Pricing and Incentive Strategy for Green Building Supply Chain with Incentive Mechanism

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Abstract. We are witnessing more frequent extreme weather events due to the global warming. Construction industry has a high carbon footprint, the development of green building is a necessary way to protect the environment and achieve sustainable development of construction Industry. The government has formulated a series of financial subsidies policies and tax preferential policies to promote the development of green buildings. Contractors play an important role in the construction process, but there is no incentive mechanism to encourage contractors to work hard to improve the green building level. This paper studies the incentive mechanism and pricing strategy of green building under a two-level supply chain system consisting of a developer and a contractor. The optimal incentive intensity and optimal price of the developer, and optimal green level of the contractor is obtained. The results show that the incentive mechanism can not only increase the profits of the developer and the contractor but also improve the green building level, then promote the sustainable development of the construction industry.

1. Introduction

Global warming caused by excessive emissions of carbon dioxide has seriously threatened the survival and development of mankind, carbon dioxide emissions mainly come from the combustion of fossil fuels such as coal, petroleum and natural gas [1, 2]. The construction industry is one of the industries with the highest consumption of natural resources. During the construction process, greenhouse gases which have adverse effects on the natural environment will be emitted [3]. The United Nations Environment Programme (UNEP) report shows that the construction sector consumes about 40% of total energy and 30% of greenhouse gas emissions [4].

Green building as an important strategy to reduce or eliminate the negative impact of construction activities on the environment and climate change has been widely accepted by governments all over the world [5]. Green buildings are generally termed as environmentally friendly buildings, not only help to reduce energy and resource consumption, but also to improve user experience and satisfaction [6, 7]. Typical example of innovation technology implemented on green building includes green roof technology, solar water heater, high efficiency HVAC systems, and prefabrication concrete technology [8].

The literature related to this study primarily focus on financial incentives on the green building. Wu et al. proposed an effective incentive mechanism for the contractor by using game theory and achieved the optimal incentive intensity of the developer and the optimal green level of the contractor [9]. Onuoha IJ et al. using structural equation modelling methods to identify and simulate the incentive factors that affect the decision-making of developers and investors to invest in green commercial real estate [10].
Darko A et al. systematic review of literature on barriers to green building adoption published in academic journals. Found that the lack of cost and incentives is the most reported obstacle in the literature [11]. Liu et al. analyses the current situation of green building incentive policy and the economic characteristics of green building, then pointed out the importance of green building incentive mechanism design, and study on green building incentives by using game analysis, finally put forward the policy proposals [12]. Lin et al. investigates the relationship among government, construction-related enterprises and consumers in the process of green building development, and puts forward the framework of incentive and restraint mechanism based on the basic principles of multi-stakeholder-based green building incentive and restraint [13]. Jin et al. established a complete information dynamic game model between the government and real estate developers, and draws the conclusion that economic incentive quota is an important factor affecting the decision-making of real estate developers and incentive effect determines whether the government implements economic incentive policy [14]. Ji et al. makes a comparative analysis of the economic development, construction industry development and building energy consumption between China and Japan. Finally given the advice that China should increase the incentive policy efforts to promote the development of green building in China [15].

The literature above considered green building incentives from various perspectives including government, consumer, and construction developer. The construction contractor plays a significant role in the process of green building construction. However, very little research has been done regarding encourage contractors to build green building. Therefore, this paper aims to address this research gap by focusing on the incentive mechanism of the contractor.

This paper studies the optimal profits of the developer and the contractor under incentive mechanism and without incentive mechanism. Similar to existed green building incentives, the developer established an incentive mechanism to encourage the contractor to achieving high green building certification levels before the project starts. A decision-making is faced with the contractor, increase green investment to reach a high green level and achieve the bonus. Alternatively, low green level can be economic saving but give the reward up. The questions of interest in this paper are as follows:

1) What is the optimal incentive intensity setting for the developer to encourage the contractor to achieve high green building certification level?
2) What is the optimal green level for the contractor under the incentive mechanism?
3) What is the optimal sale price of the developer?

To answer these questions, the profit model of the developer and the contractor is established by using stackable game theory in this paper. The optimal decision of both participates is obtained, and the optimal profit under incentive mechanism is compared with that without incentive mechanism. Further, the influence of cost efficiency and the initial green building level on optimal decision is examined.

