Environmental Science and Pollution Research (2023) 30:67019–67039
https://doi.org/10.1007/s11356-023-27212-w

RESEARCH ARTICLE

Subsidy or not? How much government subsidy can improve performance level of energy-saving service company?

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Received: 24 October 2022 / Accepted: 20 April 2023 / Published online: 27 April 2023

Abstract

Contract energy management model is a new energy-saving mode based on single market mechanism. Due to its externality, the energy efficiency market cannot realize the optimal allocation of resources. Government energy-saving subsidy can solve the market failure of energy-saving service market and improve the performance level of energy-saving service company. However, due to the unbalanced support fields and single incentive tools in the government incentive policy, the incentive effect of the government subsidy policies for contract energy management projects is not satisfactory. Based on a two-stage dynamic decision-making model, this article analyzes the impact of different forms of government subsidy policies on the performance-level decision-making of energy service company, and draws the following conclusions: (1) The effect of the government's variable subsidy policy with payment conditions is better than the fixed subsidy policy without payment conditions. (2) Government incentive policy for contract energy management needs to be directed against different energy-saving fields. (3) The government should adopt different forms of incentive policies for energy-saving service companies with different energy-saving levels in the same energy-saving field. (4) When the government implements the variable subsidy policy with preset energy-saving target, each within a reasonable range, with the increase of which, the incentive effect on energy-saving service companies with lower energy-saving level decreases. When the subsidy policy has no incentive effect, it is more unfavorable for the energy-saving service companies which are below the average level of the industry.

Keywords Contract energy management · Energy-saving benefit-sharing mode · Government energy-saving subsidy form · Effect of incentive policy

Introduction

The rapid economic growth of China is largely driven by energy consumption (Wang and Jiang 2019). The expansion of the energy market has promoted the rapid development of China's economy; on the other hand, it also brought environmental problems. China's energy development largely depends on traditional fossil energy, resulting in serious environmental pollution (Liu and Feng 2020), in response to the environmental problems (global warming) caused by energy consumption. By taking environmental issues like global warming into account, China's economic development has entered a new normal, among which the growth of energy consumption has slowed down, and its development quality and efficiency have become the most prominent problems in energy development (Yuan et al. 2014; Zou et al. 2016).

Based on the above problems in China's energy development, the contract energy management model has emerged in the energy conservation service market, which aims to improve energy efficiency and achieve energy conservation goals. It is basically a market-based energy conservation model. This model alleviates China's energy problems to some extent (Zhang et al. 2021). It means that the energy service company (ESCO) optimizes the energy distribution system for energy-saving enterprises to improve their energy efficiency. In 2018, the contracted energy management project alone saved more than 43 million tons of coal

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energy (1.3EJ) and reduced 117 million tons of CO_2 emissions. The Efficient World Scenario (EWS, IEA) pointed out the importance of improving energy efficiency to achieve efficiency savings. Compared with traditional measures, such as reducing energy consumption and reducing exhaust emissions, improving energy efficiency can also bring various social benefits. Based on this, China began to implement the contract energy management model. The government has attached great importance to the effect of contract energy management mode in energy saving, and the government strongly supports the development of the contract energy management model. The energy-saving service market has achieved continuous growth over the past 5 years (2015–2020) (Fig. 1). By 2020, the number of ESCO had increased from 500 to 7108, with more than 766,000 employees. China has become the largest ESCO market in the world (IEA, 52% in 2019). That number rose to 8725 in 2021 and 8733 in the first half of 2022.

There are quite a few uncertain factors in the implementation of contract energy management projects, such as energy-saving market environment and energy prices (Guo et al. 2019), which directly affect relevant contract parameters and further affect the actual interests of both parties. At present, the research on dynamic decision-making of energy contract management focuses on optimizing contract parameters (amount of investment, proportion of energy-saving benefit distribution, and term of contract) (Feng et al. 2022). Like taking the optimization of benefit distribution as the main example, sharp value method, game theory, and bargaining model are frequently used to study benefit distribution (Shang et al. 2015, 2020; Basallote et al. 2020; Zhang et al. 2022).

With energy conservation and emission reduction rising to the national strategic level, the energy conservation service industry has begun to pay attention to EPC since 2010. With the policy support of the government, ESCO is willing to invest in energy-saving technologies to implement energy-saving renovations (Bertoldi and Boza-Kiss 2017). The performance level can measure the enthusiasm of ESCO for energy-saving services (Lu and Shao 2016), and its value is determined by the ratio of energy saving to the benchmark energy consumption before the energy-saving transformation of EPC project, which is affected by macro (government incentives) and micro factors (energy-saving benefit sharing ratio) (Hong et al. 2014; Nurcahyanto et al. 2020). Incentive policies are the driving force for ESCO to carry out energy-saving services and improve performance (Brunke et al. 2014; Cagno et al. 2015; Liu and Gao 2016; Zhang et al. 2018; Qiu et al. 2022); subsidy is more important than tax and regulation (Yao et al. 2014; Chen and Nie 2016; García-Quevedo and Jové-Llopis 2021; Chen, 2022). However, market failures caused by imperfections in the energy market, such as ineffective incentives (Brown 2001), may cause the energy efficiency after energy-saving retrofits to be lower than the socially ideal level, that is, the energy efficiency gap (Jaffe and Stavins 1994).

Government subsidy can motivate enterprises to pursue energy-saving technological innovations to improve energy efficiency, but it becomes ineffective beyond a certain level and there is a double threshold effect at the same time. Policy-making requires a certain continuity (Shen et al. 2016), which means that different energy-saving fields should implement differential strategy, and adjust dynamically according to changes in energy prices (Liang et al. 2019). Energy-saving subsidy can be divided into two forms based on emission reduction and fixed investment cost. The former can always improve social welfare which is suitable for emerging industries, while the latter is suitable for mature

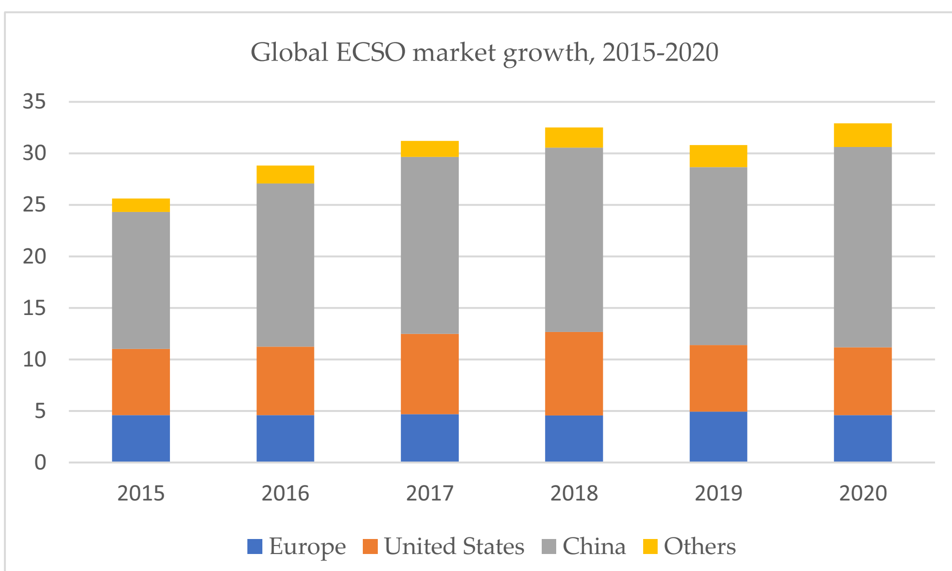

Fig. 1 Growth of global ESCO market from 2015 to 2020 (data source: Energy Conservation Service Industry Committee of China Energy Conservation Association (EMCA)

industries (Li et al. 2021). Although the current incentive policy has been linked to performance, there are still deviations in performance measurement (Tzani et al. 2022); moreover, the local central government has not implemented differentiated subsidy policies according to different regions (Hou et al. 2016). In the implementation of energy-saving incentive policies among different countries, there are still problems that exist, such as a single incentive tool, unbalanced government support fields, long policy update intervals as well as the lack of necessary super vision (Alam et al. 2019; Zhou et al. 2020; Zhang et al. 2020; Han et al. 2021; Wang, 2022). The above literatures are all based on empirical research. There is a certain degree of subjectivity in the qualitative evaluation policies, while the quantitative methods are more scientific. Qualitative policy evaluation methods have been applied in some fields (Li, 2021), but lack application in the field of contract energy management.

Research on China's energy development issues	Yuan et al. (2014), Zou et al. (2016), Liu and Feng (2020)
Research on uncertainty factors of energy contract management projects	Guo et al. (2019)
Research on optimal decision-making of contract energy management	Feng et al. (2022), Shang et al. (2015, 2020), Basallote et al. (2020), Zhang et al. (2022)
Research on the factors affecting ESCO's energy-saving services	Bertoldi and Boza-Kiss (2017), Lu and Shao (2016), Hong et al. (2014), Nurcahyanto et al. (2020)
Research on the impact of incentive policies in the energy market	Brunke et al. (2014), Cagno et al. (2015), Liu and Gao (2016), Zhang et al. (2018), Qiu et al. (2022), Yao et al. (2014), Chen and Nie (2016), García-Quevedo and Jové-Llopis (2021), Chen (2022), Brown (2001), Jaffe and Stavins (1994)
Research on the negative effects of government subsidy policy	Tzani et al. (2022), Hou et al. (2016), Alam et al. (2019), Zhou et al. (2020), Zhang et al. (2020), Han et al. (2021), Wang (2022), Li (2021)
Research on the effect of government subsidies on encouraging enterprises	Shen et al. (2016), Liang et al. (2019), Li et al. (2021)

The main innovation of the paper is that the quantitative policy evaluation method is applied in the field of contract energy by using the two-stage game model. The current research on contract energy management mostly uses the qualitative evaluation method, and only subjectively analyzes the impact of various government policies on the energy-saving service industry. This paper uses the dynamic game method to build the decision-making model of energy-saving service companies. It focuses on government subsidy policies without considering other aspects, and then carries out numerical example analysis to support theoretical research with data. Therefore, this paper will mainly discuss the following issues: (1) Does the current energy-saving subsidy policy have defects? (2) What kind of incentive policies can better stimulate ESCO to improve their performance? (3) How to design government incentive measures more effectively?

The structure of this paper is arranged as follows. The "Model building" section is the dynamic decision model construction and solution of energy-saving enterprises and energy-saving service companies in different situations. The "Comparative analysis of results" section is the comparative analysis of decision-making results in different situations. The fourth part is the "Example analysis," which studies the influence of different parameters on the decision-making results. The fifth part is the "Conclusion."

