Research on the benefits of digital enabled agricultural products circulation

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Abstract. Taking digital portraits to empower new consumption of agricultural products as the research theme, this paper studies the digital label information in the whole life cycle of digitally empowered agricultural products from breeding to terminal sales. At the same time, this paper introduces the game theory model to discuss the dynamic game process among agricultural producers, distributors and consumers in the context of the circulation of agricultural products empowered by digital portraits under the condition of relatively complete digital information, using economic bargaining model to deduce and calculate the economic benefits brought by the figures to the circulation of agricultural products.

1 Introduction

As a traditional agricultural country, China's agriculture occupies a pivotal position in the national economy and people's lives. At present, China's agricultural products trade in a variety of ways, and the supply chain and agricultural industrialization models are constantly innovating. However, no matter what transaction method is used, price is widely discussed as an important factor. During transaction negotiation, we can abstract this process as a bargaining model. Xiaolian Zhou et al. described the bargaining model as a game model based on cooperation in *The Bargaining Game Model and Its Realistic Supplement*. The game of agricultural product circulation and sales is a manifestation of the comparison of information between the supply and demand sides. In order to solve this problem to achieve a win-win situation means it's necessary to reduce the information gap between the two parties on the circulation of agricultural products.

Based on the above research, this paper relies on bargaining model to calculate digital benefits. In today's digital economy era, digital is not only the productivity of industrial upgrading, but also the assets and even resources of the new era. Therefore, the introduction of digital benefits into the game of agricultural industry embodies the benefits brought by data to improve information transparency for both sides through the calculation of digital benefits, so as to improve the circulation efficiency of agricultural products and reduce the circulation cost to promote new consumption to provide a certain reference.

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2 Model hypothesis

Hypothesis 1: in the trading and circulation of agricultural products, producers, distributors or consumers of agricultural products have a game on how to make decisions to maximize their own interests. All parties aim to maximize their own interests, that is, they are rational economic people.

Hypothesis 2: producers or distributors of agricultural products cooperate with consumers. π is the binding benefit of the two. The effort of producers or distributors of agricultural products and consumers is positively correlated with π .

Hypothesis 3: t is the number of stages in the dynamic game of agricultural product trading and circulation, which is a positive integer. In the t-period bargaining model, the producer or distributor of products first proposes the profit sharing, and then the consumer proposes the profit sharing, and the two parties alternately propose the profit sharing in turn.

Hypothesis 4: there is negotiation cost, and the discount proportion is added to the model δ ($0<\delta<1$), indicating the bargaining power of agricultural producers or distributors and consumers, which are represented by δ_f and δ_m respectively.

Hypothesis 5: the return rate in the total expected π of the agricultural product producer or distributor is expressed by E_f, and the agricultural product producer or distributor only knows $E_f \sim$ [a, b] ($0\le a\le b\le 1$). However, consumers constantly adjust [a, b] according to the behavior of producers or distributors of agricultural products. In the same way, means that consumers have the lowest expectation of E_m for producers or distributors of agricultural products, and consumers are always aware of $E_m \sim$ [c, d] ($0\le c\le d\le 1$). However, producers or distributors of products can continuously adjust [c, d] based on consumer behavior. Assuming $a<c\le b<d\in[0, 1]$, the game has practical meaning and representativeness.

3 Model building

When t=1, the agricultural product producer or distributor first proposes the profit sharing E_{f1}. From the perspective of a rational economic man, the agricultural product producer or distributor's proposed profit sharing is greater than or equal to the ideal profit sharing, that is, $E_{f1}\ge E_f$. Consumers can choose to agree or disagree with the ideas of producers or distributors of agricultural products. If and only if the agricultural product producer or distributor proposes that the benefit share does not exceed the consumer's bottom line, that is, $E_{f1}\le E_m$, the consumer will agree to this benefit distribution, and the two parties can further bargain. If the consumer agrees, the game ends. According to the plan put forward by the producer or distributor of agricultural products, the benefit is distributed, that is, the producer or distributor of agricultural products gets the bundled benefit $\pi^* E_{f1}$, and the rest $1-E_{f1}$ is distributed by consumers. Obviously, knowing the expected distribution of benefits between the two parties in the game, the benefits of both parties in bargaining are $(E_{f1}-E_f,\ E_m-E_{f1})$. If consumers disagree with the distribution plan proposed by the producer or distributor of products, the game enters the t=2 stage.