The rest of this paper is organized as follows. The model description and assumptions are presented in Section 2. The base model and its optimal decision are obtained in Section 3. The model with incentive mechanism and its optimal decision are obtained in Section 4. The effect of incentive mechanism is carrying out in Section 5. Sensitive analysis of optimal decision is discussed in Section 6. Section 7 is the conclusion and some further working directions.

2. Model Descriptions and Assumption
In this paper, we propose a stackable game between a construction developer and a construction contractor. We assume that the construction developer is the stackable leader and the contractor is the stackable follower.

First, the developer set up a bonus incentive mechanism to encourage the contractor construct green building with high certification level. Then, the contractor decides the green building certification level to be achieved in the completion of the construction process. Finally, the developer decides the price. In this paper, we consider the basic operation cost, basic construction investment and bonus investment of the developer. The contractor’s cost consists of basic operation cost and green technology investment cost.

Throughout this paper, we use the parameters and variables as the following notations in Table 1.
In addition, to make the model more practical, the parameters must satisfy certain conditions for the model to make sense, so we assume:

1. The bonus is a linear function related to bonus intensity and green building level, that is \( B(A) = A(g - g_0) \).

2. The incremental cost function of the contractor is a strictly monotonic increasing of \( g \), then \( T = t(g - g_0)^2 \). This represents the increasing marginal cost for the contractor while innovating green building technology and promoting green level higher than \( g_0 \).

3. The market demand is a linear function related to price and green building level, that is \( D(p, g) = a - bp + cg(a > b > c > 0) \) [16].

### 3. The Base Model

First, we consider the basic model without incentive mechanism. Without the decision of bonus setting, the contractor decides the green building certification level and then the developer decides the price.

The construction contractor’s profit, denoted by \( \pi_1(p) \), is

\[
\pi_1(p) = pD - (C_0 + C_s) = p(a - bp + cg) - C_0 - C_s
\]

The first term is total revenue. The last two items are the basic operation cost of building and the basic construction investment. Then the decision model for the developer’s profit maximization is \( \max_p \pi_1(p) \).

The construction contractor's profit, denoted by \( \pi_2(g) \), is

\[
\pi_2(g) = C_s - C_b - T = C_s - C_b - t(g - g_0)^2
\]

The first term is the basic construction investment of the developer. The second term is the basic construction cost. The last terms represent the incremental cost of green technology investment. Then the decision model for the contractor’s profit maximization is \( \max_g \pi_2(g) \).

For the optimal green level \( (g^*) \) of the contractor and the optimal price \( (p^*) \) of the developer without incentive mechanism, the following proportion is obtained.

**Proposition 1.** \( g^* = g_0 \), \( p^* = \frac{a + cg_0}{2b} \)

**Proof.** The first deviation of \( \pi_2(g) \) is \( \frac{d\pi_2(g)}{dg} = 2g_0t - 2gt \). The second deviation is \( \frac{d^2\pi_2(g)}{dg^2} = -2t < 0 \). The profit function of contractor \( \pi_2(g) \) is a convex function of \( g \). From \( \frac{d\pi_2(g)}{dg} = 0 \), the best response of the contractor is \( g^* = g_0 \). Bring \( g^* = g_0 \) into equation (1), we get \( \pi_1(p) = \)
\[ p(a - bp + cg_0) - (C_o + C_s). \]
Then \( \frac{d\pi_1(p)}{dp} = a - 2bp + cg_0 \) and \( \frac{d^2\pi_1(p)}{dp^2} = -2b < 0. \) The profit function of developer \( \pi_1(p) \) is a convex function of \( p. \) Let \( \frac{d\pi_1(p)}{dp} = 0 \) we get \( p^* = \frac{a+cg_0}{2b}. \) This completes the proof.

This proposition means that without bonus incentive mechanism, the optimal green building level of the contractor and optimal price of the developer are existent and unique.

