Chapter 6
Coordination of Value Chain Members

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Abstract The innovation-driven coordination of "green" and "growth" in enterprises' green growth model (EGGM) requires value chain members to collaborate, to facilitate the coordination of business processes in the upstream and downstream of the value chain. Value co-creation and sharing among members in a value network drive firms to implement the green growth model and green transformation. From the perspective of the internal and external environment surrounding the green transformation of the value chain, this chapter explores the coordination mechanism among value chain members that is aimed at ensuring the sharing of value among entities. This coordination mechanism also motivates enterprises to implement the green growth model to coordinate "growth" with economic performance goals and "green" with environmental performance goals. With a better understanding of the relationship between the coordination of value chain members and an enterprise's green growth, this chapter introduces the concepts and structure of member coordination in the green growth model, analyzes the path of members to achieve coordination, and finally evaluates the characteristics and mechanism of value co-creation in the green growth model. We show that for the internal coordination mechanism, the Shapley value method and cost sharing contract can coordinate the profits and green level of the value chain. In particular, the Shapley value method has a better coordination effect, which can address the externality effect of green transformation investment and encourage value chain members to make cooperative investments. For the external coordination mechanism, government subsidies can effectively motivate value chain enterprises to invest in green levels and increase the market share of green products.

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6.1 Relationship Between Coordination of Value Chain Members and Enterprises' Green Growth Model

6.1.1 Coordination of Value Chain Members in Enterprises' Green Growth Model

Coordination is the process of managing the dependencies between activities. The purpose of coordination is to achieve the overall goal of all activities [1]. However, value chain members are primarily concerned about optimizing their own goals; these sub-goals may affect and even contradict one another. Individual rational decision-making leads to Olson's dilemma in the overall value chain network. By setting incentive and coordination mechanisms rationally, one may realize the cooperation of multiple members and the overall "growth" and "green" development of the value network. Relative to a traditional value chain, the value chain in enterprises' green growth model (EGGM) shows the following changes in terms of coordination environment and goals.

(1) Coordination Environment

The internal and external coordination environment of enterprises greatly affects the implementation of EGGM [2]. The coordination environment includes external factors, such as environmental pressure and consumers' green preferences; and internal factors, such as environmental protection technologies and the structure of the value chain. The coordination environment changes in EGGM, thus influencing the choice of coordination mechanism.

(a) Environmental Pressure

To alleviate the resource and environmental pressure caused by waste, governments around the world have launched a series of environmental legislations that guide and regulate enterprises as they seek green transformation. Government regulation is a key driving force for enterprises to implement EGGM [3].

To gain a competitive advantage in the market, companies in the value chain must make green transformation investments, that is, products should be harmless to the environment and human health in terms of raw material supply, production, use, and disposal, and resource circulation and recycling should be promoted. In the early stage of the green transformation of enterprises, the maximization of the overall economic, environmental, and social benefits of the value chain network cannot be achieved solely by members' independent behavior. As the production, marketing, and procurement costs of the value chain in EGGM are often much higher than those of the traditional value chain, the green premium often hinders the development process of EGGM under the market mechanism. Consequently, EGGM can be successfully implemented if the government offers sufficient incentives.

Therefore, the active guidance and regulation of the government can help value chain members select coordination mechanisms in EGGM, and effectively achieve not only cooperation but also value co-creation and sharing with one another in the value chain. In practice, governments usually adopt laws and regulations, reward and punishment mechanisms, and financial measures as external factors of the value chain to influence the decision-making and coordination of value chain members.

(b) Consumers' Green Preferences

Environmentally conscious consumers tend to choose green products that are harmless to the environment, and they have a higher willingness to pay for low-carbon and energy-saving products [4]. Stronger public environmental consciousness motivates enterprises to implement EGGM.

In EGGM, the differences in consumers' willingness to pay for green products affect the product pricing strategies and profits of value chain members, which further influence the choice of value chain members' coordination mechanism. This part of the research focuses on the coordination of value chain members under the assumption that consumers have different utilities for green and nonsustainable products [5].

(c) Environmental Protection Technology

In EGGM, environmental protection technology presents a trend of transformation from end control to whole process management, including environmental control of all relevant activities, including the design, manufacture, and recovery of products [6].

The promotion of new environmental protection technologies increases the costs of enterprises and changes the existing decision-making and operation strategies of value chain enterprises. The coordination of various members in the traditional value chain is more about individual optimization, which makes it difficult to achieve the overall optimization of the entire value chain. Therefore, it is necessary to align individual goals with the overall optimization of EGGM.

(d) Structure of Value Chain

In EGGM, the leadership of value chain members also affects coordination decisions among members. In the process of implementing EGGM, core enterprise is responsible for cooperating with upstream and downstream enterprises. Core enterprises play leading roles in decision-making, and their green demand for intermediate products in the value chain directly affects the green behavior of their upstream and downstream enterprises through the procurement and sales chain. For example, Honda achieves green growth for the overall value chain by providing training programs and sharing its green knowledge with partners, including subcontractors or suppliers in the value chain [7].

In EGGM, members of the value chain are not always willing to bear the expenses for implementing green transformation; in this case, the technology and knowledge levels of other enterprises in the chain may be incompatible [4]. When the willingness of value chain members to invest in green transformation is low, the core enterprises of the value chain need to stimulate the enthusiasm of their subordinate enterprises.

Moreover, an effective revenue sharing mechanism should be implemented to ensure the stability of the value chain in EGGM.

In EGGM, the external and internal coordination environment shows changes. Given these influencing factors, the coordination goals of the value chain members in EGGM are as follows:

(2) Coordination Goals

Coordination provides a driving force for members to cooperate in the value chain to achieve global optimization and value co-creation. In terms of coordination goals, the value chain in EGGM aims to consider cost, environment, and security to achieve the innovation-driven coordination of "green" and "growth" goals and to achieve the global optimization of economic, social, and environmental benefits. At this stage, enterprises often encounter the following problems when implementing EGGM.

(a) Members Cannot Form a Stable Cooperation Relationship

Value chain members are often partially optimized because of their self-interest and varying goals. However, there is a lack of an effective value co-creation mechanism among enterprises to share the costs, risks, and benefits of value chain members. Moreover, upstream and downstream enterprises in the value chain cannot form a cooperative and stable value community and thus cannot realize overall optimization and value co-creation for the value chain. The top goals of decision making for the value community need to cover the overall economic, environmental, and social benefits of the whole value chain, the overall optimization of the value chain through coordination and cooperation mechanisms, and the establishment of EGGM for the whole value chain.