Model building

Under the contract energy management model, the decision-making process of ESCO performance level is a dynamic process. ESCO and energy-saving enterprises decide the contract and energy-saving goals jointly. Dynamic game is suitable for decision-making of energy-saving contracts (Qian and Guo 2014; Song and Gao 2018; Huimin et al. 2019).

The two-stage dynamic decision-making process of both parties is as follows: first stage: the energy-saving enterprises set the energy-saving benefit sharing ratio φ under the assumption of the optimal response of the energy-saving service company and second stage: as the energy-saving benefit sharing ratio is fixed, the ESCO has selected the optimal performance level s to maximize the profit under the given energy-saving benefit sharing ratio.

Decision variables and basic assumptions

Decision variables and other parameters

In the decision-making process, energy-saving enterprises propose the energy-saving benefit sharing ratio φ according to their own energy-saving needs. ESCO needs to select performance level s based on energy-saving benefit sharing ratio. There are two variables involved, energy-saving benefit sharing ratio φ and performance level s.

In the contract energy management model, the performance level is determined by the ratio of annual energy savings to benchmark energy consumption. The performance level is used to describe the completion of ESCO's energy saving for the project objectives. The performance level of the energy-saving service company will affect the energy-saving benefits of the whole project. The energy-saving benefit of the project is the main benefit source of ESCO, and the energy-saving benefit sharing ratio in the contract will have an impact on the performance level of ESCO. As an additional benefit, government subsidies can also affect ESCO performance level and the decision-making of energy-saving benefit sharing ratio of energy-saving enterprises.

The settings and meanings of all decision variables and other parameters are shown in Table 1.

Basic assumptions

This paper uses dynamic game method to solve the problem of contract decision between ESCO and energy-saving enterprises and make the following assumptions.

H1: Cost assumptions of ESCO

The total cost TC of an energy-saving service company consists of two parts, fixed cost C_f and average unit variable cost C_v, without considering other stakeholders. Assume that the average variable cost is nonlinear, $C_v(s) = a + bs^{\lambda}$ and meet $\lambda \geq 1, a \geq 0, b > 0$, obey $C_v'(s) > 0$ and $C_v''(s) > 0$. Set the fixed cost function to be linear, $C_f(s) = c + ds$, and meet $c \geq 0,\ d \geq 0,\ TC = C_v(s) + C_f(s) = c + ds + a + bs^{\lambda}$. $C_g'(s) > 0$ and $C_f'(s) > 0$ can ensure that fixed and variable costs do not decrease as the performance level s increases.

H2: Energy efficiency service market assumptions

The technical capability of ESCO is the key factor for the success of the contract energy management project. The feasibility and advantages of energy-saving technology determine whether it can meet the requirements of energy-saving enterprises (Qin et al. 2017). It is assumed that there are differences in the energy-saving level (technical capability) of ESCO in the energy-saving service market of a certain industry; the highest energy-saving service level in the industry is $\bar{e}$. The energy-saving level of the ESCO is evenly distributed in the interval $[0, \bar{e}]$

H3: Determination of project energy-saving benefits

The income of the contract energy management project mainly comes from the cash flow converted from the saved energy in the plan, a result of the realization of the energy-saving target after the ESCO provides energy-saving transformation and other related supporting services for energy-saving enterprises. Project energy-saving benefit is a function of project benchmark energy consumption, performance level, energy price, project life cycle, and discount rate. At the same time, the time value of cash is fully considered, and the project income is calculated using the NPV net present value. This method is widely accepted in the study of long-term investment decision and life cycle cost (Jafari and Valentin 2017).

$$R = esp_e \sum_{i=1}^{t} \left(1 + r_i\right)^{-i} = esp_e \frac{1 - \left(1 + r_i\right)^{-t}}{r_i}$$

Among them, $e > 0$, $p_e > 0$, $t > 0$. The current interest rate of the bank, $r_i \in (0, 1)$. This paper uses backward induction method to solve the above dynamic decision model, solves the second stage first to get the optimal performance level s^*. Under the condition of the second stage s^*, the paper solves the first stage to get the optimal energy-saving benefit distribution ratio s*.

A dynamic decision-making model for both parties in a non-government subsidy situation

Benefit function of energy-saving enterprises and ESCO

1. The benefit function of energy-saving enterprises

According to the setting of relevant theories and parameters, the energy-saving benefits of energy-saving enterprises within the sharing period agreed in the contract come from the energy-saving benefits generated by the energy-saving renovation projects, which are shared according to the energy-saving benefit sharing ratio stipulated in the contract. Thus, the benefit function of the energy-saving enterprise can be obtained as

Table 1 Parameter setting

Variables	Description	Variables	Description
s	Performance level	e	Benchmark energy consumption of EPC projects
C_f	Fixed costs	C_v	Average variable cost
a,b,c,d	ESCO cost parameters	η	ESCO's cost coefficient effort
t	Project contract period	r_i	Discount rate
β	Distribution ratio of government subsidies	k	Government subsidy
φ	Energy-saving benefit sharing ratio in contract	K	Lump sum fixed subsidy amount
$\bar{e}$	The highest energy consumption benchmark in an energy-saving field	e_0	Energy-saving targets set by the government
U_e	Energy-saving benefits of energy-saving enterprises	U_c	Energy-saving benefits of ESCO

$$U_e = esp_e \sum_{i=1}^{t} \left(1 + r_i\right)^{-i} (1 - \varphi) = esp_e \frac{1 - \left(1 + r_i\right)^{-t}}{r_i} (1 - \varphi) \tag{1}$$

2.Efficiency function of energy-saving service company

The energy-saving service company can obtain energy-saving benefits according to the share ratio φ preset in the contract within the time limit specified in the contract. In this case, the ESCO's revenue is the one generated by the energy-saving project minus the total cost of ESCO. The benefit function of energy-saving service company is

$$U_c = esp_e \frac{1 - \left(1 + r_i\right)^{-t}}{r_i} \varphi - \left(a + bs^{\lambda}\right) - (c + ds) \tag{2}$$

Model solving and analysis

1. Determine the optimal performance level for a given energy-saving benefit sharing ratio

Energy-saving service companies maximize their own benefits, the first derivative of Formula (2) must satisfy the following conditions.

$$\frac{dU_c}{ds} = \frac{ep_e\varphi\left(1 - \left(1 + r_i\right)^{-t}\right)}{r_i} - \lambda bs^{\lambda - 1} - d = 0 \tag{3}$$

The optimal performance level s^* can be obtained (Formula (4)). At this time, the energy-saving enterprise's energy-saving benefit is U_e^* (Formula (5)).

$$s^* = \left(\left(ep_e \frac{1 - \left(1 + r_i\right)^{-t}}{r_i} \varphi - d\right) / (\lambda b)\right)^{\frac{1}{\lambda - 1}} \tag{4}$$

$$U_e^* = e\left(\left(ep_e \frac{1 - \left(1 + r_i\right)^{-t}}{r_i} \varphi - d\right) / (\lambda b)\right)^{\frac{1}{\lambda - 1}} p_e \frac{1 - \left(1 + r_i\right)^{-t}}{r_i} (1 - \varphi) \tag{5}$$

The relationship between s^* and other parameters can be obtained (see Fig. 2). In order to more intuitively reflect the impact of parameters on s^*, we set the benchmark energy consumption data at [0,100] by controlling a single variable. And the φ at [0,1], b at [0,1], d at [0,100].

Proposition 2.1 *The cost structure characteristics of energy-saving service companies will affect their choice of optimal performance level*

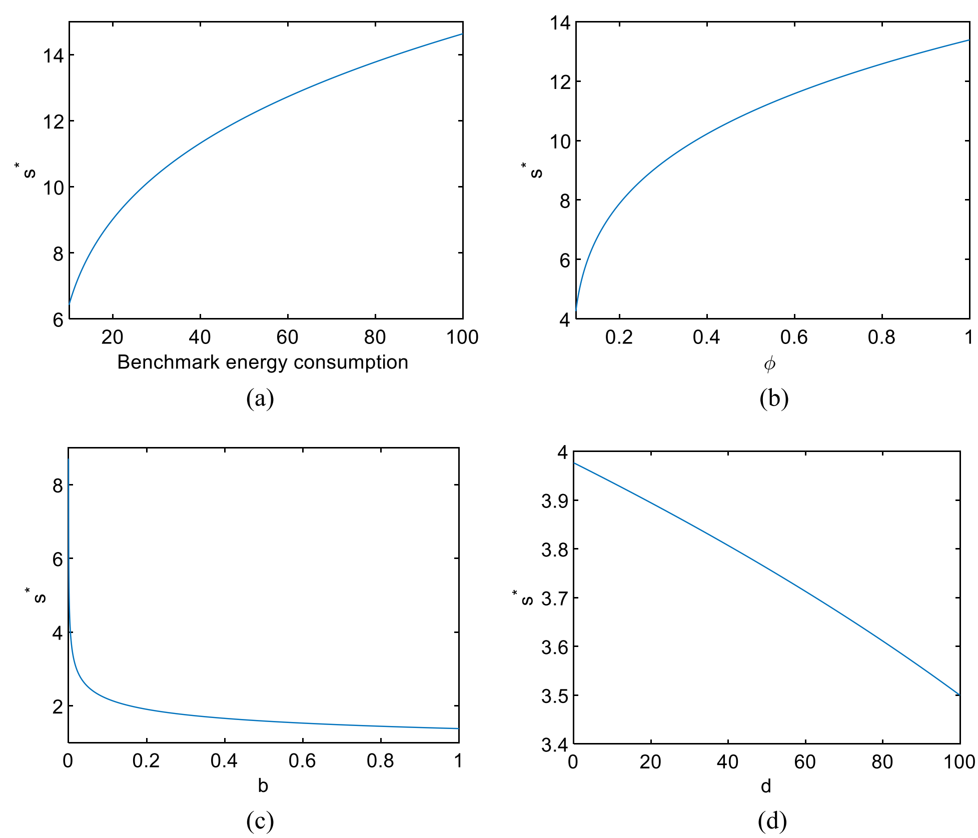

Fig. 2 Relationship between s^* and other parameters

(1) There is a positive relationship between the benchmark energy consumption of energy-saving enterprises and the energy-saving benefit sharing ratio and the performance level selected by ESCO based on the assumption of its benefit maximization.

(2) The cost structure characteristics of energy-saving service companies will affect their choice of optimal performance level; with the increase of b, d, and λ, s^* will decrease.

