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Research on the Development of the Golden Acacia Supply Chain Based on a Three-party Evolutionary Game—Taking the "Gold of Sophora" Quanzhou, Guilin as an Example

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Abstract

In this paper, we selected the acacia production area of Quanzhou, Guilin, China, known as the "gold of acacia", as our research site. We analyzed the behavioral decision-making of the best interests among the three parties by constructing a three-party evolutionary game model of acacia growers, buyers, and sellers. The optimal decision point is found to be (1, 1, 1), the acacia buyers can provide the acacia growers with ordering demand according to the market demand orientation, while the acacia growers will plant and pick the appropriate acacias according to these orders. Additionally, the government will offer excellent services and incentives to both acacia growers and buyers to promote the three parties' sustainable and healthy development. In turn, the government will implement suitable solutions to enhance the low-carbon practices of enterprises. Firstly, the government will promote the establishment of a long-term mechanism through policy initiatives, urging all departments to focus on the development of the golden locust industry and prioritize it as a central task for the state's economic advancement. Secondly, this paper advocates for the creation of an innovative alliance within the golden locust industry, the establishment of an ecological organization dedicated to this sector, and the formation of a green and efficient supply chain system. Simultaneously, enterprises should internally advance low-carbon technologies and contribute to rural revitalization through industrial ecologization and eco-industrialization.

Keywords

Three-way evolutionary game; Golden locust supply chain; Golden locust industry; Rural revitalization; Carbon neutral supply chain

1. Introduction

Global climate change is regarded as one of the great challenges facing human society in the 21st century, which is not only related to changes in the living environment of human beings but also involves the global economy and geopolitical pattern. 2023 global energy carbon emissions reached 37.4 billion tons, which is at an all-time high, and in the face of the increasingly severe climate situation, it is urgent to take active measures to promote the realization of net-zero emission of greenhouse gases. "On September 22, 2020, General Secretary Xi proposed a "dual carbon target" at the 75th session of the United Nations General Assembly, in which China will ensure that its CO_2 emissions peak by 2030 and strive to achieve carbon neutrality by 2060, which will give a strong impetus to the global response to climate change and

accelerate the global GHG emissions reduction. Strengthening the green and carbon-neutral supply chain is an important factor in planning a carbon-neutral pathway for enterprises. In addition, General Secretary Xi attaches great importance to the development of Chinese medicine and has made a series of important instructions, ushering in a favorable situation for the development of Chinese medicine.

Based on golden acacia, a geographical indication of Guilin, this paper investigates the current situation of the carbon-neutral supply chain system of golden acacia and its ecological heterogeneity and isomorphism, with Quanzhou County, the hometown of golden acacia in China, as the research site. "The special climate and original ecological soil composition of Quanzhou have contributed to the golden color of the acacia rice produced in Quanzhou, and the rutin content of the acacia rice in Quanzhou is between 30-42%, which is the most in the world, and the industry recognizes the acacia rice in Quanzhou as the " gold of acacia". Sophora gold", which is also the reason why Quanzhou produced Sophora japonica called golden Sophora japonica. Quanzhou County is located at 26° north latitude, 111° east longitude of the world's most beautiful Guilin, has a unique environment suitable for the growth of acacia trees, so far, acacia planting a total area of more than 270,000 acres, which is the country's planting of acacia the most of a county. Quanzhou County currently has more than a hundred years of age of more than a thousand trees, more than three hundred years of age of more than two hundred trees, and is regarded as the world's treasures. The acacia tree, also known as the locust tree, has a long history of propagation in Jeonju, the birthplace of golden acacia tea is in Jeonju, and the intangible cultural heritage bearer of golden acacia tea is in Jeonju.