(b) Members Lack Motivation for Green Transformation

Most enterprises lack environment-friendly awareness, and green technology is a typical knowledge product that entails high research and development (R&D) investment and features increasing marginal returns, thus making it difficult to quickly generate expected outcomes. Consequently, enterprises lack motivation and incentives to invest in green transformation, leading to the rupture of the cooperation mechanism for green transformation [2].

Establishing a coordination mechanism for value chain management in EGGM is particularly important. Reasonable incentive mechanisms are mainly economic incentives, such as cost sharing, profit sharing, and technical subsidies, which ensure the stability of the green value network and the implementation of EGGM. The coordination of multiple entities in the value chain strengthens the cooperation between enterprises, realizes green transformation, and provides an impetus for the overall optimization of and the value co-creation in the value chain.

6.1.2 Value Co-creation and Sharing in EGGM

The research on value co-creation in EGGM mainly identifies enterprise value, consumer value, and value co-creation mechanism.

(1) Enterprise Value in EGGM

The enterprise value in the traditional value chain is solely the economic value, which is the total income obtained by the enterprise minus the total cost paid for it. Maximizing profits is the optimal goal of an enterprise. EGGM emphasizes the coordination of the economic and environmental performances of enterprises. Implementing EGGM and green transformation to realize value co-creation brings new value to enterprises, such as improved environmental performance, opportunities to enter new market segments, and sustainable competitive advantages [8].

(2) Consumer Value in EGGM

Traditionally, consumer value is defined as the difference between customers' benefits and costs. In EGGM, consumer value includes factors such as consumer loyalty and satisfaction with green brands [9]. Consumers pay more attention to the value brought by using green products that contribute to environmental protection and sustainable development, thus are willing to pay a premium for green value [4]. Consequently, additional markets and new income sources become available for enterprises and help them obtain economic benefits and generate more value. Consumers participate in the value co-creation process in EGGM, and their participation is beneficial for enterprises to integrate consumers' green demands and preferences into product design, meet their personalized green requirements, achieve higher product acceptance and reduced product failure risk, and decrease information asymmetry between consumers and manufacturers [10]. For example, companies such as Patagonia, BMW, and the Body Shop develop innovative ecofriendly products in collaboration with consumers, thereby demonstrating that the development of green products/services has become a new competitive advantage for companies [2].

(3) Value Co-Creation Mechanism in EGGM

The value co-creation mechanism in EGGM mainly identifies the best cooperation method among members of the value chain, determines the way to share green transformation costs and profits, and realizes an increase in consumer value, enterprise value, and enterprise alliance value, as well as the total value of the value chain [2]. Li et al. compared three green value co-creation strategies, that is, manufacturer and supplier, manufacturer and competitor, manufacturer and retailer value co-creation, for sharing the cost of green investment [4]. They showed that manufacturers can collaborate with competitors to co-create value and share the cost of green investments, resulting in higher-quality products, improved industry standards, and increased overall value. When value chain members share green costs, the products can be more environmentally friendly, and the overall profit of the value network can increase [2]. With the joint participation of all members, their respective resources become integrated into the process of co-creation, and they ultimately and share value with all stakeholders.

In EGGM, the value co-creation of green innovation and transformation faces challenges owing to the diverse characteristics, interests, and goals of different stakeholders. Therefore, it is necessary to explore the value co-creation mechanism in EGGM, establish coordination among value chain members, ensure that members are motivated to implement EGGM, and allocate the economic and environmental value created by the value chain through a reasonable mechanism.

6.2 Path of Coordination Among Value Chain Members in EGGM

The value chain in EGGM is composed of multiple members, and these members make decisions independently to maximize their own goals. This condition leads to double marginalization and hinders the overall optimization of the value chain. Therefore, cooperation should be established among value chain members through measures such as technical alliances or revenue sharing to achieve an all–win situation for all members and overall optimization of the value chain.

Contracts are commonly used in member coordination. Classic contracts include wholesale price, buyback, revenue sharing, and quantity discount contracts [11]. The main purpose of these contracts is to align conflicting interests in the value chain, avoid non-optimal results caused by decentralized decision making, and coordinate the profits of a nonvertically integrated value chain close to the centralized scenario level. Other contracts include quantity flexible, sales rebate, transfer payment, cost sharing, and two-part tariff contracts. Given the external and internal driving factors in implementing EGGM, there are three main streams of literature on the contract coordination of value chain members.

6.2.1 Coordination of Value Chain Members Considering Government Environmental Regulations

The research on the coordination of value chain members considering government environmental regulations mainly focuses on the optimal method of government regulations and the profit sharing of members. The environmental control methods adopted by the government usually include regulatory behavior and economic incentive behavior.

From the perspective of government regulations, Xie studied the impact of the threshold energy saving level set by the government on the actual energy saving level and the price of green products. The results indicate that the government's supervision promotes the energy saving investment of enterprises, improves the energy saving level in the production process, and coordinates members with wholesale price, profit sharing, and lump sum transfer contracts [12]. From the perspective of government economic incentives, Zhang and Yousaf proposed a two-part tariff contract between manufacturers and retailers involving government intervention in terms of taxes or subsidies, and proved that such contract can improve the green performance of the value chain [13]. In terms of product recovery, Heydari et al. considered the case in which a retailer offers a discount, in addition to government incentives, for consumers who return used products; their results indicated that governments' tax exemptions and subsidies, quantity discount and increasing fee contracts can increase the number of remanufactured products and the overall performance of the value chain [14].

6.2.2 Coordination of Value Chain Members Considering Consumers' Green Preferences

The second stream of literature focuses on the influence of consumers' green preferences on the decision-making, including pricing, profit, and coordination of value chain members. Consumers' green preferences are reflected in a higher willingness to pay for green products. Cao and Zhang assumed that consumers have different utilities for green products and traditional products and examined the coordination strategy between manufacturers and their upstream suppliers [5]. Zhang et al. studied the impact of consumer environmental awareness on order quantity and member coordination in a value chain consisting of a manufacturer and a retailer [15]. In addition, some studies have integrated the influence of consumers and governments on member coordination. Hafezalkotob studied competitive value chains for green and nongreen products and conducted a game analysis on the basis of direct government tariffs and tradable permits [16].