Bring \( g^* = g_0 \) and \( p^* = \frac{a+cg_0}{2b} \) into equation (1), we can get the maximum profit of the developer is

\[ \pi_1(p^*) = (\frac{a+cg_0}{2b})^2 - (C_o + C_s) \]  
(3)

Bring \( g^* = g_0 \) into equation (2), the maximum profit of the contractor is

\[ \pi_2(g^*) = C_s - C_0 \]  
(4)

4. The Model with Incentive Mechanism

In this section, we discuss the model with incentive mechanism. The decision problem faced by the developer is to decide the optimal bonus intensity and optimal price. The developer's profit with incentive mechanism, denoted by \( \pi_1'(p, A) \), is

\[ \pi_1'(p, A) = pD - (C_o + C_s) = p(a - bp + cg) - C_o - C_s - A(g - g_0) \]  
(5)

Where \( C_c = C_s + B, \) Total construction investment of the developer consist of basic construction investment and bonus.

The first term is total revenue. The second term is the basic operation cost of building. The third term is the basic construction investment. The last terms represent the bonus of construction developer. Then the decision model for the developer’s profit maximization is \( \max_{p, A} \pi_1'(p, A). \)

The contractor must determine the green building certification level. The contractor's profit with incentive mechanism, denoted by \( \pi_2'(g) \), is

\[ \pi_2'(g) = C_c - C_0 - T = C_c + A(g - g_0) - C_b - t(g - g_0)^2 \]  
(6)

The first two items are the basic construction investment and the bonus of the developer. The third term is the basic construction cost. The last terms represent the incremental cost of green technology investment. Then the decision model for the contractor’s profit maximization is \( \max_g \pi_2'(g) \).

For the optimal bonus intensity \( (A'^*) \) and price \( (p'^*) \) of the developer and optimal green level \( (g'^*) \) of the contractor under incentive mechanism, the following proportion is obtained.

**Proposition 2.** \( A'^* = \frac{(\frac{at}{b} + cg_0)}{(bt-c^2)} \), \( p'^* = \frac{(bt+c^2)}{(bt-c^2)} \), \( g'^* = \frac{(g_0+bt+ac)}{(bt-c^2)} \).

**Proof.** The first deviation of \( \pi_2'(g) \) is \( \frac{d\pi_2'(g)}{dg} = A - 2gt + 2g_0t \). The second deviation is \( \frac{d^2\pi_2'(g)}{dg^2} = -2t < 0. \) The profit function of contractor \( \pi_2'(g) \) is a convex function of \( g \). From \( \frac{d\pi_2'(g)}{dg} = 0 \), the best response of the contractor is a function of \( A \), \( g(A) = \frac{A}{2t} + g_0 \). Bring \( g = g(A) \) into equation (5). Then \( \frac{d\pi_1'(p, A)}{dp} = a - 2bp + cg_0 + \frac{Ac}{2t} \) and \( \frac{d^2\pi_1'(p, A)}{dp^2} = -2b < 0. \) Hence, the profit of construction developer is a convex function of \( p \). Similarly, \( \frac{d\pi_1'(p, A)}{dA} = \frac{pc}{2t} - \frac{A}{t} \) and \( \frac{d^2\pi_1'(p, A)}{dA^2} = -\frac{1}{t} < 0 \). Hence, the profit of construction developer is a convex function of \( A \). Let \( \frac{d\pi_1'(p, A)}{dp} = 0 \) and \( \frac{d\pi_1'(p, A)}{dA} = 0 \), we get the optimal bonus intensity \( A'^* = \frac{(\frac{at}{b} + cg_0)}{(bt-c^2)} \), the optimal price is \( p'^* = \frac{(bt+c^2)}{(bt-c^2)} \) and the optimal decision of the contractor is obtained as \( g'^* = \frac{(g_0+bt+ac)}{(bt-c^2)} \). This completes the proof.

This proposition means that in a bonus incentive mechanism, the optimal bonus intensity and price of the developer and optimal green building level of the contractor are existent and unique. From observation, \( g'^* > g_0 \) represent that optimal green level is consistently greater than initial green level.

Bring \( A'^* \) and \( p'^* \) into equation (5), that the maximum profit of the developer is
π₁(p²*, A²*) = \frac{2t(a+cg₀)^2}{(btct-c²)} - (C₀ + Cₛ)

Bring \ g²* \ into \ equation \ (6), \ that \ the \ maximum \ profit \ of \ the \ contractor \ is

\[ \pi₂(g²*) = \frac{c²(a+cg₀)^2}{(btct-c²)^2} + Cs - Cb \]

5. The Effect of Incentive Mechanism

This part of the study attempts to analyse the impact of incentive mechanism compares to without incentive. The following proposition is obtained.