In the current acacia rice supply shortage, consumers of acacia medicinal value of the situation, acacia supply chain status quo but there are many rural trading chains, small scale and complex, acacia product information network systems lack of effective orientation, and other issues. Acacia market price fluctuations, acacia growers urgently need the government to play a leading role in the macro to stabilize market prices and regulate the market order. At the same time, under the goal of "double carbon", Guibei acacia also needs to continue to adhere to the carbon reduction and expansion of green, and improve the green supply chain management system of Guibei acacia products. By creating a unique form of carbon sink economy, promoting the industry to low-carbon, green transformation, planting acacia trees, energy saving and emission reduction, as well as strengthening the acacia carbon neutral supply chain system management and other "soft technology" as the main way to improve the regional climatic conditions, in line with the "low-carbon "and zero-carbonization" trend of the times, assume the responsibility of the times, take advantage of the trend, help the country to achieve the "dual-carbon goal", improve and perfect the acacia carbon-neutral supply chain system, and contribute to the sustainable development of the Chinese nation and the construction of the community of human destiny. For the sustainable development of the Chinese nation and the building of a community of human destiny, we are committed to greenhouse gas emission reduction.

2. Analysis of the three-party evolutionary game

2.1 Three-way evolutionary game premise assumptions

(1) Without considering the influence of other conditions, each participant group of the game constitutes a supply chain system. This game analysis involves three main participant groups, i.e., acacia plantation group, acacia acquisition group, and acacia sales group, the three participant groups seek to maximize their own interests, follow the assumption of finite rationality, and learn from each other and emulate each other in the process of the game.

(2) Each participant group in the game will modify the strategy it adopts based on the strategy chosen by the other party.

(3) The strategies of the acacia grower group, the acacia buyer group, and the acacia association are proactive or passive. The probability of the acacia association adopting proactive behavior is x ($0 \leqq x \leqq 1$), and the probability of negative passive behavior is 1-x; the probability of the acacia grower group adopting proactive behavior is y ($0 \leqq y \leqq 1$), and the probability of negative passive behavior is 1-y; the probability of the acacia buyer group adopting proactive behavior is z, and the probability of negative passive behavior is 1-z ($0 \leqq z \leqq 1$).

(4) In the game process, when the gold locust association chooses to take the initiative to provide services, it will support or serve the gold locust grower group, giving the comprehensive benefit for I service support, if the support strength of the gold locust association is α, then the gold locust grower group is subjected to the strength of the service support of the gold locust association is αI, and at the same time, it will penalize the gold locust grower group's speculative behaviors, such as substandard goods, etc., M (in the form of contractual margin), if the If the strength of the punishment is β, the acacia grower group will be punished as βM. When the acacia buyer group takes the initiative the acacia association will give the acacia buyer group the incentive Rp, if the strength of the incentive is γ, the acacia buyer group will be rewarded as γRp. The acacia association chooses to take the initiative to provide the service to obtain the benefit (government encouragement, acacia common brand premium, etc.) as Rg, the acacia association takes the initiative to provide the service to obtain the cost as Cg; and the cost for the association to take the initiative is Cg. proactive services is Cg; the cost of negative passive service support taken by the Golden Locust Association is Cg′ (Cg> Cg′). The loss suffered by

each participant when a negative event occurs in the process of value creation and realization in the whole acacia supply chain is Fp. The cost for the acacia buyer group to choose proactive purchasing is Ce, and if they choose speculative or passive purchasing the cost is Ce′ (Ce> Ce′), and when the acacia association or acacia growers find out that the acacia buyer group violates the law to cause losses to the acacia growers, the cost of the loss is K, which is borne by the gold locust buyers. For the gold locust buyer group, the cost of proactive acquisition is Cp and the reward from the gold locust association is Rp. The related parameters and meanings are shown in Table 1 below.