6.2.3 Coordination of Value Chain Members Considering Green Cooperative Investment

Green technological innovation and transformation often require cooperation among members of the value chain. Cooperative investment has the following advantages: it achieves higher economies of scale, reduces risks, reduces duplication of investment, increases the total investment volume, accumulates more technical knowledge, and avoids free riding. Chen et al. discussed green R&D cooperation among enterprises. In the cooperation process, the two parties first cooperate to make strategic decisions on green R&D investment, and then decide on wholesale and retail prices [17]. By comparing cooperative and noncooperative models, they investigated the impact of green R&D cooperation, technology spillovers, and the value chain power relationship on economic, environmental, and social performances. In previous studies, green cooperative investment between enterprises was often realized through cost sharing or revenue sharing contracts.

Roma and Perrone proposed three cost sharing contracts, namely, quantity proportional, total margin proportional, and fixed share mechanisms; and compared the effects of the three contracts on profits and total welfare [18]. Yang et al. studied horizontal and vertical cooperation in two green value chains under a revenue sharing contract, and found that vertical cooperation leads to higher carbon emission reduction rates and lower retail prices and that horizontal cooperation harms retailers' profits and consumer welfare [19]. Bai et al. used a revenue sharing contract to improve the profit and carbon emission reduction level under a decentralized case such that they match the performance under a centralized case [20].

The existing research mainly focuses on the individual decentralized decision-making of members. However, each member can play cooperative games to form a coalition. Under the decision of maximizing the overall interests of the coalition, members can cooperate in "profit sharing" or "cost sharing" fairly. The Shapley value method measures profit allocation based on expected marginal revenue.

Ghadimi et al. used the Shapley value method to study the fair allocation of profits among three members, including a manufacturer and two retailers, to achieve value chain coordination [21]. Zhang and Liu considered that market demand is affected by the green degree of the product and showed that the profit under cooperative decision-making is better than that under a noncooperative game [22]. Through revenue sharing, Shapley value coordination, and asymmetric Nash negotiation mechanisms, members are motivated to cooperate in producing and selling green products.

In summary, most existing studies focused on using contracts to coordinate supply profit and on providing incentives for green investment. Meanwhile, there is little research that quantitatively analyzes the coordination mechanism with consideration of the impacts of the government and consumers on the value chain system for the implementation of EGGM. The coordination goals in EGGM not only include costs and profits but also extend to the environment and safety perspectives. Through contract design and incentive mechanisms, this study considers the effects of government and consumer incentives and the supervision of enterprises, followed by value sharing among different enterprises in the value chain. The former consideration mainly includes the incentive and supervision mechanisms of the government and society to regulate enterprise behavior. These mechanisms include the government's reward and punishment mechanism, subsidies, and the establishment of carbon emission trading mechanisms. The latter consideration mainly involves the contract design between different enterprise entities in the value chain, e.g., green cost sharing.

6.2.4 Research Gap

(1) Coordination subjects and goals: Various studies have investigated coordination mechanisms. In contrast to these studies, the current research focuses on analyzing the driving and impact factors of enterprises implementing EGGM and the selection of coordination mechanisms among members of the value chain. In EGGM, consumers participate in value creation activities, such as value discovery, value creation, and value transfer. The interaction effects among enterprises, governments, and consumers promote enterprises' green development. In EGGM, the selection of the coordination mechanism among value chain members need to be addressed to ensure that enterprises have the motivation to achieve their "green" and "growth" goals. Previous studies rarely discussed coordination mechanism selection and profit sharing among members of the value chain in EGGM. For the topic of achieving the economic and environmental goals of value chain members, this chapter considers internal and external drivers in investigating the coordination mechanism of green transformation investment by value chain members.

(2) Coordination methods: A stream of literature has considered the coordination of supply chains. Previous research focused on using contracts to solve the problem of insufficient green investment incentives. Relatively few studies have used cooperative game methods, such as the Shapley value method, for member profit sharing in EGGM. Therefore, this chapter considers two internal coordination methods, that is cost sharing contract and the Shapley value method, to coordinate the members of the value chain and thereby build a value co-creation and sharing mechanism. The external driving mechanism considers government subsidies for promoting the green transformation investment of value chain members. This study uses the internal and external dual driving methods to coordinate, motivate, and conduct cooperative games among value chain members and to ultimately reveal the value sharing and co-creation mechanism in EGGM.

6.3 Value Co-creation and Sharing Model of Value Chain Members

Governments have set strict environmental regulations, and consumers have a growing interest in green products. More consumers with environmental awareness favor green products with healthy, energy-saving, and pollution-free features. EGGM is driven by the internal and external environment of enterprises. In a stable internal and external environment, enterprises often lack the motivation to invest in innovative technology and management systems to achieve better green benefits. Therefore, as described in this section, the characteristics of value co-creation in EGGM are studied, and a value co-creation and sharing mechanism is designed to achieve effective cooperation, decision-making, and coordination among members of the value chain in EGGM.

6.3.1 Characteristics of the Value Chain Co-creation Mechanism in EGGM

Relative to that in the traditional value chain, value co-creation in EGGM has the following characteristics.

(1) Reducing the Risks and Costs of Environmental Regulations

Traditional value chain enterprises often incur high costs when dealing with hazardous materials and wastes, whereas value chain companies in EGGM avoid or reduce the use of hazardous materials and hazardous waste through green design and recycling networks. As companies reduce environmental impact, they also reduce the cost of environmental management, such as the cost of emission reduction, and the penalties under environmental regulations [4]. In this way, the economic and environmental benefits of enterprises are increased, and the value added and co-creation across the value chain are achieved.

(2) Extending the Green Market and Enhances Competitiveness

Given their awareness of environmental protection, consumers are paying more attention to green products and remanufactured products, and they are willing to pay higher costs for greener products. Enterprises implementing EGGM and investing in innovation meet consumers' needs and gain differentiated competitive advantages [23], which can effectively protect them from fierce price competition. With the expansion of the market for green products, enterprises have economies of scale, thus achieving win–win outcomes through economic and environmental benefits, which promote the implementation of EGGM.