**Proposition 3.** \ p₁* > p* \ and \ g₁* > g*.

**Proof.** From Proposition 1 and Proposition 2 we get \ g₁* - g* = \frac{ac + c²g₀}{2bt - c²} > 0 \ and \ p₁* - p* = \frac{ac² + c²g₀}{2bt - c²} > 0.

This proposition shows that with the establishment of incentive mechanism, both the optimal price of developers and the optimal green level of the contractors are increased.

**Proposition 4.** \ π₁(p₁*, A₁*) > π₁(p*) , \ π₂(g₁*) > π₂(g*) , \ and \ [π₁(p₁*, A₁*) - π₁(p*)] > \ [π₂(g₁*) - π₂(g*)]

**Proof.** From the proof of proposition 1 and proposition 2 we get \ π₁(p₁*, A₁*) - π₁(p*) = \frac{c²(a+cg₀)^2}{4c(btct-c²)} > 0 \ and \ π₂(g₁*) - π₂(g*) = \frac{tc²(a+cg₀)^2}{(btct-c²)^2} > 0. \ Then \ [π₁(p₁*, A₁*) - π₁(p*)] - [π₂(g₁*) - π₂(g*)] = \frac{c²(4btct-c²+a+cg₀)^2}{4b(btct-c²)^2} > 0. \ This \ completes \ the \ proof.

This proposition shows that with the establishment of incentive mechanism, both the profits of developers and the profit contractors are increased. The increased profit of developer is more than the increased profit of contractor.

6. Sensitive Analyse

In order to achieve better understanding of the impact from other parameter, including the initial green building level of the developer required and maturity of green building technology etc., on the optimal decision strategies, this part applies sensitivity analysis on the parameter \ t, g₀. And a well experienced contractor can capable of a smaller cost efficiency. The following proposition is obtained.

**Proposition 5.** All of \ A₁* , \ p₁* \ and \ g₁* \ are increasing in \ g₀ \ and decreasing in \ t.

**Proof.** From proposition 1, we have \ A₁* = \frac{2tc(a+cg₀)}{(btct-c²)} \ and \ g₁* = \frac{(8g₀bt+ac)}{(btct-c²)}. \ Then \ \frac{da₁*}{dg₀} = \frac{2tc}{(btct-c²)} > 0, \ \frac{dp₁*}{dg₀} = \frac{4tc}{(btct-c²)} > 0, \ \frac{dg₁*}{dg₀} = \frac{8bt}{(btct-c²) > 0, \ \frac{da₁*}{dt} = \frac{-2c(a+cg₀)}{(btct-c²)²} < 0, \ \frac{dp₁*}{dt} = \frac{-4c²(a+cg₀)}{(btct-c²)²} < 0, \ \frac{dg₁*}{dt} = \frac{-8bc(a+cg₀)}{(btct-c²)²} < 0. \ Thus, \ all \ of \ A₁*, \ p₁* \ and \ g₁* \ are \ increasing \ in \ g₀ \ and \ decreasing \ in \ t. \ This \ completes \ the \ proof.

This proportion indicates that the higher the initial green building level of the developer the higher the optimal price of the developer and optimal green level of the contractor. Moreover, the optimal decision of developer and contractor are affected by increment cost coefficient. As the increment cost coefficient increases, the contractor decreases the green building level to ensure his own profit is maximized. Then the optimal price of developer will also decrease.

7. Conclusion

The purpose of this study is to promote the development of green buildings through incentive construction contractors. In this paper, we build a two-level supply chain game model consisting of the developer and the contractor, the pricing and incentive strategy for green building supply chain with incentive mechanism is studied. The study finds that under the incentive mechanism, the profit of both the developer and contractor increased, the profit of the developer increased more than the profit of the contractor, and the green building level also improved. The results of sensitivity analysis show that the
contractor's cost efficiency is the key to the contractors and developers whether implement the incentive. The higher the contractor's cost efficiency, the less profit the contractor and the developer will get.

Similar to many other previous studies, this research has some limitations which open avenues for future research. For example, this paper only considers the stackable game between developer and contractor. It can be extended the model by considering subcontractors and other participants. Moreover, the market advantage of green building, stochastic demand and demand preference are not considered in this paper. It will be useful and a more challenging research if these factors are considered.

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