2. Given the optimal performance level, determine the optimal energy-saving benefit sharing ratio.

Energy-saving enterprises will determine the optimal energy-saving benefit sharing ratio to meet their own benefits according to s^*. Taking the first derivative of φ with respect to Formula (5), we get

$$\varphi^* = \frac{1}{\lambda} + \frac{dr_i(\lambda - 1)}{\lambda e p_e\left(1 - \left(1 + r_i\right)^{-t}\right)} \tag{6}$$

By analyzing Formula (6), the relationship between φ^* and other parameters can be obtained, as the simulation shown in Fig. 3. In order to more intuitively reflect the impact of parameters on the energy-saving benefit sharing ratio, we set the benchmark energy consumption data at [0,100] by controlling a single variable. And the discount rate of the project at [0,1], contract period of an energy management project at [0,100].

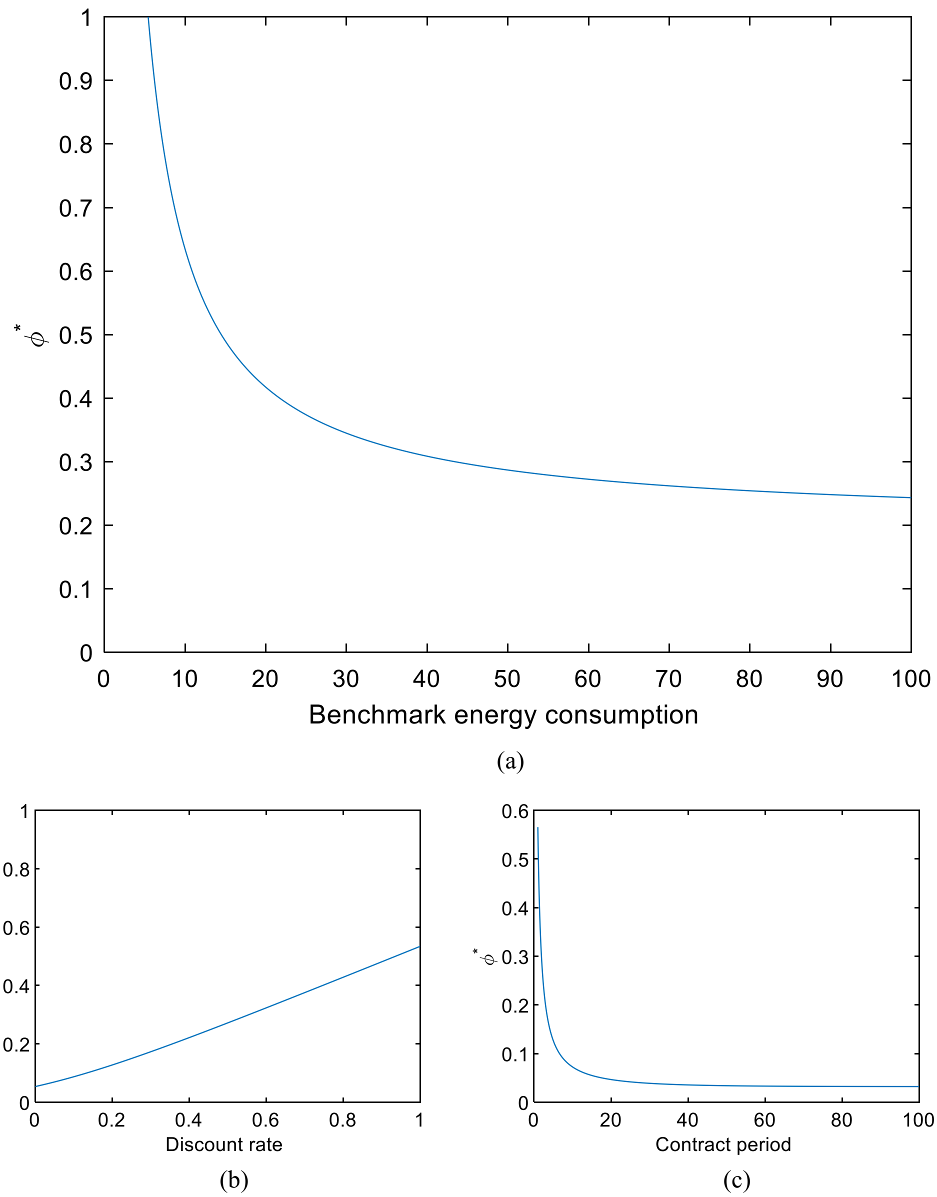

Fig. 3 Relationship between φ^* and other parameters

Proposition 2.2 *The sharing ratio of energy-saving benefits is affected by the energy management contract project.*

(1) There is also an inverse relationship between the energy-saving benefit sharing ratio selected by energy-saving enterprises and the baseline energy consumption of the energy-saving projects of the energy-saving enterprises.

(2) There is a positive relationship between the energy-saving benefit sharing ratio selected by energy-saving enterprises and the discount rate of the project; the longer the contract period of an energy management project, the higher the selected energy-saving benefit sharing ratio.

Combined with the above analysis, the Nash equilibrium solution of energy-saving service companies and energy-saving enterprises in the mode of sharing energy-saving benefits is:

$$\left\{ s^* = \left(\left(ep_e\frac{1-(1+r_i)^{-t}}{r_i}\varphi - d\right)/(\lambda b)\right)^{\frac{1}{\lambda-1}}, \varphi^* = \frac{1}{\lambda} + \frac{dr_i(\lambda-1)}{\lambda ep_e\left(1-(1+r_i)^{-t}\right)} \right\}$$

A fixed government subsidy without payment conditions

Assuming that the government provides fixed subsidy K without payment conditions for the contract, the proportion of energy-saving subsidy obtained by the energy-saving service company is β, $0 < \beta < 1$, and the proportion of government subsidy shared by the energy-saving enterprise is $1-\beta$. At this point, the benefit function of energy-saving enterprises and energy-saving service companies will be composed of two parts, energy-saving benefits and government subsidies generated by the project itself. After modification, the benefit function of both sides will become

$$U_e = esp_e\sum_{i=1}^{t}(1+r_i)^{-i}(1-\varphi) = esp_e\frac{1-(1+r_i)^{-t}}{r_i}(1-\varphi) + (1-\beta)\mathrm{K} \quad (7)$$

$$U_c = esp_e\frac{1-(1+r_i)^{-t}}{r_i}\varphi - \left(a+bs^{\lambda}\right) - (c+ds) + \beta K \quad (8)$$

1. The modified model is still a two-stage dynamic decision-making process, which adopts backward induction as the solution method in Part 2.2.

The second stage is solved first. The first derivative of formula (8) must satisfy the following conditions.

$$\frac{dU_c}{ds} = \frac{ep_e\varphi\left(1-(1+r_i)^{-t}\right)}{r_i} - \lambda bs^{\lambda-1} - d = 0 \quad (9)$$

Obtain the optimal performance level s^*.

$$s^* = \left(\left(ep_e\frac{1-(1+r_i)^{-t}}{r_i}\varphi - d\right)/(\lambda b)\right)^{\frac{1}{\lambda-1}} \quad (10)$$

2. Under the condition of s^* in the second stage, the efficiency of energy-saving enterprises is

$$U_e^* = e\left(\left(ep_e\frac{1-(1+r_i)^{-t}}{r_i}\varphi - d\right)/(\lambda b)\right)^{\frac{1}{\lambda-1}} p_e\frac{1-(1+r_i)^{-t}}{r_i}(1-\varphi) + \mathrm{K}(1-\beta) \quad (11)$$

The optimal energy-saving benefit sharing ratio φ^* is obtained.

$$\varphi^* = \frac{1}{\lambda} + \frac{dr_i(\lambda-1)}{\lambda ep_e\left(1-(1+r_i)^{-t}\right)} \quad (12)$$

In the form of fixed subsidy without payment conditions, the optimal Nash equilibrium solution of both energy-saving enterprises and energy-saving service companies is

$$\left\{ s^* = \left(\left(ep_e\frac{1-(1+r_i)^{-t}}{r_i}\varphi - d\right)/(\lambda b)\right)^{\frac{1}{\lambda-1}}, \varphi^* = \frac{1}{\lambda} + \frac{dr_i(\lambda-1)}{\lambda ep_e\left(1-(1+r_i)^{-t}\right)} \right\}$$

The Nash equilibrium solution obtained by the government adopting fixed subsidies without payment conditions is consistent with the Nash equilibrium solution in section "A dynamic decision-making model for both parties in a non-government subsidy situation," without considering the government's energy-saving subsidy policy. Therefore, the selection of the optimal performance level of ESCO and energy-saving enterprises and the determination of the energy-saving benefit sharing ratio will not be affected by the fixed government energy-saving subsidy policy. In this case, government energy-saving subsidy cannot motivate ESCO to improve their performance. However, considering that the fixed government energy-saving subsidy policy without payment conditions can increase the profits of both parties to the contract, this form of subsidy essentially belongs to after-the-fact subsidy type.

Variable government subsidies with payment terms

Variable energy-saving subsidy without preset energy-saving target

The government energy-saving subsidy will be given according to the energy-saving effect (energy saving) realized by the energy-saving service company, which is a variable subsidy with payment conditions. Without loss of generality, it is assumed that the variable energy-saving subsidy price with payment conditions provided by the government for the contract is K, the proportion of energy-saving subsidy obtained by the energy-saving service company is β, $0 < \beta < 1$, and the proportion of government subsidy shared by the energy-saving enterprise is $1 - \beta$. At this point, the benefit function of energy-saving enterprises and energy-saving service companies will be composed of two parts, energy-saving benefits generated by the project itself and government subsidies. After modification, the benefit function of both sides will become

$$U_e = esp_e \sum_{i=1}^{t} \left(1 + r_i\right)^{-i} (1 - \varphi) = esp_e \frac{1 - \left(1 + r_i\right)^{-t}}{r_i} (1 - \varphi) + (1 - \beta)esk \tag{13}$$

$$U_c = esp_e \frac{1 - \left(1 + r_i\right)^{-t}}{r_i} \varphi - \left(a + bs^{\lambda}\right) - (c + ds) + \beta esk \tag{14}$$

The modified model is still a two-stage dynamic decision-making process, which adopts backward induction as the solution method in "A dynamic decision-making model for both parties in a non-government subsidy situation" section.

