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Cooperative Game of Income Allocation of Shell-egg Industry Supply Chain

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***Abstract*—The Shapley-like value for cooperative interval games was introduced to study the income allocation problem of shell-egg industry supply chain in China. In this paper, the cooperative game model and the example analysis method of Shapley model are used to explore the influence of game participants' alliance behavior under various cooperation situations, such as the number of game participants, weighting factor, income, cost, shell egg weight, loss and so on. According to the reality of the China's market, the dominant situation of big supermarket and farmers need to be considered for the time being. Meanwhile this study turns out that the heavy costs is borne by middlemen or farmers and their profit obtained in the supply chain is relatively small. Finally, from the point of view of shell-egg market industry chain, a series of management enlightenment is given.**

Keywords*—shell egg; supply chain; allocation; game theory; Shapley

I. INTRODUCTION

Shell eggs are rich in nutrition and are one of the main sources of protein in dietary nutrition of residents. China is a big producer and consumer of shell eggs, and according to FAO statistics, production of Chinese shell eggs has maintained a world leading position since it first overtook the United States in 1985 [1]. The laws of developed countries and regions in Europe and the US prohibit the sale of bulk shell eggs. Shell eggs must pass through hygienic standards and be graded and packaged before they can enter the market. But the domestic shell egg market, because the income allocation on industry supply chain is unreasonable, the legal standard has not been perfected, the human environment and the consumption habit and so on, most of the shell eggs have not gone through any processing directly into the market, resulting in the greater security risks of shell-egg market in China. In response to the growing demand for safe shell eggs in the market and to the 2015 central "First Document" proposed "to increase farmers' income, it is necessary to extend the agricultural industry chain" [2], shell egg grading and industrial chain upgrading is an inevitable trend in the future. Meanwhile forming mutual incentive, reciprocal bond and balanced income, the management mechanism is one of the necessary means to improve the supply chain efficiency of shell and egg industry.

This paper discusses the supply chain cooperation mode of shell and egg industry-"solo management" and "cooperative management", in which "individual management" is mainly divided into: "Farmer" alone operation , "Processor" alone operation, "Big supermarket" alone operation, of which "cooperative management" is mainly divided into: "Farmer + Processor", "Farmer + Big supermarket", "Processor + Big Supermarket", "Farmer + Processor + Big supermarket". Among them, the "Farmer + Big Supermarket" model is considered to be a win-win choice, which can not only increase the income and scale of farmers, but also reduce the cost and risk of large supermarkets. However, in the process of cooperation, because the advantages of farmers are low, the income allocation of farmers on the shell and egg industry supply chain is often not fair protected. Also the contract stability is poor and the rate of breach is higher. "Farmer + Processor + Big supermarket" model is considered to be a maximum benefit of the choice in theory, but it can not form a coordinated, convergent reciprocal symbiotic relationship, because of the higher costs of existing Processors using shell eggs intelligent cleaning, disinfection, sorting, packaging and other technical and the not-yet-landed corresponding national subsidy policy. Thus, the unstable, unreliable and inefficient "farmer + Big Supermarket" model is difficult to evolve into a stable, reliable and efficient "Farmer + Processor + Big supermarket" model through the full supply chain.

II. LITERATURE REVIEW

Domestic academic research on the shell-egg industry problems gradually in on the development, mainly around the industry status, income distribution status, distribution methods and so on. Qin et al. through the investigation found that China's shell egg consumption , processing accounted for less than 5% , while the United States processed egg products accounted for 33%, Europe accounted for about 20%~30%, Japan accounted for 50%. Therefore, China's shell-egg deep processing industry needed to expand , and would welcome in a rapid development period[3]. Yu et al. through the investigation of North China to get: egg prices was under pressure in short term, and a good development was expected from the medium to long term. Medium and long-term positive factors include: Firstly, environmental protection to stimulate the expansion of the scale of farm scale , small and medium-sized farms gradually quit and withdraw the market even faster. The expansion rate of large-scale farms was slower than the exit speed of small and medium-sized farms to some extent, and there will be a gap of supply in the future market; Secondly, large-scale farms pay much attention to the food safety and egg epidemic prevention and invest more funds , so that the cost of breeding, large-scale farm was still in a state of break-even. It was necessary to be cautious in expanding of farm; Thirdly, the increasing prices of corn and soybean feed in the second half of 2018 led to an increase in feed costs [4]. Yang et al. through a large number of information and field research of China and the United States and Japan's egg circulation market, it turns out that the coverage of China's market "Farmers + Wholesale Market" model was 50%~60%, the coverage of "Farmers + Company" model was 30%~40%, the coverage of "production and marketing integration" model of product was about 5% [5]. Bai there were serious defects in the management , disease and safety of chickens raised in the current free-range and scattered mode, and suggested that the relevant food safety laws and regulations should be improved and the large-scale modern breeding enterprises should be vigorously developed to meet the growing needs of consumers [6]. Li proposed the profit distribution mechanism of dairy industry chain based on Shapley value method [7]. Huang Yong proposed the benefit distribution mechanism of pork supply chain based on Shapley value method [8].