Table 1. Indicators and data related to the three-party evolutionary game

Indicator symbol	Significance of the indicator
Rg	Benefits derived from the proactive services chosen by the Society of the Golden Sophora Association
Cg	The Golden Locust Association adopts the cost of proactive services
Cg ′	Costs of passive and reactive service support by the Golden Locust Society
Fp	Losses incurred by each participant in the event of a negative incident in the entire Kim Sopo supply chain
Ce	The cost of choosing proactive purchasing by gold locust buyers
Ce ′	The cost of choosing speculative or passive purchases by gold acacia acquirers
K	Golden acacia buyers' violations cause losses to golden acacia growers
Cp	The cost of proactive acquisition by gold locust buyers
Rp	Rewards for proactive purchasing by gold locust buyers
I	Combined benefits received by acacia growers when the government actively regulates services
α	The support and services provided by the Golden Sophora Association to golden sophora growers
M	Penalization of speculative behaviors such as negative production by acacia growers
β	The extent to which speculative behaviors such as negative production by acacia growers are penalized
γ	Strength of government incentives for acacia buyers for aggressive acacia purchasing behavior

2.2 Equilibrium analysis of the tripartite evolutionary game among acacia grower group, acacia buyer group, and acacia seller group

Let $\mathbf{U_{A1}}$ be the benefit of proactive service provision by the Golden Locust Association, $\mathbf{U_{A2}}$ the benefit of passive service support by the Golden Locust Association, and $\overline{\boldsymbol{U_A}}$ be the average benefit of proactive service provision and passive service support by the Golden Locust Association.

$$U_{A1} = yz(Rg - Cg - \gamma Rp - K - \alpha I) + y(1-z)(Rg - Cg - K - \alpha I) + (1-y)z(Rg - Cg - \gamma Rp + \beta M) + (1-y)(1-z)(Rg - Cg + \beta M) \tag{1}$$

$$U_{A2} = yz(-Cg' - \gamma Rp - K) + y(1-z)(-Cg') + (1-y)z(-Cg' - \gamma Rp + \beta m) + (1-y)(1-z)(-Cg' - Fp) \tag{2}$$

$$\overline{U_A} = xU_{A1} + (1-x)U_{A2} \tag{3}$$

Let $\mathbf{U_{B1}}$ be the gain from acacia growers actively cooperating with buyers' contracts to sell acacia, $\mathbf{U_{B2}}$ be the gain from acacia growers negatively cooperating with buyers' contracts to sell acacia, and $\overline{\boldsymbol{U_B}}$ be the average gain from acacia growers actively cooperating with buyers' contracts to sell acacia and the gain from acacia growers' speculative behaviors such as substandard selling (penalized with a negative gain).

$$U_{B1} = xz(\alpha I - Ce) + x(1-z)(\alpha I - Ce) + (1-x)z(-Ce) + (1-x)(1-z)(-Ce) \tag{4}$$

$$U_{B2} = xz(-Ce' - \beta M - K) + x(1-z)(-Ce' - \beta M - K) + (1-x)z(-Ce' - K - \beta m) + (1-x)(1-z)(-Ce' - Fp) \tag{5}$$

$$\overline{U_B} = yU_{B1} + (1-y)U_{B2} \tag{6}$$

Let $\mathbf{U_{C1}}$ be the gain from the gold acacia acquirer's choice of proactive purchasing and $\mathbf{U_{C2}}$ be the gain from acacia acquirers choosing speculative or passive purchasing, and $\overline{\boldsymbol{U_C}}$ be the average gain from acacia acquirers choosing proactive purchasing and speculative or passive purchasing.

$$U_{C1} = xy(\gamma Rp - Cp) + x(1-y)(\gamma Rp - Cp) + (1-x)(1-y)(\gamma Rp - Cp) + (1-x)y(\gamma Rp - Cp) \tag{7}$$

$$\overline{U_C} = zU_{C1} + (1-z)U_{C2} \tag{8}$$

$$U_{C2} = (1-x)(1-y)(-Fp) \tag{9}$$

2.3 Dynamic equations for the evolutionary replication of the tripartite game among groups of acacia growers, acacia buyers, and acacia sellers

Based on the principle of replication dynamic equations, the replication dynamic equations for the proactive service delivery strategy of the Golden Locust Association are constructed according to equations (1) and (2) as:

$$\begin{aligned} F(x) &= \frac{dx}{dt}x(U_{A1} - \overline{U_A}) = x(1-x)(U_{A1} - U_{A2}) \\ &= x(1-x)[Rg - Cg + \beta M + Cg' + Fp - y\beta M - yK - yFp \\ &\quad - y\alpha I + z(-Fp - \beta M + yK + y\beta M + yFp)] \end{aligned} \tag{10}$$

