER-10-2020-0254

Zameer, H., Shahbaz, M., and Vo, X. V. (2020). Reinforcing poverty alleviation efficiency through technological innovation, globalization, and financial development. *Technol. Forecast. Social Change* 161, 120326. doi: 10.1016/j.techfore.2020.120326

Zhou, Y., and Che, Y. (2021). Research on government logistics subsidies for poverty alleviation with non-uniform distribution of consumers. *Omega* 104, 102489. doi: 10.1016/j.omega.2021.102489

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, Y., Bashir, S., and Marie, M. (2022). Assessing the relationship between poverty and economic growth: does sustainable development goal can be achieved? *Environ. Sci. Pollut. Res.* 29, 27613–27623. doi: 10.1007/s11356-021-18240-5

Zhuang, X., Li, Z., Zheng, R., Na, S., and Zhou, Y. (2021). Research on the efficiency and improvement of rural development in China: based on two-stage network SBM model. *Sustainability* 13, 2914. doi: 10.3390/su13052914