(3) Promoting Environmental Friendliness and Resource Recycling

Apart from cost, EGGM increases the efficiency of enterprise resources and energy use, and it makes enterprises more competitive [24]. Relative to that in the traditional value chain, value co-creation in EGGM requires all members, including suppliers, manufacturers, retailers, consumers, recyclers, to form a stable green and environmental cooperation relationship and avoid using hazardous materials in the product design stage to minimize the environmental pollution generated by products throughout their life cycles. Meanwhile, recycling, remanufacturing, and refurbishing used products, by-products, waste, etc. save resources and energy, improve the recovery efficiency of resources, and add value to the value chain.

6.3.2 Value Co-creation Mechanism of Value Chain Members Considering the Externality of Green Investment

Government regulations and consumers' preferences for green products have forced enterprises to pay more attention to the environmental impact of their products. Enterprises have invested in green transformation, and an increasing number of green products have appeared in the market, e.g., energy-saving air conditioners and new energy vehicles.

In practice, retailers may sell products from multiple competing manufacturers. Relative to traditional product manufacturers, green product manufacturers carry out green transformation by improving technology in product design and production and investing in a certain degree of product greening efforts, thereby reducing product energy and raw material consumption, as well as waste and environmental hazard emissions. These efforts are likely to be favored by consumers with green preferences, increase demand and sales, and make green products competitive. However, transformation investment inevitably increases the cost of green products. Meanwhile, manufacturers' green investments may have externalities; green investments increase their own sales while other members, including retailers and competitors, also benefit. If the higher production costs of green manufacturers cannot be compensated for in terms of sales prices, the motivation for producing green products is likely to be affected. For example, BYD[1] has invested in green transformation by creating a lithium iron phosphate battery system. This system has some advantages, such as small size and light weight, versatility in deployment, manufacturing that meets the Restriction of Hazardous Substances Directive standard, and absence of harmful substances. Green technology has been applied to multiple BYD car models. However, the development of the industry has hit a major roadblock with sharply falling subsidies and weak demand for passenger electric vehicles (EVs). As a result of the lower-than-expected sales of EVs, BYD is under huge financial and operational pressure with high green technology investment and huge labor costs. Therefore, BYD has started selling in-vehicle batteries to other companies. The move comes as BYD seeks to expand the scale of its battery manufacturing business by supplying to other companies, including DongFeng Motor. It has also shared its green technologies to form alliances with other vehicle producers instead of simply using the key EV component it produces in its own products, thereby further boosting production efficiency. BYD is making a long-term shift in its lithium-ion battery strategy from internal supply to external marketization. In other words, BYD's previous rival becomes a BYD battery customer and forms an alliance with BYD. Under these circumstances, the promotion of cooperation among enterprises in the value chain, the sharing of green technology cost, and the consideration of the value co-creation mechanism among members are urgent problems that BYD needs to solve.

We aim to address the following issues: designing a value co-creation and sharing mechanism when two competing manufacturers sell their products to the same

[1] http://www.juda.cn/news/101824.html.

retailer, achieving effective cooperation among value chain members, and ultimately realizing the overall optimization of the value chain and environmental friendliness in EGGM.

We identify the factor that drives value chain members to invest in green transformation, ensure that enterprises have the motivation to achieve "green" and "growth" goals, and coordinate the value chain from internal and external dual-driven coordination mechanisms. This chapter studies a value chain system composed of a green product manufacturer, a nongreen product manufacturer, and a retailer. Moreover, game theory is used to solve optimal production, pricing, and green transformation investment decisions. Finally, the value chain system is coordinated using internal methods, that is, Shapley value method and cost sharing contract, and external method, that is, government subsidies.

(1) Internal Value Co-Creation Mechanism

(a) Basic Model

We consider a value chain system that consists of two manufacturers and one retailer. Two manufacturers, G and N, first produce green and nongreen products, and decide their wholesale price w_G, w_N and green level m. Meanwhile, the retailer decides the retail price of the two products p_G, p_N to maximize profits.

Assumption 1: Green products are functionally identical to nongreen products because the green manufacturer has invested in emission reduction, which increases production costs. Green transformation investment reduces emissions during the manufacturing process of green products; thus, some consumers with environmental awareness prefer to buy green products. We set product demand as a linear function of the selling price. The demand for green and nongreen products is as follows [25]:$d_G = a - p_G + bp_N + \gamma m$ and $d_N = a - p_N + bp_G$, where a is basic market demand, b represents the cross-price sensitivity of the product to the substitutable product, where $a > 0, b > 0$. γ denotes the sensitivity of consumers to green investment, and m is the green level of the product.

Assumption 2: The green manufacturer incurs a quadratic green transformation investment cost of ηm^2 [26], depending on the green level of products. A higher η means that the green manufacturer's transformation investment is more costly or less efficient.

Assumption 3: As manufacturers have greater bargaining power over the retailer, we implement a Stackelberg game in which the manufacturer is the leader and the retailer is the follower [27]. This research uses backward induction to ensure subgame perfection. The model parameters are summarized, as shown in Table 6.1:

(i) Centralized Model (Fig. 6.1)

The profit function for centralized case can be written as:

$$\max_{p_G, p_N, m} \pi = (p_G - c_G)(a - p_G + bp_N + \gamma m) + (p_N - c_N)(a - p_N + bp_G) - \eta m^2$$

We obtain:

$$m = \frac{((1-b)c_G - a)(b+1)\gamma}{4b^2\eta + \gamma^2 - 4\eta}$$

$$p_G = \frac{2\left(b^2 c_G - ba - a - c_G\right)\eta + \gamma^2 c_G}{4b^2\eta + \gamma^2 - 4\eta}$$

Table 6.1 Notations of parameters

Parameter	Definition
a	Intrinsic demand of products
b	Cross-price sensitivity of the product to the substitutable product
w_G	Wholesale price of green product
w_N	Wholesale price of nongreen product
c_G	Manufacturing cost of green product
c_N	Manufacturing cost of nongreen product
p_G	Selling price of green product
p_N	Selling price of nongreen product
γ	Consumers sensitivity of green investment
m	Product's green level
η	Cost index of green level
d_G	Consumer demand for green product, with $d_G = a - p_G + bp_N + \gamma m$
d_N	Consumer demand for non-green product, with $d_N = a - p_N + bp_G$
t	Cost sharing index
τ	Government subsidy index