When t=2, the consumer proposes to distribute the benefit E_{m1}. Similarly, from the perspective of a rational economic man, consumers propose that the distribution benefit is less than or equal to the bottom line expectation, that is, $E_{m1}\le E_m$. Producers or distributors of agricultural products can agree or disagree with the consumer's proposal. If and only if the consumer benefit distribution is not less than the ideal benefit of the agricultural product producer or distributor, that is, $E_{m1}\ge E_f$, the agricultural product producer or distributor agrees to this benefit distribution. If they disagree, then the game ends, The distribution of benefits is based on the distribution of consumer plans, that is, consumers get bundled

benefits $\pi^*(1-E_{m1})$, and producers or distributors of agricultural products get bundled benefits $\pi^* E_{m1}$. In view of the discount rate, in the bargaining process, the gains of both sides of the game are [$\delta_f(E_{m1}-E_f)$, $\delta_m(E_m-E_{m1})$]. If the agricultural product producer or distributor disagrees, then the game enters the t=3 stage.

When t=3, the agricultural product producer or distributor proposes to distribute the benefit E_{f2}. In a similar way, if $E_{f2} \geq E_f$, consumers can agree or disagree. If and only if $E_{f2} \leq E_m$, the consumer will agree, and in this case, the game ends. The benefit is based on the distribution plan of the agricultural product producer or distributor, that is, the agricultural product producer or distributor gets the bundled benefit $\pi^* E_{f2}$, and the consumer gets the bundled benefit $\pi^*(1-E_{f2})$. Under such circumstances, the discount rates of the two sides of the game are δ_f^2 and δ_m^2 respectively, so in the bargaining process, the benefits of the two sides of the game are [$\delta_f^2(E_{f2}-E_f)$, $\delta_m^2(E_m-E_{f2})$]. If the consumer disagrees, then the game enters the t=2 stage. It is observed that producers or distributors of agricultural products propose distribution benefits in the 2t-1 stage, while consumers propose distribution benefits in the 2t stage.

4 Solution method for model

4.1 Stage 3: balanced solution between the two sides of the game

First analyze the t=3 consumer choice. For consumers, this is the last time. If the consumers disagree, the result of the game between the two parties is zero bundled income. Therefore, if the self-income $\delta_m^2(E_m-E_{f2}) \geq 0$, the consumer will agree. At this time, in the bargaining process, the income of the producer or distributor of products is $\delta^2(E_{f2}-E_f)$.

Discussion on the distribution of benefits proposed by producers or distributors of agricultural products. When the agricultural product producer or distributor relies on the digital information brought by the agricultural product digital portrait to be relatively complete, they know that the lowest expected benefit of consumers at this stage is $\delta_m^2(E_m-E_{f2}) \geq 0$. At this time, the information density function of agricultural product producers or distributors is 0, and the rest of the interval estimates continue to obey the uniform distribution. Producers or distributors of products adjust their minimum expected benefits E_m based on the distribution benefits of consumers in the t=2 stage, so that $E_m \sim [E_{m1}, d]$. Therefore, producers or distributors of agricultural products consider how to choose E_{f2} to maximize their own interests, that is, $\max[\delta_f^2(E_{f2}-E_f)*P_{mca}+0*P_{mch}]$.

where, P_{mca} and P_{mch} represent the probability that the distributor or consumer agrees and disagrees with E_{f2}.

$$P_{mca}=P[\delta_m^2(E_m-E_{f2})\geq 0]=P[E_m \geq E_{f2}]=\frac{d-E_{f2}}{d-E_{m1}} \tag{1}$$

Then
$$P_{mch}=1-P_{mca}=\frac{E_{f2}-E_{m1}}{d-E_{m1}} \tag{2}$$

Combining the above three equations, the optimal first-order condition is solved:

$$E_{f2}=\frac{d+E_f}{2} \tag{3}$$

Therefore, in the t=3 stage, the largest digital benefit brought by the producer or distributor of agricultural products by relying on the digital information of consumers' "preferences" reflected in the digital portraits of agricultural products is $\delta_f^2(\frac{d-E_f}{2})$.

4.2 Stage 2: balanced solution between the two sides of the game

By analyzing the distribution of benefits E_{m1} by consumers at stage t=2, consumers adjust the benefits E_f agreed by the producers or distributors of agricultural products based on the information at stage t=1, so that E_f~[a, E_{m1}]. If the producer or distributor of agricultural products agrees to E_{m1}, the following must be met:

$$E_f \geq \frac{2E_{m1}-d\delta_f}{2-\delta_f} \tag{4}$$

Therefore, after consumers make the digital information of agricultural products relatively complete based on the digital portrait, they still need to consider how to choose E_{m1} to maximize their own interests, namely $\max[\delta_m(E_m-E_{m1})*P_{ca}+\delta_m^2(E_m-E_{f2})*P_{mca}]$.