According to Equations (4) and (5), it can be constructed the replication dynamic equation of gold acacia growers actively cooperating with the purchaser's contract to sell gold acacia strategy as:

$$\begin{aligned} F(y) &= \frac{dy}{dt}y(U_{B1} - \overline{U_B}) = y(1-y)(U_{B1} - U_{B2}) \\ &= \beta m - zFp + x(\beta m + k - Fp + zFp - zk - z\beta m) \end{aligned} \tag{11}$$

According to Equations (7) and (8), it can be constructed the replication dynamic equation of gold acacia growers actively cooperating with the buyers' contract sales of gold acacia strategy as:

$$\begin{aligned} F(z) &= \frac{dz}{dt}z(U_{C1} - \overline{U_C}) = z(1-z)(U_{C1} - U_{C2}) \\ &= z(1-z)[\gamma Rp - Cp + Fp - xFp - y(Fp - xFp)] \end{aligned} \tag{12}$$

2.4 Analysis of the evolutionary asymptotic stability point of the tripartite game among acacia growers, acacia buyers, and acacia sellers

Let $\mathbf{F(x) = 0}$ get x=0, x=1 two zeros;
Let $\mathbf{F(y) = 0}$ get y=0, y=1 two zeros;
Let $\mathbf{F(z) = 0}$ get z=0, z=1 two zeros.

The set of replicated dynamic equations consisting of Eqs. (*10), (*11), and (*12) have a value domain of [0,1] × [0,1] × [0,1], and the asymptotic stability of the equilibrium of the evolutionary game is (0, 0,0), (0, 0,1), (0, 1,0), (0, 1,1), (1, 0, 0), (1, 0, 1), (1, 1,0), and (1, 1, 1).

$\mathbf{F(X)} = \frac{dx}{dt} = \mathbf{0}$, $\mathbf{F(Y)} = \frac{dy}{dt} = \mathbf{0}$, $\mathbf{F(Z)} = \frac{dz}{dt} = \mathbf{0}$, that is, the rate of change of the system strategy is 0, at this time, the system is in a stable state will not change the strategy with the change of time, at this time, when and only when a certain combination of strategy system is a strict Nash equilibrium, the combination of strategies in the evolutionary game system is stable, and the strict Nash equilibrium solution is a pure strategy Nash equilibrium solution, so for the gold acacia grower group, gold acacia buyer group, Gold locust association's evolutionary game equilibrium analysis only need to discuss the asymptotic stability of the eight system equilibrium points of (0,0,0), (0,0,1), (0,1,0), (0,1,1), (1,0,0), (1,0,1), (1,1,0), and (1,1,1).

Conclusion 1: When (0, 0, 0) is the asymptotic stabilization point, it indicates that when the cost reduction of proactive

service provision by the acacia association is greater than the benefit of proactive service provision by the acacia association plus the punishment given by the acacia association when speculative behaviors such as second best are committed by acacia growers and the social loss caused by speculative behaviors such as second best by acacia growers, the acacia association will resort to passive and reactive service support. When the cost reduction of speculative behaviors such as second-guessing by acacia growers is greater than the social loss caused by speculative behaviors such as second-guessing by acacia growers, acacia growers will adopt speculative behaviors. When the cost of acacia buyers choosing proactive purchasing is greater than the benefit of acacia buyers choosing proactive purchasing plus the social loss caused by speculative behaviors such as second-guessing by acacia growers, the acacia associations will adopt the strategy of passive service support.