1. Solve the second stage first, and the first derivative of formula (14) must meet the following conditions.

$$\frac{dU_c}{ds} = \frac{ep_e \varphi \left(1 - \left(1 + r_i\right)^{-t}\right)}{r_i} - \lambda bs^{\lambda - 1} - d + \beta ek = 0 \tag{15}$$

Obtain the optimal performance-level s^*.

$$s^* = \left(\left(ep_e \frac{1 - \left(1 + r_i\right)^{-t}}{r_i} \varphi - d + \beta ek\right) / (\lambda b)\right)^{\frac{1}{\lambda - 1}} \tag{16}$$

By analyzing Formula (16), the relationship between s^* and other parameters can be obtained, as shown in Fig. 4. In order to more intuitively reflect the impact of parameters on s^*, we set the benchmark energy consumption data at [0,100] by controlling a single variable. And φ is [0,1], the unit energy subsidy price k determined in the government subsidized energy policy is [0,1], the distribution ratio β of the two parties to the energy conservation subsidy is [0,1].

(1) There is a positive relationship between the benchmark energy consumption of an energy-saving enterprise and the selected efficiency sharing ratio and the performance level of the ESCO based on the assumption of its maximum efficiency.

(2) There is a positive relationship between the unit energy subsidy price k determined in the government subsidized energy policy and the distribution ratio β of the two parties to the energy conservation subsidy and the performance level selected by the ESCO based on the assumption of maximizing its benefits.

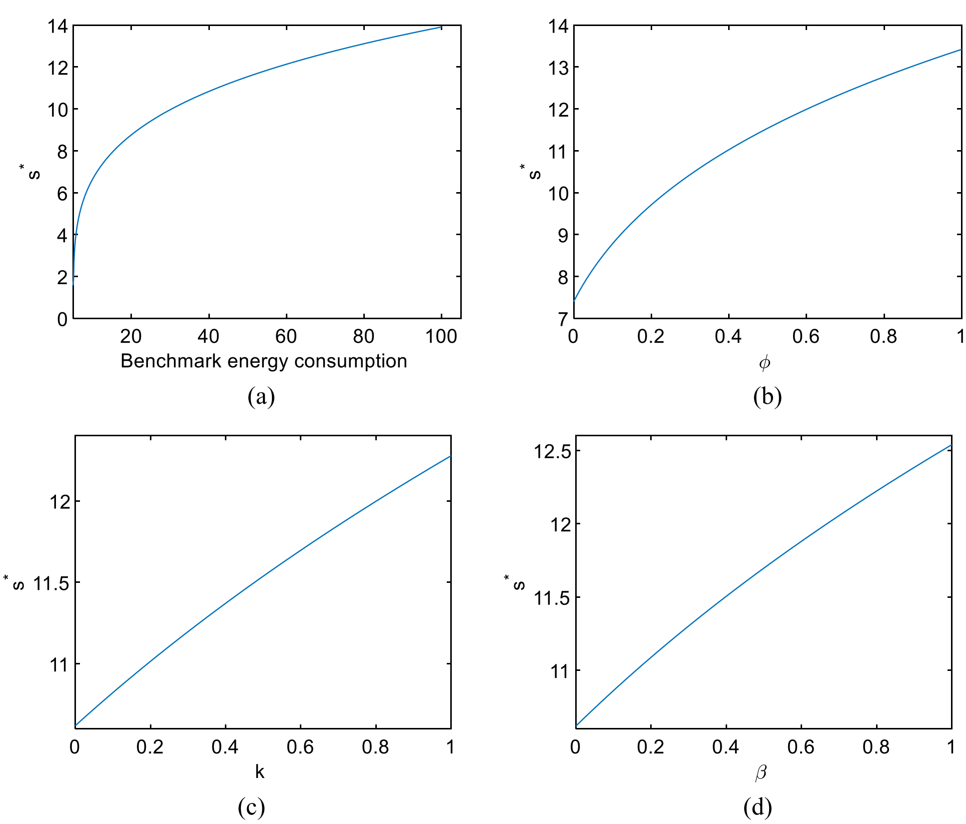

Fig. 4 Relationship between s^* and other parameters

2. Under the condition of s^* in the second stage, the benefits of energy-saving enterprises is

$$U_e^* = e\left(\frac{\left(ep_e\frac{1-(1+r_i)^{-t}}{r_i}\varphi - d + \beta ek\right)}{(\lambda b)}\right)^{\frac{1}{\lambda-1}} p_e\frac{1-\left(1+r_i\right)^{-t}}{r_i}(1-\varphi) + (1-\beta)eks \tag{17}$$

(s^*, φ^*) of both parties to a certain extent. The government aims to promote the development of energy-saving service industry and encourage energy-saving service companies to improve s^*, and it can appropriately increase energy-saving subsidy sharing ratio and change the price of energy-saving subsidy per unit. At the same time, the sharing ratio of energy-saving subsidies determined by the government is closely related to the cost structure λ of energy-saving enterprises, according to the cost structure of the government.

The optimal energy-saving benefit distribution ratio φ^* is obtained.

$$\varphi^* = \frac{1}{\lambda} + \frac{dr_d(\lambda-1)}{\lambda ep_e\left(1-\left(1+r_i\right)^{-t}\right)} + \frac{kr_i(\beta\lambda-1)}{\lambda p_e\left(1-\left(1+r_i\right)^{-t}\right)} \tag{18}$$

By analyzing Formula (18), the relationship between s^* and other parameters can be obtained, as shown in Fig. 5.

Proposition 2.3 *The government wants to promote the development of the energy conservation service industry by appropriately increasing the share of energy conservation subsidies and changing the price of energy conservation subsidies per unit.*

(1) There is a positive relationship between the energy-saving benefit sharing ratio selected by energy-saving enterprises and the discount rate of the project; the longer the contract period of the energy management project, the higher the selected energy-saving benefit sharing ratio.

(2) When $\beta > \frac{1}{\lambda}$, $(\beta\lambda-1)>0$. In this case, there is a positive relationship between the unit energy subsidy price k determined in the government subsidy energy policy and the distribution ratio β of the two parties to the energy-saving subsidy and the energy-saving benefit sharing ratio φ determined by the energy-saving enterprise in the contract. When $\beta = \frac{1}{\lambda}$, $(\beta\lambda-1)=0$. At this time, the energy-saving benefit sharing ratio φ determined by the energy-saving enterprises in the contract is consistent with the fixed government energy-saving subsidy policy without payment conditions and without considering the government energy-saving subsidy. When $\beta < \frac{1}{\lambda}$, $(\beta\lambda-1)<0$, At this time, there is a negative relationship between the unit energy subsidy price k determined in the government subsidy energy policy and the distribution ratio β of the two parties to the energy-saving subsidy and the energy-saving benefit sharing ratio φ determined by the energy-saving enterprise in the contract; the optimal energy-saving ratio in this case will be less than the one without government energy-saving subsidies.

The analysis shows that the government's implementation of the variable energy-saving subsidy policy with payment conditions will affect the optimal equilibrium solution (s^*, φ^*) of both parties to a certain extent. The government aims to promote the development of energy-saving service industry and encourage energy-saving service companies to improve s^*, and it can appropriately increase energy-saving subsidy sharing ratio and change the price of energy-saving subsidy per unit. At the same time, the sharing ratio of energy-saving subsidies determined by the government is closely related to the cost structure λ of energy-saving enterprises, according to the cost structure of the government.

Variable energy-saving subsidies with preset energy-saving targets

In order to conduct further study on the variable energy-saving subsidy policy with payment conditions, it is assumed that the government's requirement to provide energy-saving subsidies for energy-saving benefit-sharing projects is that the energy-saving service company achieves the preset energy saving $e_0\dot{s}$, e_0, $\dot{s}$ are both constants, and $\dot{s}$ is the reference value determined by the government, considering the development degree of energy-saving service industry in a certain field. In the energy management project, according to the project's baseline energy consumption e and performance level s, the actual energy saving achieved by the energy-saving service company is $e \cdot \dot{s}$. The highest energy saving that can be achieved in a certain energy-saving field is $\bar{e} \cdot \dot{s}$, meet $e \in [0, \bar{e}]$, $0 \leq e_0 \leq \bar{e}$ This shows that when the energy-saving preset by the government exceeds the best level in the industry, the energy-saving level of the energy-saving service company will not be able to achieve the preset energy-saving target. Therefore, it will not be able to obtain government energy-saving subsidies which will no longer have an incentive for ESCO. To simplify the calculation, take $\dot{s} = 1$

ESCO need to make efforts to obtain government subsidies. Based on the view that effort is a kind of cost, this paper assumes that the effort cost of ESCO to obtain government subsidies is

$$\eta + \delta\beta\left(e\dot{s} - e_0\dot{s}\right)^2 \tag{19}$$

η is the basic effort cost, $\delta > 0$. For easy calculation, assume $\eta = 0$

As can be seen from Formula (19) above, when the share ratio of government subsidy β is higher, energy-saving service