Foreign scholars mainly focus on various problems of the shell-egg industry chain and the uneven distribution of income phenomenon. Hofman believed that information and information exchange technologies can provide opportunities for agricultural affiliates to increase their competitiveness and increase market share [9]. Clevenger, et al. believed that the government should invest the information exchange technology with a rational reason [10-11]. Hollister first proposed that allocation efficiency was a key factor affecting economic efficiency, and another factor was technical efficiency [12]. Yang found that the inefficiency of factor allocation had a greater impact on agricultural output, especially the improper allocation of elements of small-scale farmers [13]. Chi et al. used stochastic frontier functions to break down total factor productivity into technological progress, technological efficiency, scale efficiency and allocation efficiency, and to distinguish the impact of allocation efficiency on agricultural economic growth from the impact of input scale [14-15]. Samarajeewa, et al. believed that factor allocation efficiency was the key factor restricting productivity, in the development of scale efficiency at the same time, we should pay attention to the rational allocation of factors [16-17].

III. Basic Assumptions and Symbol

A. Basic Assumptions

In order to facilitate game analysis , we make the following assumptions: (1) Although there is only one alliance but any subset within the Alliance may form cooperation; (2) The alliance generated by interaction in the course of the game gets the maximum benefit , the cooperation income is not less than the income when not cooperating; (3) Any sub-union does not send spies to each other. The Alliance is cooperative and non-confrontational; (4) There are three decision-making behaviors of farmers: independent (*I*) , in cooperation with processors (*IM*) or in cooperation with big supermarket (*IS*); there are three types of decision-making behaviors by processors: Independent (*M*) , cooperation with farmers (*MI*) or with big supermarket (*MS*); Big supermarket has three decision-making behaviors: Independent (*S*), working with farmers (*SI*) or with processors (*SM*); (5) in the domestic reality $p_{ij}<p_{ii}$, indicating that cooperation can greatly reduce the purchase price and cost; (6) Considering that the actual dominant decision-making behavior of domestic processors is two kinds: the processor and the farmer cooperate (*MI*) or processor in cooperation with big supermarket (*MS*). Taking the domestic realities into account, it is generally assumed that in *MI*, the purchase price of the processor is the dominant P_{12} of the farmers (considered here are all million chicken farms, large farmers). The *MS* of the purchasing price of the big supermarket is mainly dominant P_{32}.

B. Symbol

- n: the number of game participants;
- i: the No. i of game participants, i=1, 2, …, n;
- I: the set of game participants;
- $V(I)$: the benefit function obtained after the alliance;
- S: the set of n individuals forming an alliance;
- s_i: all subsets of member i are included in collection I;
- $|s|$: number of elements in collection S;
- $(n-|s|)!(|s|-1)!$: consider only the No.i participants in the game who did not join all members prior to alliance S and all members after joining alliance S;
- $(n-|s|)!(|s|-1)!/n!$: each of the sub-alliances of S formed by the cooperation of interest shares a fair share of marginal contributions;
- $w(|s|)$: weighting factor of the set of S;
- $v(s)$: benefits of subset S;
- $v(s|i)$: benefits to be derived from the removal of partner i in subset;
- $\eta_i(v)$: benefits of partner i in the alliance, i=1, 2, 3;
- C_i: cost of breeding,C_1 represents fixed cost, C_2 represents variable cost, i=1, 2;
- P_i: the price of shell eggs sold by farmers, ¥/g per unit, divided into 4 levels according to their weight, i=1, 2, 3, 4;
- P_{ij}: sale price after the cooperation of the No.i and the No. j of game participants ,$P_{ij}\neq P_{ji}$,P_{ij} indicates i advantage in alliance negotiation , P_{ji} indicates j advantage in alliance negotiation ,i or j=1, 2, 3, when $i=j$, average market price;
- V_{ij}: benefits of after the cooperation of the No.i and the No. j of game participants, $V_{ij}\neq V_{ji}$, V_{ij} indicates i advantage in alliance negotiation, V_{ji} indicates j advantage in alliance negotiation, i or j=1, 2,3;

- P_{i0}: dvided into two situations, i=1, 2, P_{10}: the price of shell eggs of online supermarket, ¥/g per unit; P_{20}: the price of shell eggs of offline supermarket, ¥/g per unit;
- W_i: weight of shell eggs sold by farmers, g per unit, divided into 4 levels according to their weight, i=1, 2, 3, 4;
- W_0: loss of breeding in farm, for example, shell and egg deformation, rupture, blood ring, stain, etc.;
- λ: proportion of the feed required to the unit weight of shell eggs;
- C_s: feed costs required in the breeding process;
- P_j: average cost per square metre of chicken coop, ¥/m^2 per unit, according to the egg grade standard is divided into 4 levels, i=1, 2, 3, 4;
- P_{j0}: average housing cost and depreciation cost per gram of eggs in the breeding chain, ¥/g per unit;
- C_c: cocks and hatched chicks is not sold due to the breeding costs(in small quantities), which are counted as the fixed costs that need to be counted in to breeding costs;
- C_0: fixed cost per gram of shell eggs including labor, water and electricity, epidemic prevention, disinfection and death costs in the farming process;
- C_{m1}: purchasing cost and artificial hydropower cost in the processing;
- C_{m2}: the cost of ground rent and processing equipment technology of the plant in the processing;
- C_{n1}: purchasing cost and artificial hydropower cost in big supermarket sales;
- C_{n2}: operating costs in the big supermarket sales.