Conclusion 2: When (0, 0, 1) is the asymptotic stabilization point, it indicates that when the gain obtained by the gold locust association is less than the difference between the cost of the gold locust association's proactive service provision and passive service provision plus the cost of service support and the service support given by the gold locust association side to the gold locust growers to provide the service support, the gold locust association will adopt the passive service support strategy; when the gain of the speculative behaviors of the gold locust growers' second-guessing and other speculative behaviors is more than the fulfillment service When the cost of support plus the penalty given by the association when the speculative behavior of acacia growers is substandard, the acacia growers will choose the strategy of substandard speculation; when the cost of acacia buyers choosing to purchase proactively is greater than the benefit of acacia buyers choosing to purchase proactively plus the social loss caused by the speculative behavior of acacia growers being substandard, the acacia association will adopt the strategy of passive service support; When the gains from speculative behaviors such as substandard purchasing by acacia growers are greater than the cost of performance service support plus the penalty given by the acacia association side when acacia growers choose to engage in speculative behaviors such as substandard purchasing, acacia growers will choose to engage in speculative behaviors such as substandard purchasing.

Conclusion 3: When (0,1,0) is the asymptotic stabilization point, it indicates that the acacia association will adopt a passive-passive service support strategy when the benefits obtained by the association are less than the difference between the cost of proactive and passive service provision by the acacia association plus the cost of performance service support and the benefits of service support given by the association to acacia growers. When the cost reduction of speculative behaviors such as substandard acacia growers is less than the social loss caused by speculative behaviors such as substandard acacia growers, the acacia growers will adopt the strategy of proactively cooperating with purchasers' contractual sales of acacia. When the cost of choosing proactive purchasing by acacia buyers is greater than the benefit of choosing proactive purchasing by acacia buyers, acacia buyers will choose the strategy of speculative or passive purchasing.

Conclusion 4: When (1,0,0) is the asymptotic stabilization point, it indicates that the acacia association adopts passive service support when the cost reduction of the acacia association adopting passive service support is less than the benefit of the acacia association adopting passive service support plus the punishment given by the acacia association when acacia planters choose speculative behaviors such as substandard purchasing as well as the social loss caused by the acacia planters adopting speculative behaviors such as substandard purchasing. When the benefits of speculative behaviors such as second best are greater than the cost of performance support plus the punishment given by the acacia association when acacia growers adopt speculative behaviors such as second best, acacia growers will adopt speculative behaviors such as second best; when the cost of acacia buyers choosing proactive purchasing is greater than the benefits of acacia buyers choosing proactive purchasing, acacia buyers will choose the strategy of speculative or passive purchasing. strategy.

Conclusion 5: When (1,1,0) is the asymptotic stabilization point, it indicates that the acacia association will adopt the strategy of proactive service provision when the benefits obtained by the association are greater than the difference between the costs of proactive and passive service provision by the association plus the cost of fulfillment service support and the service support given to acacia growers by the association. When the benefit of speculative behavior such as substandard acacia growers is less than the cost of fulfillment service support plus the penalty given by the acacia association when acacia growers engage in speculative behavior such as substandard acacia growers, acacia growers will adopt the strategy of proactively cooperating with purchasers in contractual sales of acacia. When the cost of choosing proactive purchasing by acacia buyers is greater than the benefit of choosing proactive purchasing by acacia buyers, acacia buyers will choose the strategy of speculative or passive purchasing.

Conclusion 6: When (1,0,1) is the asymptotic stabilization point, it indicates that when the cost of proactive service provision by the golden acacia association is less than the cost of passive service provision plus the benefits gained by the golden acacia association, the golden acacia association adopts a proactive service provision strategy.

When the benefits of speculative behaviors such as second best are greater than the cost of performance service support plus the penalties given by the acacia association when acacia growers engage in speculative behaviors such as second best, acacia growers will choose speculative strategies such as second best. When the cost of choosing proactive purchasing by acacia buyers is less than the benefit of proactive purchasing, acacia buyers will choose a proactive purchasing strategy.

Conclusion 7: When (0,1,1) is the asymptotic stabilization point, it indicates that when the cost of proactive service provision by the golden acacia association plus the benefit of service support to golden acacia growers by the golden acacia association is greater than the cost of passive service support taken by the association plus the benefit gained by the association the association will adopt the strategy of passive service provision support in a passive manner, and when the benefit of speculative behaviors such as substandard purchasing by golden acacia growers is less than the cost of when the cost of performance service support plus the penalty given by the acacia association when acacia growers engage in speculative behaviors such as substitution, acacia growers will adopt the strategy of actively cooperating with purchasers in contractual sales of acacia. When the cost of choosing proactive purchasing by gold acacia buyers is less than the benefit of proactive purchasing, gold acacia buyers will choose the strategy of proactive purchasing.