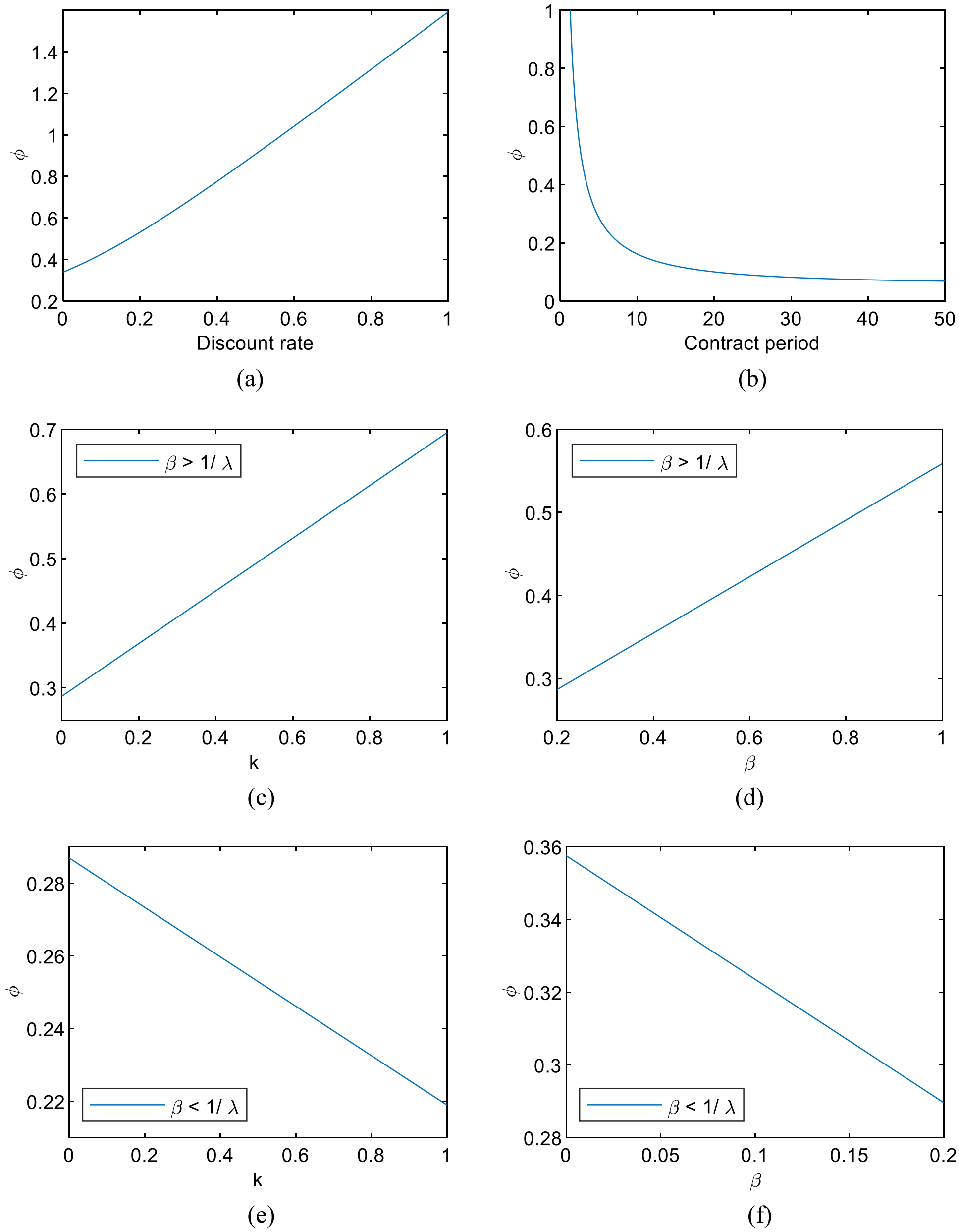

Fig. 5 Relationship between s^* and other parameters

companies are willing to make efforts to achieve excess energy-saving benefits within their capacity. When the energy-saving target $e_0\dot{s}$ set by the government is exactly equal to the energy-saving $e \cdot \dot{s}$ preset by the contract, the effort cost of the energy-saving service company is the lowest, and the energy-saving service company can obtain it without extra effort. ESCO effort cost increases with excessive energy savings $\left(e \cdot \dot{s} - e_0 \cdot \dot{s}\right)$. Equation (19) satisfies that the first derivative is greater than 0 at $e \in \left[e_0, \bar{e}\right]$; it shows that the marginal effort cost is increasing, indicating that with the realization of excess energy saving, the unit effort cost rises, and the willingness of energy-saving service companies decrease. Based on the above assumptions, the benefit function of energy-saving enterprises and energy-saving service companies becomes

$$U_e = \int_0^{e_0} \left(esp_e \frac{1-(1+r_i)^{-t}}{r_i}(1-\varphi) \right) de + \int_{e_0}^{\bar{e}} \left(esp_e \frac{1-(1+r_i)^{-t}}{r_i}(1-\varphi) + (1-\beta)esk \right) de = \frac{ks\left(e_0+\bar{e}\right)\left(e_0-\bar{e}\right)(1-\beta)}{2} + \frac{e_0{}^2 p_e s\left(1-\left(1+r_i\right)^{-t}\right)(1-\varphi)}{2r_i} \tag{20}$$

$$U_c = \int_0^{e_0} \left(esp_e \frac{1-(1+r_i)^{-t}}{r_i}\varphi - (a+bs^{\lambda}) - (c+ds) \right) de + \int_{e_0}^{\bar{e}} \left(esp_e \frac{1-(1+r_i)^{-t}}{r_i}\varphi - (a+bs^{\lambda}) - (c+ds) - \delta\beta(e-e_0)^2 + \beta esk \right) de = \delta\beta e_0^3 - \bar{e}(a+bs^{\lambda}+c+ds+\delta\beta e_0^2) + (\bar{e}^2 - e_0^2)\frac{\beta ks}{2} + \delta\beta e_0 + \bar{e}^2 sp_e\varphi\frac{1-(1+r_i)^{-t}}{2r_i} + \frac{\delta\beta}{3}(\bar{e}^3 - e_0^3) \tag{21}$$

The modified model is still a two-stage dynamic decision-making process, which adopts backward induction as the solution method in "A dynamic decision-making model for both parties in a non-government subsidy situation" section.

1. Solve the second stage first, and the first derivative of Formula (21) must meet the following conditions.

$$\frac{dU_c}{ds} = \bar{e}^2 p_e \varphi \frac{1-(1+r_i)^{-t}}{2r_i} + (\bar{e}^2 - e_0^2)\frac{\beta k}{2} - \lambda bs^{\lambda-1} \tag{22}$$

Obtain the optimal performance level s*.

$$s^* = \left(\left(\bar{e}p_e \frac{1-(1+r_i)^{-t}}{2r_i}\varphi - d + \frac{(\bar{e}^2 - e_0^2)\beta k}{2\bar{e}} \right) / (\lambda b) \right)^{\frac{1}{\lambda-1}} \tag{23}$$

By analyzing Formula (23), the relationship between s^* and other parameters can be obtained, as shown in simulation Fig. 6. In order to more intuitively reflect the impact of parameters on s^*, we set the energy-saving service targets preset by the government data at [0,100] by controlling a single variable.

2. Under the condition of s^* in the second stage, the efficiency of energy-saving enterprises is

$$U_e^* = \frac{k(\bar{e}^2 - e_0^2)(1-\beta)\sigma_1}{2} + \frac{e_0^2 p_e \sigma_3(\varphi - 1)\sigma_1}{r_i} + \frac{p_e\sigma_1\left(1-(1+r_i)^{-t}\right)(\bar{e}^2 - e_0^2)(\varphi - 1)}{2r_i(1+r_i)^t} \tag{24}$$

$$\sigma_1 = -\left(\frac{d + \frac{(e_0^2 - \bar{e}^2)\sigma_2 + \frac{e_0^2 p_e\varphi\sigma_3}{2r_i}}{h}}{\lambda b} \right)^{\frac{1}{\lambda-1}}; \sigma_2 = \frac{\beta k}{2} - \frac{p_e\varphi\sigma_3}{2r_i}; \sigma_3 = (1+\varphi)^{-t} - 1$$

The optimal energy-saving benefit distribution ratio φ^* is obtained.

$$\varphi^* = \frac{1}{\lambda} + \frac{kr_d(\bar{e}^2 - e_0^2)}{\lambda\bar{e}^2 p_e\left(1-(1+r_i)^{-t}\right)} + \frac{2dr_i(\lambda - 1)}{\lambda\bar{e}p_e\left(1-(1+r_i)^{-t}\right)} + \frac{\beta kr_i(\bar{e}^2 - e_0^2)}{\bar{e}^2 p_e\left(1-(1+r_i)^{-t}\right)} \tag{25}$$

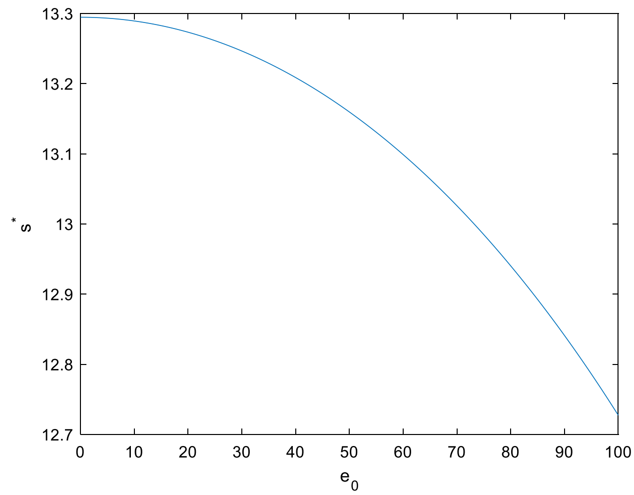

Fig. 6 Relationship between s^* and other parameters

By analyzing Formula (25), the relationship between s^* and other parameters can be obtained, as shown in Fig. 7. In order to more intuitively reflect the impact of parameters on the energy-saving benefit sharing ratio φ, we set the energy-saving service targets preset by the government data at [0,100] by controlling a single variable.

The conclusion is consistent with that of government subsidy without preset energy saving. By analyzing Formula (23) and Formula (25), the following conclusions are also obtained.

(1) There is a negative relationship between the performance level selected by the energy saving and energy-saving service companies preset by the government, based on the assumption of maximizing their benefits.

(2) There is a reverse relationship between the energy-saving benefit sharing ratio φ selected by energy-saving enterprises and the energy-saving ratio e_0 preset by the government.

(3) In particular, when $e_0 = \bar{e}$, the performance level $s^* = \left(\left(\bar{e}p_e \frac{1-(1+r_i)^{-t}}{2r_i}\varphi - d \right) / (\lambda b) \right)^{\frac{1}{\lambda-1}}$ determined by the energy-saving service company has nothing to do with the government subsidy

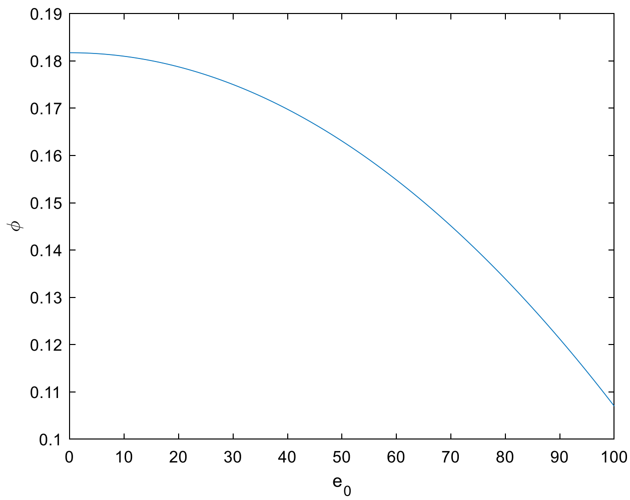

Fig. 7 Relationship between s^* and other parameters

policy parameters k and β. This shows that government subsidies have no incentive effect on energy-saving service companies, which is consistent with the hypothesis. In this case, in the field ($\bar{e}$) with high overall energy-saving level, energy-saving service companies will choose a higher service performance level. The energy-saving benefit sharing ratio chosen by energy-saving enterprises is $\varphi^* = \frac{1}{\lambda} + \frac{2dr_i(\lambda-1)}{\lambda \bar{e} p_e \left(1-(1+r_i)^{-t}\right)}$, indicating that in industries with a higher overall energy-saving level, energy-saving companies tend to reduce the proportion of energy-saving service companies obtaining energy-saving benefits.