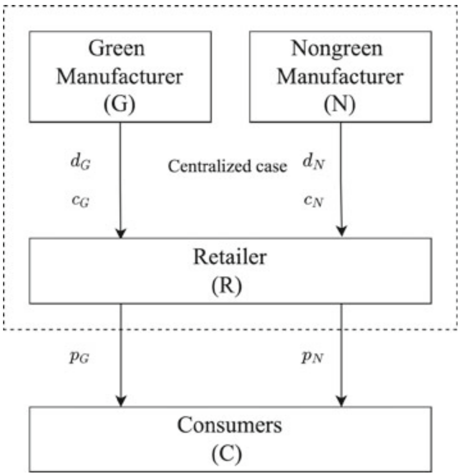

Fig. 6.1 Structure of the value chain under centralized case

$$p_N = \frac{4\left(b^2 c_N - ba - a - c_N\right)\eta + \gamma^2(c_G b + a + c_N)}{8b^2\eta + 2\gamma^2 - 8\eta}$$

(ii) Decentralized Model (Fig. 6.2)

According to assumption 3, the manufacturer is the leader, and the retailer is the follower. First, manufacturers determine the wholesale price w_G, w_N and product green level m to maximize their own profits. The retailer then decides the retail price of green products p_G and nongreen products p_N. The member's product function are as follows:

The green manufacturer:

$$\max_{w_G, m} \pi_G = (w_G - c_G)(a - p_G + bp_N + \gamma m) - \eta m^2$$

The nongreen manufacturer:

$$\max_{w_N} \pi_N = (w_N - c_N)(a - p_N + bp_G)$$

The retailer:

$$\max_{p_G, p_N} \pi_R = (p_G - w_G)(a - p_G + bp_N + \gamma m) + (p_N - w_N)(a - p_N + bp_G)$$

We obtain

$$m = \frac{\left(2c_G - b^2 c_G - (a + c_N)b - 2a\right)\gamma}{4b^2\eta + 2\gamma^2 - 16\eta}$$

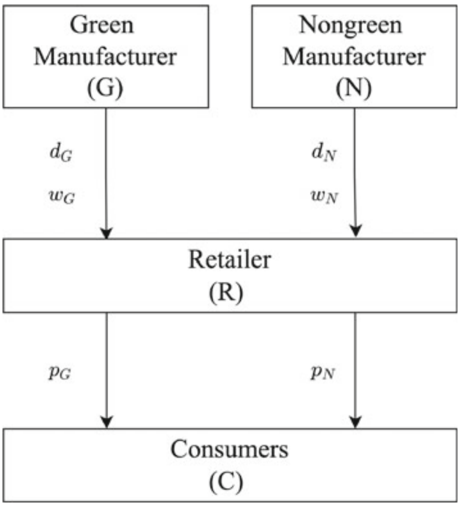

Fig. 6.2 Structure of the value chain under decentralized case

$$w_G = \frac{((-2a - 2c_N)b - 4a - 4c_G)\eta + \gamma^2 c_G}{2b^2\eta + \gamma^2 - 8\eta}$$

$$w_N = \frac{((-4a - 4c_G)b - 8a - 8c_N)\eta + \gamma^2(bc_G + a + c_N)}{4b^2\eta + 2\gamma^2 - 16\eta}$$

$$p_G = \frac{(1 - b^2)w_G^* + \gamma m^* + (b + 1)a}{2(1 - b^2)}$$

$$p_N = \frac{(1 - b^2)w_N^* + b\gamma m^* + (b + 1)a}{2(1 - b^2)}$$

(b) Shapley Value Coordination
(i) Shapley Value Method

In practice, the noncooperative decentralized case always leads to "double marginalization", which reduces the profits across the value chain. The Shapley value method can fairly allocate costs or profits according to the marginal contribution of participants. Therefore, the Shapley value method shares the R&D costs and effort costs of members, reduces the financial pressure of investors, and simultaneously solves the free rider effect among members, thereby achieving the effect of motivating the members of the value chain. The basic principle of the Shapley value method is as follows:

$I = \{1, 2, \cdots, n\}$ denotes a set of all players, which is also called the grand coalition. The coalition formed by several players can be represented as s. Obviously, coalition s is a subset of I, where $s \subseteq I$. $v(s)$ is the maximum payoff of coalition s, and the corresponding payoff equals 0 when the set is empty, where $v(\emptyset) = 0$.

Superadditivity: For any payoff $v(s)$ of coalition s of I, it has superadditivity, that is, $v(s_1 \cup s_2)) \geq v(s_1) + v(s_2)$, $s_1 \cap s_2 = \emptyset . v(s)$ is the characteristic function defined on set I, representing the payoff of cooperation. The formula reflects "1 + 1 > 2," which means that benefits allocated to each member in the cooperative coalition are greater than the benefits when they do not cooperate. The maximum cooperative benefit is $v(I)$.

Shapley value: To allocate the system's payoff, it is necessary to determine the weight of each player and the corresponding marginal contribution. $\phi_i(v)(i = 1, 2, \cdots, n)$ denotes the accessible cooperation payoff of player i of set I, that is, the Shapley value. Then, the allocation of benefits during cooperation can be expressed as $\phi(v) = (\phi_1(v), \phi_2(v), \cdots \phi_n(v))$, where $\sum_{i=1}^{n} \phi_i(v) = v(I)$ and $\phi_i(v) > v(i), i = 1, 2, \cdots, n$.

The Shapley value of each member is given as follows:

$$\phi_i(v) = \sum_{i \in s(i)} w(|s|)[v(s) - v(s \backslash i)] \quad i = 1, 2, \cdots n (Shapley\ value)$$

$$w(|s|) = \frac{(n - |s|)!(|s| - 1)!}{n!} (Weight)$$

where $s(i)$ is all subsets that contains member i of set I, $|s|$ indicates the number of players in coalition s, n is the number of all game players in I, and $w|s|$ represents the weight that is actually the probability that a member contributes to the coalition. In $w(|s|) = \frac{(n-|s|)!(|s|-1)!}{n!}$, $n!$ is the number of permutations of n members, $(|s|-1)!$ represents the number of permutations of the former members of the coalition before the entry of member i, and $(n-|s|)!$ denotes the number of permutations of the latter members after the entry of member i. $v(s)$ denotes the payoff of coalition s, and $v(s\backslash i)$ is the payoff of coalition s minus member i's payoff. After member i joins the coalition s, its marginal payoff can be denoted as $v(s) - v(s\backslash i)$, that is, member i' contribution to the coalition.