Among them, P_{ca} represents the probability that an agricultural product producer or distributor agrees to E_{m1} at the t=2 stage.

$$P_{ca}=P[E_f\geq\frac{2E_{m1}-d\delta_f}{2-\delta_f}]=\frac{E_{f1}(2-\delta_f)-2E_{m1}+d\delta_f}{(2-\delta_f)(E_{f1}-a)} \tag{5}$$

Combining the above two equations with the results of the first stage, the optimal first-order condition E_{m1} is solved:

$$E_{m1}=a+\sqrt{\frac{(E_m-E_{f2})(E_{f2}-a)(2-\delta)(E_{f1}-a)(d-E_{f2})}{2a(\delta_f-1)-2E_m-(2-\delta_f)(E_{f1}-a)}} \tag{6}$$

Therefore, in the t=2 stage, the digital benefit of consumers making the agricultural product information relatively complete based on the digital portrait is $\delta_m[E_m-a+\sqrt{\frac{(E_m-E_{f2})(E_{f2}-a)(2-\delta)(E_{f1}-a)(d-E_{f2})}{2a(\delta_f-1)-2E_m-(2-\delta_f)(E_{f1}-a)}}]$.

4.3 Stage 1: balanced solution between the two sides of the game

Entering the t=1 stage of the model based on the equilibrium solution of the second and third stages above.

At the t=1 stage, the distribution benefit E_{f1} proposed by the producer or distributor of agricultural products, if the consumer agrees, if and only if:

$$E_m-E_{f1}\geq\delta_m[E_m-a-\sqrt{\frac{(E_m-E_{f2})(E_{f2}-a)(2-\delta)(E_{f1}-a)(d-E_{f2})}{2a(\delta_f-1)-2E_m-(2-\delta_f)(E_{f1}-a)}}] \tag{7}$$

Therefore, producers or distributors relying on the digital information of consumers' "preferences" reflected in digital portraits, they need to consider how to choose E_{f1} to maximize their own interests, that is $\max[(E_{f1}-E_f)*P_a+\delta_f(E_{m1}-E_f)*P_{ac}+\delta_f^2(E_{f2}-E_f)*P_{acm}]$.

where P_a is the probability that the consumer agrees to E_{f1} at t=1. P_{ac} represents the probability that the consumer disagrees with E_{f1} at t=1 and the producer or distributor of agricultural products agrees with E_{m1} at t=2. P_{acm} represents the probability that when a consumer t=1 disagrees with E_{f1}, an agricultural product producer or distributor t=2 disagrees with E_{m1} and a consumer t=3 agrees with E_{f2}.

$$P_a = \frac{b - E_{f1}}{b - a} \tag{8}$$

$$P_{ac} = \frac{E_{f1} - a}{b - a} * \frac{E_{f1}(2 - \delta_f) - 2E_{h1} + d\delta_f}{(2 - \delta)(E_{f1} - a)} \tag{9}$$

$$P_{acm} = \frac{E_{f1} - a}{b - a} * [1 - \frac{E_{f1}(2 - \delta_f) - 2E_{h1} + d\delta_f}{(2 - \delta)(E_{f1} - a)}] * \frac{d - E_{f2}}{d - E_{m1}} \tag{10}$$

Combining the above three equations with the results of the first and second stages, the optimal first-order condition is solved:

$$E_{f1} = \frac{1}{4}\left[2E_1 + \delta_1(E_m - 2E_f + a) + \delta_m(a - b) + 2b\right] \tag{11}$$

4.4 Equilibrium contract between the game parties

The game equilibrium is obtained when producers or dealers propose to allocate benefits when the digital information of agricultural products is relatively complete. In other words, the proportion of expected binding benefits π proposed by agricultural producers or distributors at t=2 stage is $\frac{1}{4}\left[2E_1 + \delta_1(E_m - 2E_f + a) + \delta_m(a - b) + 2b\right]$, and the part of binding benefits is allocated to distributors or consumers, and consumers agree. It can be observed that any bargaining will eventually reach an agreement. However, the risk of canceling the agreement always exists, which has an impact on the distribution of benefits and the final result of the two parties in all stages of bargaining. Assume that r_f and r_m represent the critical expectations in the game between producers or distributors and consumers. Critical expectations depend on the combination of internal and external choices, and producers or distributors (consumers) will not agree when it is below r_f (r_m). Combining the if and only conditions in the t=1 stage, the equilibrium contract between the producer or distributor of agricultural products and the consumer is $\max\left[\pi\ r_m; \pi\ (1 - E_{f1})\right]$, where $E_{f1} \geq r$.

5 Conclusion

Regarding how to maximize the benefits of all parties in the supply and demand chain of agricultural products or maximize the overall benefits, this paper uses the bargaining game model to calculate the optimal benefits, and proposes the digital benefits of the agricultural product supply and demand chain and the digital portrait theory of agricultural good products. Through the backward induction method, the optimal game equilibrium solution of the supply and demand sides when the digital information of agricultural products is relatively complete under the empowerment of digital portraits is derived. By relying on digital portraits to empower the circulation of agricultural products, all parties can share the benefits of digital, give play to the spillover effect of information and the inclusive effect of digital technology, and promote new consumption.

Project Name: Design and Implementation of Digital Portrait of Agricultural Products. Item Number: X2021-266

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