Comparative analysis of results

Optimal performance level selection for energy conservation service companies

Summarize the optimal Nash equilibrium solution s^* obtained from the above four government energy-saving subsidy policies, as shown in Table 2.

Comparative analysis of fixed and variable forms of government subsidies

Proposition 3.1 *The energy-saving subsidy policy with payment conditions selected by the government will be better than the energy-saving subsidy policy without payment conditions.*

It can be seen from Table 2 that the optimal performance level determined by the energy-saving service company is the same without considering the government subsidy and the government adopting the fixed government energy-saving subsidy without payment conditions. When the government adopts variable energy-saving subsidies with payment conditions, higher energy-saving benefit sharing ratio of energy-saving enterprises will make energy-saving service companies tend to choose higher performance levels.

Table 2 Determination of optimal performance level of energy conservation service companies under four conditions

	s^*
Not considering government subsidies	$s^* = \left(\left(ep_e \frac{1-(1+r_i)^{-t}}{r_i}\varphi - d\right)/(\lambda b)\right)^{\frac{1}{\lambda-1}}$
Fixed energy-saving subsidies without payment conditions	$s^* = \left(\left(ep_e \frac{1-(1+r_i)^{-t}}{r_i}\varphi - d\right)/(\lambda b)\right)^{\frac{1}{\lambda-1}}$
Variable energy-saving subsidy without preset energy-saving target	$s^* = \left(\left(ep_e \frac{1-(1+r_i)^{-t}}{r_i}\varphi - d + \beta ek\right)/(\lambda b)\right)^{\frac{1}{\lambda-1}}$
Energy-saving subsidy for changes in the government's preset energy-saving target	When $e_0 \neq \bar{e}$, $s^* = \left(\left(\bar{e}p_e \frac{1-(1+r_i)^{-t}}{2r_i}\varphi - d + \frac{(\bar{e}^2-e_0{}^2)\beta k}{2\bar{e}}\right)/(\lambda b)\right)^{\frac{1}{\lambda-1}}$ When $e_0 = \bar{e}$, $s^* = \left(\left(\bar{e}p_e \frac{1-(1+r_i)^{-t}}{2r_i}\varphi - d\right)/(\lambda b)\right)^{\frac{1}{\lambda-1}}$

Comparative analysis of two different forms of variable government energy-saving subsidies

Proposition 3.2 *The performance of energy-saving service companies in completing energy-saving projects will be affected by the government's preset energy-saving target policies and the energy-saving level of energy-saving service companies in the industry.*

When $e < \frac{\bar{e}}{2} - \frac{\beta k}{\beta k + \frac{\varphi p_e\left(1-(1+r_i)^{-t}\right)}{r_i}} \cdot \frac{e_0^2}{2\bar{e}} < \frac{\bar{e}}{2}$, for energy-saving service companies with low energy-saving level, the incentive effect of variable energy-saving subsidy policy preset by the government will be better than that of variable energy-saving subsidy policy without preset energy-saving goal, and when the energy-saving target set by the government is closer to the best level of the industry, the incentive effect will be smaller. When $e > \frac{\bar{e}}{2} - \frac{\beta k}{\beta k + \varphi p_e\left(1-(1+r_i)^{-t}\right)/r_i} \cdot \frac{e_0^2}{2\bar{e}}$, for energy-saving service companies whose energy-saving level is at the top level of the industry or within a certain range of the industry average, the incentive effect of variable energy-saving subsidy policy without preset energy-saving goals will be better than that of variable energy-saving subsidy policy with preset energy-saving goals. Under the energy-saving subsidy policy preset by the government, the level interval of the energy-saving service companies under the incentive effect decreases with the increase of β , k , and e_0, indicating that the government blindly improves the energy-saving target, and the fewer the energy-saving service companies under the incentive effect, the worse the implementation effect of the energy-saving subsidy policy. Under special circumstances, that is, when $e_0 = \bar{e}$, the energy-saving goal preset by the government reaches the highest level in the industry. For energy-saving service companies, their energy-saving level cannot meet the highest requirements of the industry; thus, the policies no longer have an incentive effect. The government's preset energy-saving target e_0 is public information, and energy-saving service companies will obtain relevant information in advance. The optimal performance level selected by the energy-saving service company will be lower than that without the preset benchmark energy-saving target. Therefore, when $e > \frac{\bar{e}}{2}$, the energy-saving level of the energy-saving service company will above the industry average. At this point, when the government sets the energy-saving target, the government's energy-saving subsidy will have a negative impact on the energy-saving service company. When $e = \frac{\bar{e}}{2}$, the energy-saving level of the energy-saving service company is in the industry average. At this point, whether the government presets the benchmark energy-saving target or not has nothing to do with the performance level of the energy-saving service company. When $0 < e < \frac{\bar{e}}{2}$, the energy-saving level of energy-saving service companies is lower than the industry average level. At this time, the government energy-saving subsidy policy will have a positive impact on energy-saving service companies, and the optimal performance level selected by energy-saving service companies will be higher than the one without preset energy-saving goals.

Table 3 The optimal proportion of energy-saving benefit sharing determined by energy-saving enterprises under the four conditions

	φ
Not considering government subsidies	$\varphi^* = \frac{1}{\lambda} + \frac{dr_i(\lambda-1)}{\lambda e p_e\left(1-(1+r_i)^{-t}\right)}$
Fixed energy-saving subsidies without payment conditions	$\varphi^* = \frac{1}{\lambda} + \frac{dr_i(\lambda-1)}{\lambda e p_e\left(1-(1+r_i)^{-t}\right)}$
Variable energy-saving subsidy without preset energy-saving target	$\varphi^* = \frac{1}{\lambda} + \frac{dr_i(\lambda-1)}{\lambda e p_e\left(1-(1+r_i)^{-t}\right)} + \frac{kr_i(\beta\lambda-1)}{\lambda p_e\left(1-(1+r_i)^{-t}\right)}$
Energy-saving subsidy for changes in the government's preset energy-saving target	When $e_0 \neq \bar{e}$, $\varphi^* = \frac{1}{\lambda} + \frac{kr_i\left(\bar{e}^2-e_0^2\right)}{\lambda\bar{e}^2 p_e\left(1-(1+r_i)^{-t}\right)} + \frac{2dr_i(\lambda-1)}{\lambda\bar{e}p_e\left(1-(1+r_i)^{-t}\right)} + \frac{\beta kr_i\left(\bar{e}^2-e_0^2\right)}{\bar{e}^2 p_e\left(1-(1+r_i)^{-t}\right)}$ When $e_0 = \bar{e}$, $\varphi^* = \frac{1}{\lambda} + \frac{2dr_i(\lambda-1)}{\lambda\bar{e}p_e\left(1-(1+r_i)^{-t}\right)}$

The optimal proportion of energy-saving benefit sharing of energy-saving enterprises

According to Table 2, it can be found that the energy-saving benefit sharing ratio agreed in the contract between energy-saving enterprises and energy-saving service companies will encourage energy-saving service companies to improve their performance and achieve higher energy savings to some extent. This section will make a comparative analysis of the energy-saving efficiency ratio determined by the energy-saving enterprises under the four governments' energy-saving policies φ as shown in Table 3.

Fixed and changed forms of government subsidies

Proposition 3.3 *Under different circumstances, the government's determination of the subsidy sharing ratio and the unit subsidy price will affect the energy-saving benefit sharing ratio, and when* $(\beta\lambda - 1) > 0$, *it can also make up for the loss of the energy-saving enterprises' own interests caused by increasing the energy-saving benefit sharing ratio.*

According to Table 3, the optimal energy-saving benefit sharing ratio determined by energy-saving enterprises is equal without considering the government subsidy and the government's fixed energy-saving subsidy without payment conditions. When the government adopts variable energy-saving subsidies with payment conditions, it will be affected by the cost structure of energy-saving service companies λ and the energy-saving subsidy policy parameters β and k, which will affect the action of the energy-saving enterprises to choose the energy-saving benefit sharing ratio.

Comparative analysis of two different forms of variable government energy-saving subsidies

Proposition 3.4 *In view of how to improve the incentive effect of the government on energy-saving service companies when implementing the variable energy-saving subsidy policy with preset energy-saving targets, it is found that the energy-saving subsidy policy no longer has incentive effect when the preset energy-saving target of the government exceeds the highest standard of the energy-saving industry.*

When $e_0 \neq \bar{e}$, the government implemented the energy-saving subsidy policy with preset energy-saving goals, which has an incentive effect on energy-saving service companies. In this case, if $e_0 < \sqrt{\frac{2}{\beta\lambda+1}} \cdot \bar{e} < \bar{e}$ is satisfied $\beta\lambda > 1$ or $e_0 < \bar{e}$ is satisfied $\beta\lambda < 1$, for energy-saving service companies whose energy-saving level is in the range of $\left[\frac{\bar{e}d(\lambda-1)}{2d(\lambda-1)+k\bar{e}\left(2-\frac{{e_0}^2(\beta\lambda+1)}{\bar{e}^2}\right)}, \frac{\bar{e}}{2}\right]$, they will choose a higher share of energy-saving benefits when the government has set a subsidy policy for energy-saving goals, that is, for energy-saving service companies whose energy-saving level is lower than the industry average, when the government adopts variable energy-saving subsidies with payment conditions, the incentive effect of government subsidies with preset energy-saving goals is better than that without preset energy-saving goals, which can promote them to choose a higher performance level. In this case, the government can increase the variable energy-saving subsidy price k with payment conditions to protect the interests of energy-saving enterprises. When $\sqrt{\frac{2}{\beta\lambda+1}} \cdot \bar{e} < e_0 < \bar{e}$ is satisfied $\beta\lambda > 1$, at this time, for the energy-saving service companies whose energy-saving level is in the range $\left[\frac{\bar{e}}{2}, \frac{\bar{e}d(\lambda-1)}{2d(\lambda-1)+k\bar{e}\left(2-\frac{{e_0}^2(\beta\lambda+1)}{\bar{e}^2}\right)}\right]$, the energy-saving enterprises will choose a higher share proportion if the government does not have the subsidy policy of preset energy-saving goals, that is, for the energy-saving service companies above the industry average energy-saving level, when the variable energy-saving subsidies with payment conditions are adopted, the incentive effect of the subsidy form without preset energy-saving goals by the government is better than the subsidy form with preset energy-saving goals.