Conclusion 8: When (1,1,1) is the asymptotic stabilization point, it indicates that when the cost of proactive service provision by the golden acacia association plus the benefits of service support from the golden acacia association to the golden acacia growers is less than the cost of passive service support taken by the association plus the benefits gained by the association the golden acacia association will choose the strategy of proactive service provision, and when the benefits of speculative behaviors such as substandard selling to the golden acacia growers will be less than the benefits of when the cost of the fulfillment service support plus the penalties given by the acacia association when acacia growers engage in speculative behaviors such as substandard sales, the acacia growers will choose the strategy of proactively cooperating with the buyers' contracted sales of acacia. When the costs of proactive purchasing by acacia buyers are less than the benefits of proactive purchasing, acacia buyers will choose a proactive purchasing strategy.

3. Conclusions and recommendations

3.1 Conclusions of the study

It can be concluded that (1,1,1) is the best three-party strategy of the three-party game, in which the government adopts the service strategy of active supervision, the acacia growers adopt the strategy of active production and sales of acacia, and the acacia buyers choose the strategy of active purchase of acacia. In the process of adopting this strategy, the acacia buyers will provide the acacia growers with orders according to the market demand, while the acacia growers will plant and pick the appropriate acacias according to the order demand, and the government will provide excellent services and rewards to the acacia growers and acacia buyers to promote the sustainable and healthy development of the three parties.

3.2 Research recommendations

Through the research and analysis, it can be seen that the industrial chain of the acacia processing system should be based on two-way effective supply and demand and value co-creation and sharing, systematic risk control, with the government providing related public services, optimizing the business environment, leading the way, following the principle of marketization, the enterprise contractual cooperation, and promoting the synergistic support of industry-related elements and cross-border integration through a variety of means to achieve the interests of the participating main bodies of the industry chain upstream, midstream and downstream. Harmonization.

3.2.1 The government promotes the establishment of long-term mechanisms by policy

The government promotes and regulates the leverage through the policy, establishes the long-term mechanism of collaborating and supporting the related enterprises and elemental institutions of golden locust, lengthens the industrial chain, weaves the industrial network, and after collaborating and supporting the formation of a certain scale, looks for a few key nodes through the assessment of the experts, and then develops the industrial chain to the "industrial tree", so as to build the characteristic scale industry.

3.2.2 Establishing an ecological alliance of the golden locust industry

Through mutual shareholding, long-term cooperation agreements, the establishment of non-profit coordinating organizations, the establishment of project companies, and other ways to cooperate, expand business, and achieve market intensification and value co-creation and sharing.

3.2.3 Constructing innovative organizations in the gold locust industry

Industrial innovation clusters emphasize the same value chain as a link, pooling innovative resources such as talent, knowledge, and technology to form an aggregation effect. Constructing the innovative organization of the Jinhuai industry is an integrated and collaborative mode composed of all parties in the industrial chain with enterprises as the main body, market-oriented, and innovation as the purpose. Under the background of globalization and differentiation of external knowledge resources, gold locust industry affiliates, especially gold locust pharmaceutical enterprises can optimize the allocation of innovation resources only through in-depth cooperation.

3.2.4 Systematic marketing and promotion

Golden locust and its derivatives of its products and market scope are relatively narrow, the current demand is not wide enough, which needs to find reasons in marketing to expand the demand market, open up new markets, etc., from the golden locust and its derivatives, especially from the medical health care living, tourism cross-border management to expand the demand for golden locust and its derivatives of the state, the demand for expanding the golden locust and its derivatives of the influence of the golden locust and its derivatives, to build the golden locust state total Brand. Promote the registration of trademarks of golden locust and its derivatives, seize the market, enhance the position, and formulate relevant policies to promote the branding of golden locust and its derivatives.

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