(ii) Partial Coalition:

When the green and nongreen manufacturers form a coalition (GN coalition), the profit function is as follows:

GN coalition:

$$\max_{w_G, w_N, m} \pi_{GN} = (w_G - c_G)(a - p_G + bp_N + \gamma m) - \eta m^2 + (w_N - c_N)(a - p_N + bp_G)$$

The retailer:

$$\max_{p_G, p_N} \pi_R = (p_G - w_G)(a - p_G + bp_N + \gamma m) + (p_N - w_N)(a - p_N + bp_G)$$

We obtain

$$m = \frac{\left(c_G - b^2 c_G - ba - a\right)\gamma}{8b^2\eta + \gamma^2 - 8\eta}$$

$$w_G = \frac{\left(4b^2 c_G - 4ba - 4a - 4c_G\right)\eta + \gamma^2 c_G}{8b^2\eta + \gamma^2 - 8\eta}$$

$$w_N = \frac{\left(8b^2 c_N - 8ba - 8a - 8c_N\right)\eta + \gamma^2(bc_G + a + c_N)}{16b^2\eta + 2\gamma^2 - 16\eta}$$

$$p_G = \frac{\left(2b^2 c_G - 6ba - 6a - 2c_G\right)\eta + \gamma^2 c_G}{8b^2\eta + \gamma^2 - 8\eta}$$

$$p_N = \frac{\left(8b^2 c_N - 24ba - 24a - 8c_N\right)\eta + (3bc_G + 3a + c_N)\gamma^2}{32b^2\eta + 4\gamma^2 - 32\eta}$$

When the green manufacturer and the retailer form a coalition (GR coalition), the profit function is as follows:

GR coalition:

$$\max_{p_G, p_N, m} \pi_{GR} = (p_G - c_G)(a - p_G + bp_N + \gamma m) - \eta m^2$$
$$+ (p_N - w_N)(a - p_N + bp_G)$$

The nongreen manufacturer:

$$\max_{w_N} \pi_N = (w_N - c_N)(a - p_N + bp_G)$$

We obtain

$$m = \frac{\left(c_G - b^2 c_G - ba - a\right)\gamma}{4b^2\eta + \gamma^2 - 4\eta}$$

$$w_N = \frac{a + bc_G + c_N}{2}$$

$$p_G = \frac{\left(2b^2 c_G - 2ba - 2a - 2c_G\right)\eta + \gamma^2 c_G}{4b^2\eta + \gamma^2 - 4\eta}$$

$$p_N = \frac{4(b+1)\left(b^2 c_G + (a + c_N - c_G)b - 3a - c_N\right)\eta + (3c_G b + 3a + c_N)\gamma^2}{16b^2\eta + 4\gamma^2 - 16\eta}$$

When the non-green manufacturer and the retailer form a coalition (NR coalition), the profit function is as follows:

NR coalition:

$$\max_{p_G, p_N} \pi_{NR} = (p_N - c_N)(a - p_N + bp_G) + (p_G - w_G)(a - p_G + bp_N + \gamma m)$$

The green manufacturer:

$$\max_{w_G, m} \pi_G = (w_G - c_G)(a - p_G + bp_N + \gamma m) - \eta m^2$$

We obtain

$$m = \frac{(c_G - bc_N + a)\gamma}{\gamma^2 - 8\eta}$$

$$w_G = \frac{\gamma^2 c_G - (4bc_N + 4a + 4c_G)\eta}{\gamma^2 - 8\eta}$$

$$p_G = \frac{\begin{array}{c}\left(1-b^2\right)\left(4\eta(bc_N+a+c_G)-\gamma^2 c_G\right)\\ -(b+1)a(\gamma^2-8\eta)+\gamma^2(bc_N+a-c_G)\end{array}}{2(b^2-1)(\gamma^2-8\eta)}$$

$$p_N = \frac{(b^2c_N-ba-a-c_N)(\gamma^2-8\eta)+b\gamma^2(bc_N+a-c_G)}{2(b^2-1)(\gamma^2-8\eta)}$$

(iii) Grand Coalition

The grand coalition (GNR coalition) is consistent with the centralized case. The green manufacturer's Shapley values are as follows.

The green manufacturer's payoff is

$$\phi_G^*(v) = \pi_G^*/3 + (\pi_{GN}^* - \pi_N^*)/6 + (\pi_{GR}^* - \pi_R^*)/6 + (\pi^* - \pi_{NR}^*)/3$$

Similarly, the nongreen manufacturer's payoff is

$$\phi_N^*(v) = \pi_N^*/3 + (\pi_{GN}^* - \pi_G^*)/6 + (\pi_{NR}^* - \pi_R^*)/6 + (\pi^* - \pi_{GR}^*)/3$$

The retailer's payoff can be obtained as

$$\phi_R^*(v) = \pi_R^*/3 + (\pi_{GR}^* - \pi_G^*)/6 + (\pi_{NR}^* - \pi_N^*)/6 + (\pi^* - \pi_{GN}^*)/3$$

(b) Cost-Sharing Contract

Next, we set the retailer to share the green investment costs of the green manufacturer, thereby motivating manufacturers to aim for green transformation and maintaining the cooperative relationship among value chain members. The retailer shares $t(0 \le t \le 1)$ proportion of green investment costs with the green manufacturer [28]. The profit function of each member is as follows:

The profit function of the green manufacturer is

$$\max_{w_G,m} \pi_G = (w_G - c_G)(a - p_G + bp_N + \gamma m) - (1-t)\eta m^2$$

The profit function of the nongreen manufacturer is

$$\max_{w_N} \pi_N = (w_N - c_N)(a - p_N + bp_G)$$

The profit function of the retailer is

$$\max_{p_G,p_N} \pi_R = (p_G - w_G)(a - p_G + bp_N + \gamma m) + (p_N - w_N)(a - p_N + bp_G) - t\eta m^2$$