When $e_0 = \bar{e}$, the government's energy-saving subsidy policy has no incentive effect on energy-saving service companies. To improve the performance of energy-saving service companies, it is necessary to rely on the energy-saving benefit sharing ratio selected by energy-saving enterprises. In this case, the optimal energy-saving benefit sharing ratio selected by energy-saving enterprises is a constant, which is only affected by the overall energy-saving level of the industry. When $e > \frac{\bar{e}}{2}$, the share ratio of contracted energy-saving benefits without considering the government energy-saving subsidies will be lower than that when the government implements the preset energy-saving target energy-saving subsidy policy. When $e = \frac{\bar{e}}{2}$, the sharing proportion of energy-saving benefits under the contract without considering the government subsidy is equal to that when considering the government's implementation of the preset energy-saving target energy-saving subsidy policy. When $0 < e < \frac{\bar{e}}{2}$, the share proportion of energy-saving benefits under the contract without considering the government subsidy will be higher than that when considering the government's implementation of the preset energy-saving target energy-saving subsidy policy. When the government's energy-saving subsidy policy has no incentive effect, it completely depends on the energy-saving benefit sharing ratio φ of energy-saving enterprises to encourage energy-saving service companies. For energy-saving service companies below the industry average level, energy-saving enterprises are unwilling to increase the energy-saving benefit sharing ratio φ to encourage energy-saving service companies. On the contrary, for energy-saving service companies with high energy-saving level, energy-saving enterprises are willing to increase the sharing proportion of energy-saving benefits φ encourage energy-saving service companies. It further shows that the government blindly sets higher energy-saving targets and implements the variable energy-saving subsidy policy without incentive effect, which is more unfavorable to the energy-saving service companies with lower energy-saving level.

Example analysis

In order to better understand the influence of other parameters of contract energy management project on the equilibrium solution, taking the energy-saving renovation project on energy management of city street lamp of Hengyang as an example, the parameters are assigned. The local electricity standard fluctuates between 0.2 yuan/kWh and 0.7 yuan/kWh. The 1-year loan interest of local banks is about 6.3%.

Now assign the following values to the parameters. (1) The cost parameters: $a = 6$, $b = 0.0005$, $\lambda = 5$, $c = 4$, $d = 8$. (2) Project parameters: $s \in [1,100]$, $\bar{e} = 40$, $e \in [1,40]$, $t = 10$, $r_i = 0.06$, $p_e = 1/3$.

Impact analysis of project benchmark energy consumption

For simple calculation, the project benchmark energy consumption e is taken as the relative value of the project compared with the industry's highest energy consumption benchmark (benchmark energy consumption of the project / the highest benchmark energy consumption in the industry ×100).The lower the benchmark energy consumption of the project, the higher the opposite. The results are shown in Table 4.

Proposition 4.1 *Based on the high return of the project, energy-saving service companies will choose the higher performance level proposed by energy-saving enterprises to maximize the energy-saving benefits.*

Table 4 shows that users with low benchmark energy consumption will choose higher energy-saving benefit sharing ratio of energy-saving service companies to attract investment from high-level energy-saving service companies in the industry, while energy-saving enterprises with high benchmark energy consumption of the project will consider the overall energy-saving level of the industry and propose a lower energy-saving benefit sharing ratio for a few energy-saving service companies.

Analysis of the impact of government subsidies on unit energy prices

In order to better distinguish the influence of government unit subsidy energy price on high/low energy-saving enterprises, $e = 24$ (15) represents high/(low) energy-saving enterprises. Parameters of government subsidies, $k \in [0.3,0.6]$, $\beta = 0.7$, $e_0 = 20$; the results are shown in Table 5.

Proposition 4.2 *With the preset benchmark energy consumption unchanged, the effect of the government's variable*

Table 4 Analysis of the influence of the variation of the project benchmark energy consumption

		Fixed subsidy without payment conditions	Variable subsidies without preset energy-saving goals	Variable subsidies with preset energy-saving goals
φ^*	$e = 5$	0.722	0.820	0.440
	$e = 10$	0.461	0.559	0.440
	$e = 15$	0.374	0.472	0.440
	$e = 20$	0.330	0.428	0.440
	$e = 25$	0.304	0.402	0.440
	$e = 30$	0.287	0.385	0.440
	$e = 35$	0.275	0.372	0.440
s^*	$e = 5$	4.298	6.140	9.226
	$e = 10$	6.031	7.681	9.226
	$e = 15$	6.928	8.629	9.226
	$e = 20$	7.571	9.339	9.226
	$e = 25$	8.082	9.916	9.226
	$e = 30$	8.511	10.407	9.226
	$e = 35$	8.884	10.836	9.226

Table 5 Analysis of the influence brought by the change of unit energy-saving price of government subsidy

		Fixed subsidy without payment conditions	Variable subsidies without preset energy-saving goals	Variable subsidies with preset energy-saving goals
φ^*	$k = 0.30$	0.308 (0.374)	0.369 (0.435)	0.413
	$k = 0.35$	0.308 (0.374)	0.380 (0.416)	0.427
	$k = 0.40$	0.308 (0.374)	0.390 (0.466)	0.440
	$k = 0.45$	0.308 (0.374)	0.400 (0.466)	0.454
	$k = 0.50$	0.308 (0.374)	0.409 (0.475)	0.468
	$k = 0.55$	0.308 (0.374)	0.419 (0.486)	0.482
	$k = 0.60$	0.308 (0.374)	0.430 (0.497)	0.496
s^*	$k = 0.30$	7.987 (6.928)	9.314 (8.174)	8.861
	$k = 0.35$	7.987 (6.928)	9.488 (8.334)	9.029
	$k = 0.40$	7.987 (6.928)	9.651 (8.486)	9.188
	$k = 0.45$	7.987 (6.928)	9.808 (8.628)	9.339
	$k = 0.50$	7.987 (6.928)	9.957 (8.766)	9.483
	$k = 0.55$	7.987 (6.928)	10.100 (8.896)	9.620
	$k = 0.60$	7.987 (6.928)	10.237 (9.022)	9.752

energy-saving subsidy with payment conditions is better than that of the fixed subsidy.

It can be seen from Table 5 that with the rise of government subsidized energy prices, the energy-saving benefit sharing ratio selected by energy-saving enterprises and the performance level of energy-saving service companies will increase. Increasing the subsidy price of government units can narrow the gap between the variable energy-saving subsidy with government preset energy saving and the variable energy-saving subsidy without preset energy-saving. The difference in the proportion of energy-saving income sharing obtained by energy-saving service companies in projects is more obvious in energy-saving enterprises that are lower than the industry average.

Analysis on the impact of government subsidy allocation ratio

Assign values to the parameters of government subsidy, $k = 0.3$, $\beta \in [0.1, 0.7]$, $e_0 = 20$. The results are shown in Table 6.

Proposition 4.3 *The government's energy-saving subsidy policy may not have a positive impact on the cost structure of energy-saving enterprises*

Table 6 Analysis of the influence brought by the change of proportion of government subsidy allocation

		Fixed subsidy without payment conditions	Variable subsidies without preset energy-saving goals	Variable subsidies with preset energy-saving goals
φ^*	$\beta = 0.1$	0.308	0.296	0.357
	$\beta = 0.2$	0.308	0.317	0.367
	$\beta = 0.3$	0.308	0.321	0.376
	$\beta = 0.4$	0.308	0.333	0.385
	$\beta = 0.5$	0.308	0.345	0.395
	$\beta = 0.6$	0.308	0.357	0.403
	$\beta = 0.7$	0.308	0.369	0.413
s^*	$\beta = 0.1$	7.987	7.992	7.955
	$\beta = 0.2$	7.987	8.256	8.128
	$\beta = 0.3$	7.987	8.501	8.291
	$\beta = 0.4$	7.987	8.726	8.445
	$\beta = 0.5$	7.987	8.953	8.590
	$\beta = 0.6$	7.987	9.131	8.729
	$\beta = 0.7$	7.987	9.314	8.861

Table 7 Analysis of the influence brought by the change of government preset energy-saving target

		Fixed subsidy without payment conditions	Variable subsidies without preset energy-saving goals	Variable subsidies with preset energy-saving goals
φ^*	$\beta = 0.1$	0.374 (0.526)	0.435 (0.587)	0.425
	$\beta = 0.2$	0.374 (0.526)	0.435 (0.587)	0.413
	$\beta = 0.3$	0.374 (0.526)	0.435 (0.587)	0.397
	$\beta = 0.4$	0.374 (0.526)	0.435 (0.587)	0.379
	$\beta = 0.5$	0.374 (0.526)	0.435 (0.587)	0.356
	$\beta = 0.6$	0.374 (0.526)	0.435 (0.587)	0.330
	$\beta = 0.7$	0.374 (0.526)	0.435 (0.587)	0.301
s^*	$\beta = 0.1$	6.928 (5.522)	8.174 (6.755)	9.008
	$\beta = 0.2$	6.928 (5.522)	8.174 (6.755)	8.861
	$\beta = 0.3$	6.928 (5.522)	8.174 (6.755)	8.660
	$\beta = 0.4$	6.928 (5.522)	8.174 (6.755)	8.394
	$\beta = 0.5$	6.928 (5.522)	8.174 (6.755)	8.043
	$\beta = 0.6$	6.928 (5.522)	8.174 (6.755)	7.570
	$\beta = 0.7$	6.928 (5.522)	8.174 (6.755)	6.899

It can be seen from Table 6 that with the increase of the share proportion of government subsidies, the share proportion of energy-saving benefits determined by energy-saving enterprises in the contract and the performance level selected by energy-saving service companies will rise. In particular, when $\beta < \frac{1}{\lambda}$, the government's implementation of the variable subsidy policy will reduce the share of energy-saving benefits obtained by energy-saving service companies.

Analysis of the impact of the government's preset energy-saving target

The energy-saving level of energy-saving service companies is below the industry average

In order to better distinguish the influence of the government's energy-saving targets on energy-saving service companies with different energy-saving levels, $e = 15$ (8) is

Table 8 Analysis of the influence brought by the change of government preset energy-saving target

		Fixed subsidy without payment conditions	Variable subsidies without preset energy-saving goals	Variable subsidies with preset energy-saving goals
φ^*	$e_0 = 15$	0.309 (0.287)	0.369 (0.348)	0.425
	$e_0 = 20$	0.309 (0.287)	0.369 (0.348)	0.413
	$e_0 = 25$	0.309 (0.287)	0.369 (0.348)	0.397
	$e_0 = 30$	0.309 (0.287)	0.369 (0.348)	0.379
	$e_0 = 35$	0.309 (0.287)	0.369 (0.348)	0.356
	$e_0 = 40$	0.309 (0.287)	0.369 (0.348)	0.343
	$e_0 = 45$	0.309 (0.287)	0.369 (0.348)	0.325
s^*	$e_0 = 15$	7.987 (8.511)	9.314 (9.890)	9.008
	$e_0 = 20$	7.987 (8.511)	9.314 (9.890)	8.861
	$e_0 = 25$	7.987 (8.511)	9.314 (9.890)	8.660
	$e_0 = 30$	7.987 (8.511)	9.314 (9.890)	8.394
	$e_0 = 35$	7.987 (8.511)	9.314 (9.890)	8.043
	$e_0 = 40$	7.987 (8.511)	9.314 (9.890)	7.570
	$e_0 = 45$	7.987 (8.511)	9.314 (9.890)	6.899

taken to represent two different energy-saving service companies with lower energy-saving levels. Assign a value to the government subsidy parameter, $k = 0.3$, $\beta = 0.7$, $e_0 \in [15,45]$. The results are shown in Table 7.

Energy-saving service company's energy-saving level is above the industry average

In order to better distinguish the influence of the government's energy-saving targets on energy-saving service companies with different energy-saving levels, $e = 24$ (30) is taken to represent two different energy-saving service companies with higher energy-saving levels. Assign a value to the government subsidy parameter, $k = 0.3$, $\beta = 0.7$, $e_0 \in [15,45]$. The results are shown in Table 8.

Proposition 4.4 *The subsidy form with preset energy-saving goals will be more conducive to promoting energy-saving service companies with low energy-saving levels to choose higher performance levels and achieve higher energy-saving goals. But the government cannot blindly set higher energy-saving goals. When the government's preset energy-saving goal exceeds the industry's maximum energy saving, the government subsidy policy will play a negative role.*

It can be seen from Tables 7 and 8 that for energy-saving service companies whose energy-saving level is below the industry average, the government's implementation of energy-saving subsidy policy can effectively encourage energy-saving service companies to choose a higher performance level, and provide them with a higher share of energy-saving benefits. The lower the benchmark energy consumption of energy-saving enterprises, the subsidy form with preset energy-saving goals will further promote energy-saving service companies to choose a higher performance level specifically; the difference between the performance levels of the two forms of variable energy-saving subsidies with payment conditions is greater. At the same time, the difference in performance level between the two forms of subsidies will be more obvious for energy-saving enterprises above the industry average than for energy-saving enterprises below the industry average. For energy-saving service companies, although they choose a higher performance level, the proportion of energy-saving benefits shared by them will probably be lower than that without preset energy savings, or even the one without government subsidies.

Analysis on the impact of cost structure changes of energy-saving service companies

According to "Comparative analysis of results" section, the cost structure of energy-saving service companies will affect the equilibrium solution. Therefore, the following assumptions are made for analysis of the impact of an energy-saving service company's cost structure change. $\lambda \in [3.25,4.75]$, $e = 24$. Government subsidy parameters: $k = 0.3$, $\beta = 0.7$, $e_0 = 20$, $K = 90$. The results are shown in Table 9.

It can be seen from Table 9 that with the increase of λ, the optimal energy-saving benefit sharing proportion selected by energy-saving enterprises will become lower and lower, and the performance level, total cost, and energy-saving income selected by energy-saving service companies will also decrease. At the same time, if the cost corresponds to a higher performance level, energy-saving service companies will prefer to choose a lower performance level, and energy-saving enterprises will also choose a lower share ratio.

Table 9 Analysis on the impact of cost structure change of energy-saving service company

		Fixed subsidy without payment conditions	Variable subsidies without preset energy-saving goals	Variable subsidies with preset energy-saving goals
φ^*	$\lambda = 3.25$	0.402	0.450	0.513
	$\lambda = 3.50$	0.383	0.433	0.493
	$\lambda = 3.75$	0.366	0.419	0.475
	$\lambda = 4.00$	0.351	0.407	0.460
	$\lambda = 4.25$	0.340	0.396	0.446
	$\lambda = 4.50$	0.328	0.386	0.434
	$\lambda = 4.75$	0.318	0.378	0.423
s^*	$\lambda = 3.25$	58.963	69.656	66.210
	$\lambda = 3.50$	36.964	44.067	41.417
	$\lambda = 3.75$	25.320	30.048	28.314
	$\lambda = 4.00$	18.528	21.898	20.681
	$\lambda = 4.25$	14.259	16.789	15.890
	$\lambda = 4.50$	11.415	13.394	12.700
	$\lambda = 4.75$	9.429	11.028	10.475

Conclusions

In terms of research scope, this paper mainly focuses on encouraging energy-saving service companies to choose a higher performance level, and focuses on the analysis and research content on the form level of the government's energy-saving subsidy policy, with the intention of analyzing the reasons why the current energy-saving subsidy policy can not motivate energy-saving service companies well. Based on the construction of a two-stage dynamic game model that only considers government subsidy policies, and then conducts research and analysis to reach the following conclusions, other government policies such as tax policies, regulatory policies, and other incentive policies are not considered, so the research has certain limitations. In order to enhance the credibility of our research, our future work direction is to conduct in-depth research on the incentive effects of new forms of subsidies in China's current energy conservation industry, in combination with government regulatory policies for energy conservation service companies and to provide theoretical and methodological support for improving China's energy-saving subsidy incentive policies for energy-saving service companies, so as to facilitate the rational use of government subsidy resources and government regulatory resources by the government, compensate for the externalities of the energy-saving market, and more likely exert the incentive effects of subsidy policies and regulatory policies.

By constructing a two-stage dynamic decision-making model, this paper analyzes and discusses the incentive effect of government subsidies and different forms of government energy-saving subsidies on energy-saving service companies (fixed subsidies and variable subsidies). The conclusion of the model analysis is further tested by using the example analysis, which provides an empirical explanation. Some main points and conclusions are refined through the verification of theory and practice. The main points and conclusions of this paper are as follows.

(1) The optimal Nash equilibrium solution of the dynamic game model between energy-saving enterprises and energy-saving service companies (s^*, φ^*) is determined by the cost structure and project characteristics of energy-saving service companies. There is a positive relationship between the selection of performance level of energy-saving service companies and the proportion of energy-saving benefit sharing selected by energy-saving enterprises.

(2) The single market-oriented mechanism of the energy-saving market has not worked. Although the government energy-saving subsidy can theoretically make up for the "externality" of the energy-saving market, the current subsidy policy still cannot well motivate energy-saving service companies, mainly because the policy only presets different energy-saving targets in industrial and none industrial fields to show differences, but on the other hand, it is without specific implementation rules. By comparing and analyzing the fixed energy-saving subsidy policy without payment conditions and the variable energy-saving subsidy policy with payment conditions, this paper finds that direct fixed subsidy policy does not have an incentive effect, while indirect variable subsidy policy (variable energy-saving subsidy price with payment conditions, government subsidy distribution ratio) will affect the choice of performance level of energy-saving service companies; theoretically, it shows the rationality of our government to implement the variable energy-saving subsidy policy with payment conditions based on the actual energy savings.

(3) In view of how to improve the incentive effect for energy-saving service companies when the government implements the variable energy-saving subsidy policy with preset energy-saving targets, it is found that when the government's preset energy-saving targets exceed the highest standards of the energy-saving industry, the energy-saving subsidy policy no longer has an incentive effect. By analyzing and studying whether the government has preset energy-saving goals under the variable energy-saving subsidy policy with payment conditions, we can see that the government adopts different forms of energy-saving subsidies for different energy-saving levels of energy-saving service companies. For energy-saving service companies with energy-saving service level in the range of $\left[\frac{\bar{e}d(\lambda-1)}{2d(\lambda-1)+k\bar{e}\left(2-\frac{{e_0}^2(\beta\lambda+1)}{\bar{e}^2}\right)}, \frac{\bar{e}}{2}\right]$, the incentive effect of the government's energy-saving subsidy policy with preset energy-saving goals is better than that without preset energy-saving goals. Moreover, the government's preset energy-saving target should meet $e_0 < \sqrt{\frac{2}{\beta\lambda+1}} \cdot \bar{e} < \bar{e}$. In this case, energy-saving enterprises will also increase the energy-saving benefit sharing ratio agreed in the contract to encourage energy-saving service companies. The government can increase the variable energy-saving subsidy price with payment conditions k to make up for the loss of their own benefits caused by the increase of the energy-saving benefit sharing ratio φ. For energy-saving service companies in the range of $\left[\frac{\bar{e}}{2}, \frac{\bar{e}d(\lambda-1)}{2d(\lambda-1)+k\bar{e}\left(2-\frac{{e_0}^2(\beta\lambda+1)}{\bar{e}^2}\right)}\right]$, the incentive effect of the government's energy-saving subsidy policy without preset energy-saving goals is better than that with preset energy-saving goals. Moreover, the government's preset energy-saving target should meet $\sqrt{\frac{2}{\beta\lambda+1}} \cdot \bar{e} < e_0 < \bar{e}$. The government should not blindly set energy-saving targets too high. When the government's energy-saving subsidy policy has no incentive effect, it completely depends on the energy-saving benefit sharing of energy-saving enterprises to encourage

energy-saving service companies. For energy-saving service companies that are below the average level of the industry, energy-saving enterprises are unwilling to increase the energy-saving benefit sharing ratio φ to encourage energy-saving service companies. On the contrary, for energy-saving service companies with the high energy-saving level, energy-saving enterprises are willing to increase the sharing proportion of energy-saving benefits to encourage energy-saving service companies. It further shows that the government blindly sets higher energy-saving targets and implements the variable energy-saving subsidy policy without incentive effect, which is more detrimental to the energy-saving service companies with lower energy-saving levels.

Author's contribution All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by Tao Zhang and Ke Wu. The first draft of the manuscript was written by Tao Zhang, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Funding This research was funded by the Natural Science Foundation of Shandong (ZR2022MG083), the Fundamental Research Funds for the Central Universities (22CX04008B).

Data availability Not applicable.

Declarations

Ethical approval Not applicable.

Consent to participate Not applicable.

Consent for publication All of the authors have read and approved the paper for publication. We confirmed that it has not been published previously nor is it being considered by any other peer-reviewed journal.

Conflict of interest The authors declare no competing interests.

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