We obtain

$$m = \frac{\left(2c_G - b^2 c_G - (a + c_N)b - 2a\right)\gamma}{4b^2\eta(1-t) + 2\gamma^2 - 16\eta(1-t)}$$

$$w_G = \frac{\gamma^2 c_G - 2((a + c_N)b + 2a + 2c_G)\eta(1-t)}{2\left(b^2 - 4\right)(1-t)\eta + \gamma^2}$$

$$w_N = \frac{\gamma^2(c_G b + a + c_N) - 4((a + c_G)b + 2a + 2c_N)\eta(1-t)}{4\left(b^2 - 4\right)\eta(1-t) + 2\gamma^2}$$

$$p_G = \frac{(1-b^2)w_G^* + \gamma m^* + (b+1)a}{2(1-b^2)}$$

$$p_N = \frac{(1-b^2)w_N^* + b\gamma m^* + (b+1)a}{2(1-b^2)}$$

We compare the coordination effects of the two internal mechanisms and the economic and environmental parameters of internal and external coordination mechanisms.

(2) External Value Co-Creation Mechanism: Government Subsidies

Green investment has a strong positive externality, and individual benefits are less than the overall social benefits, thus making enterprises lack the internal motivation to invest in green transformation. Therefore, government subsidies are needed to promote the implementation of EGGM by enterprises.

Assumption 4: To encourage the manufacturer to produce green products, the government directly subsidizes the green manufacturer on green level of products. We assume that τm is the unit product subsidy given by the government [29], where m is the green level of products and τ is the unit product subsidy coefficient related to the green level.

(a) Centralized Model (Fig. 6.3)

The profit function for the centralized case is

$$\max_{p_G, p_N, m} \pi = (p_G + \tau m - c_G)(a - p_G + bp_N + \gamma m) + (p_N - c_N)(a - p_N + bp_G) - \eta m^2$$

We obtain

$$m = \frac{(b+1)((b-1)(c_N b + a - c_G)\tau - \gamma(c_G b + a - c_G))}{\left(1 - b^2\right)\tau^2 + \left(-2b^2\gamma + 2\gamma\right)\tau + 4b^2\eta + \gamma^2 - 4\eta}$$

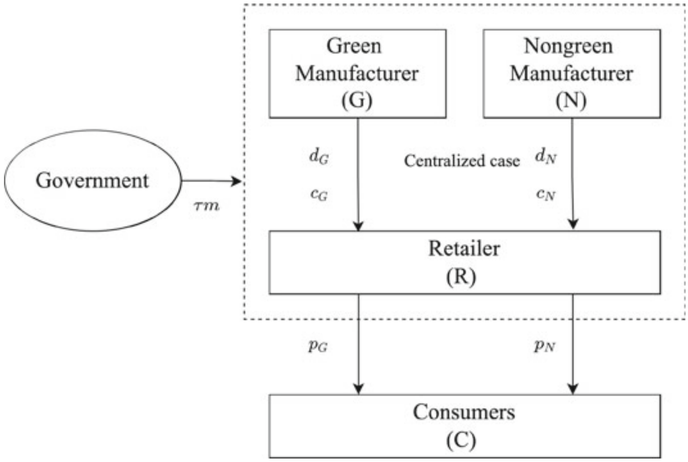

Fig. 6.3 Structure of the value chain considering government subsidies under centralized case

$$p_G = \frac{\begin{array}{l} -(b+1)\left(c_N b^2 + (a - c_N)b - 2a\right)\tau^2 + \left(b^2 c_G + (3a - c_N)b + 2a + 2c_G\right)\gamma\tau \\ + 4b^2\eta c_G - 4ab\eta + 2\gamma^2 c_G - 4\eta(a + c_G) \end{array}}{\left(2 - 2b^2\right)\tau^2 + \left(-4b^2\gamma + 4\gamma\right)\tau + 8b^2\eta + 2\gamma^2 - 8\eta}$$

$$p_N = \frac{\begin{array}{l} (b+1)(-c_N b + a + c_N)\tau^2 + \gamma\left(-3c_N b^2 + (a + c_G)b + 2a + 2c_N\right)\tau \\ + (c_G b + a + c_N)\gamma^2 - 4\eta(b+1)(-c_N b + a + c_N) \end{array}}{\left(2 - 2b^2\right)\tau^2 + \left(-4b^2 + 4\right)\gamma\tau + 8b^2\eta + 2\gamma^2 - 8\eta}$$

(b) Decentralized Model (Fig. 6.4)

The profit function of the green manufacturer is

$$\max_{w_G, m} \pi_G = (w_G + \tau m - c_G)(a - p_G + bp_N + \gamma m) - \eta m^2$$

The profit function of the nongreen manufacturer is

$$\max_{w_N} \pi_N = (w_N - c_N)(a - p_N + bp_G)$$

The profit function of the retailer is

$$\max_{p_G, p_N} \pi_R = (p_G - w_G)(a - p_G + bp_N + \gamma m) + (p_N - w_N)(a - p_N + bp_G)$$

We obtain

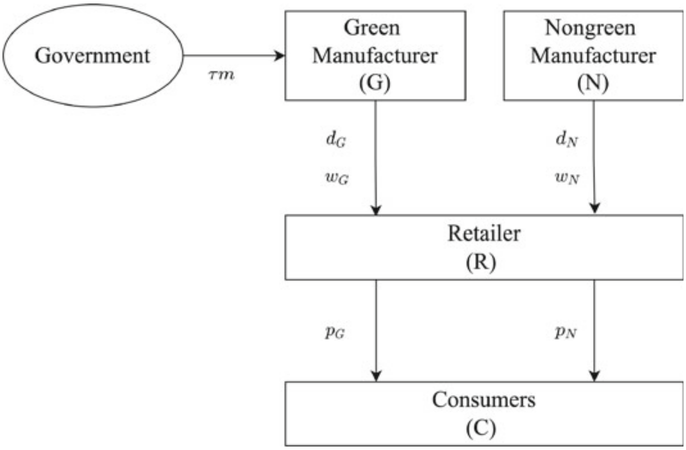

Fig. 6.4 Structure of the value chain considering government subsidies under decentralized case

$$m = \frac{\left(2c_G - b^2 c_G - (a + c_N)b - 2a\right)(\tau + \gamma)}{\left(4\eta - \gamma\tau - \tau^2\right)b^2 + 2\tau^2 + 4\gamma\tau + 2\gamma^2 - 16\eta}$$

$$w_G = \frac{((a + c_N)b + 2a)\tau^2 + \gamma((a + c_N)b + 2a + 2c_G)\tau - 4\eta(a + c_N)b + 2\gamma^2 c_G - 8\eta(a + c_G)}{\left(2 - b^2\right)\tau^2 + \left(-b^2\gamma + 4\gamma\right)\tau + 4b^2\eta + 2\gamma^2 - 16\eta}$$

$$w_N = \frac{(ba + a + c_N)\tau^2 + ((a + c_G)b + 2a + 2c_N)\gamma\tau + (bc_G + a + c_N)\gamma^2 - 4((a + c_G)b + 2a + 2c_N)\eta}{\left(2 - b^2\right)\tau^2 + \left(-b^2 + 4\right)\gamma\tau + 4b^2\eta + 2\gamma^2 - 16\eta}$$

$$p_G = \frac{(1 - b^2)w_G^* + \gamma m^* + (b + 1)a}{2(1 - b^2)}$$

$$p_N = \frac{(1 - b^2)w_N^* + b\gamma m^* + (b + 1)a}{2(1 - b^2)}$$

By setting $a = 5, b = 0.4, \gamma = 0.5, c_G = 2.5, c_N = 1.5, \eta = 1, t = 0.5, \tau = 0.1$, we obtain the coordination results shown in Tables 6.2 and 6.3.

Through comparative analysis and numerical study, we obtain the following findings.

From the perspective of the internal coordination mechanism, the coordination of the Shapley value increases the profits of the green manufacturer, nongreen manufacturer, and retailer, as the Shapley value method allocates profits according to the marginal contribution of members. The Shapley value method solves the double marginalization problem, thus reducing the wholesale and retail prices of products, increasing sales volume, and enhancing the profit of the entire value chain. Consequently, each member of the value chain obtains more profit and achieves value co-creation and sharing among the value chain members. For the product green level, when the green manufacturer and retailer form a coalition, the green manufacturer is motivated to invest in the highest green level, which can effectively solve the externalities of green investment and promote green transformation. Second, the cost sharing contract can also effectively improve the green level of the green manufacturer; however, the retailer's sharing of green investment costs leads to an increase in the selling price of green products. In other words, the retailer transfers the costs to consumers. By contrast, the selling price of nongreen products decreases. Although the cost sharing contract can increase profits among members of the value chain, the Shapley value method has a better coordination effect.

From the perspective of the external coordination mechanism, when the government subsidizes the green product manufacturer, a price advantage for green products emerges, and their market share increases. Meanwhile, the market share of nongreen products decreases. Therefore, the government can use subsidy policies to effectively control the proportion of green and nongreen products in the market. Government subsidies increase not only the profits of green manufacturers but also the profits of retailers and the overall value chain because of the increase in sales of green products. However, nongreen manufacturers' profits decrease. This indicates that the profit increase in the market share of green products exceeds the decrease in the market share of nongreen products, thereby increasing profits in the overall value chain.

Table 6.2 Coordination results

Coordination methods		m	w_G	w_N	p_G	p_N	π_G	π_N	π_R	π
Internal coordination mechanism	Decentralized	0.27	4.65	4.18	6.29	6.57	2.25	3.60	4.89	10.73
	Shapley	\	\	\	\	\	2.73	3.91	5.88	12.52
	Cost sharing contract	0.56	4.73	4.20	6.70	6.33	2.33	3.63	4.92	10.88
External coordination Mechanism	Government subsidy (Centralized)	0.90	\	\	5.64	5.02	\	\	\	12.93
	Government subsidy (Decentralized)	0.32	4.65	4.18	6.59	6.30	2.28	3.59	4.95	10.82

Table 6.3 Shapley value method parameters

Coalition	m	w_G	w_N	p_G	p_N	π_{GN}	π_{GR}	π_{NR}	π_G	π_N	π_R
GN coalition	0.38	5.53	4.96	7.04	6.69	6.24	\	\	\	\	3.19
GR coalition	0.78	\	3.75	5.65	6.14	\	8.99	\	\	2.53	\
NR coalition	0.2	4.10	\	6.28	4.94	\	\	10.58	1.24	\	\

By comparing the profits of value chain members, the green levels of products, and the profits of the entire value chain under internal and external value sharing and co-creation mechanisms, we select the optimal coordination mechanism from the perspective of economic goals, i.e., value chain profits, and environmental goals, i.e., product green level. We find that the internal coordination mechanism can motivate the green manufacturer to invest in its green level, for which the Shapley value method can effectively coordinate the profits among value chain members to reach the optimal profits of the value chain relative to the level in the centralized case. The external coordination mechanism of government subsidies can effectively encourage enterprises to invest in green products and increase their market share. The government should subsidize enterprises in the early stage of green transformation so that they can maximize their own targets and optimize the overall profit of the value chain. At present, the green transformation of Chinese enterprises is still in its initial stage, the ability of green management in enterprises is low, and the adoption of environmental protection measures has yet to become a conscious behavior of enterprises. Therefore, at this stage, government subsidies remain the main driving force for enterprises to ensure value co-creation in EGGM. Through proper subsidies, the government can guide and motivate enterprises to adopt green technologies, carry out green transformation, and improve economic benefits to coordinate "green" and "growth" targets.

6.4 Summary

This chapter investigates the value co-creation and sharing mechanism of value chain members in EGGM, that is, their motivation for implementing EGGM. Specifically, this chapter analyzes the main external influencing factors, that is, government, consumers, and internal influencing factors, that is, enterprises' environmental protection technology and value chain structure, of coordination in EGGM. Then, it compares the value chain coordination environment, coordination targets, and changes in enterprise value, consumer value, and value co-creation in EGGM with those in the traditional value chain. Subsequently, this chapter analyzes the path of coordinating value chain members in EGGM. Finally, this chapter proposes internal and external value co-creation and sharing mechanisms, including Shapley value coordination, cost sharing contract coordination, and government subsidies, to promote effective cooperation, coordination, and value sharing among members of the value chain. Consequently, enterprises can achieve overall economic optimization and environmental friendliness for the value chain.

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