IV. The Model

A. The Cooperative Game Model

If S represents the set of n individuals forming a alliance, $\forall S_i$,$\exists v(s)$ satisfies:

$v(\varphi)$=0;

$$v\left(s_1 \cup s_2\right) \geq v\left(s_1\right)+v\left(s_2\right), s_1 \cap s_2=\varphi$$

S represents any alliance that may be formed in I, and the characteristic function $v(s)$ represents the maximum benefit that alliance S gains from interaction in the alliance.

If the distribution of n people from $v(I)$, satisfying:

$$\sum_{i=1}^{n} x_i = v\left(I\right),\ x_i \geq v(i),\ i=1, 2, \ldots, n$$

The benefits obtained by the No.i of participants *of* S can be expressed as:

$$x_i=\sum_{s \in S_i} w\left(|s|\right)[v\left(s\right)-v\left(s \mid i\right)],\ i=1, 2, \ldots, n$$

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

In a word, the Shapley value method for the income distribution is carried out mainly according to the contribution degree of the participating subjects. The greater the contribution of members, the more gains they make, and the less the vice versa. This distribution method takes into account the degree of contribution of members and has certain rationality.

B. The Values of the Model

Table I shows that the profit of cooperation is greater than that of independent operation. In general, $V_{11}<V_{12}<V_{13}$, $V_{22}<V_{21}<V_{23}$, $V_{33}<V_{31}<V_{32}$.

TABLE I. VALUES OF SOLO MANAGEMENT AND COOPERATIVE MANAGEMENT

(¥/g)	I	M	S
I	*I*: V_{11}	*IM*: V_{12}	*IS*: V_{13}
M	*MI*: V_{21}	*M*: V_{22}	*MS*: V_{23}
S	*SI*: V_{31}	*SM*: V_{32}	*S*: V_{33}

1) *Solo management:*

$V_{11}=P_{11}-[P_{j0}+C_c+\lambda P_i(W_i-W_0)+C_0]$;

$V_{22}=P_{22}-C_{m1}-C_{m2}-P_{12}$;

$V_{33}=P_{i0}-C_{n1}-C_{n2}-P_{32}$.

2) *Bilateral cooperative management:*

$V_{12}=P_{22}-C_{m1}-C_{m2}-[P_{j0}+C_c+\lambda P_i(W_i-W_0)+C_0]$;

V_{21}: the dominant situation of processors in the alliance is relatively small in China, and it is not discussed in this paper;

V_{13}: the dominant situation of farmers in the alliance is relatively small in China, and it is not discussed in this paper;

$V_{31}=P_{i0}-C_{n1}-C_{n2}-[P_{j0}+C_c+\lambda P_i(W_i-W_0)+C_0]$;

V_{23}: the dominant situation of processors in the alliance is relatively small in China, and it is not discussed in this paper;

$V_{32}= P_{i0}-C_{n1}-C_{n2}-C_{m1}-C_{m2}-P_{12}$;

3) *Tripartite cooperative management:*

$Max\ V= P_{i0}-C_{n1}-C_{n2}-[P_{j0}+C_c+\lambda P_i(W_i-W_0)+C_0]$

Then, an example is used to demonstrate the proportion of income distribution between the participating subjects of the game, which is farmers, processors and big supermarket.

V. Analysis of Samples of The Shapley Value Model

According to the domestic reality analysis and paper research, there are P_{j0}=1×10^{-3}, C_c=2×10^{-3}, $\lambda P_i(W_i\text{-}W_0)$=2× 10^{-3}, C_0=3×10^{-3}, C_{m1}=0.5×10^{-3}, C_{m2}=0.3×10^{-3}, C_{n1}=3×10^{-3}, C_{n2}= 1×10^{-3}, P_{12}=8.5×10^{-3}, P_{22}=9.5×10^{-3}, P_{32}=9.55×10^{-3}, P_{i0}=33×10^{-3}, *Max V*=21×10^{-3}. Calculate profit of each game participant when they run alone and profit of each game participant when they cooperate in the operation. Among them, the calculation of cooperative profit does not calculate the repetition cost during gaming, only the game participants in the cooperative game as a whole, with the total income minus the total cost. (See Table II-V)

TABLE II. Values of Solo Management and Cooperation Management

(¥/g)	I	M	S
I	I: 0.5×10^{-3}	IM:0.7×10^{-3}	IS: 21×10^{-3}
M	MI: 0.7×10^{-3}	M: 0.2×10^{-3}	MS: 19.7×10^{-3}
S	SI: 21×10^{-3}	SM: 19.7×10^{-3}	S: 20×10^{-3}

TABLE III. THE SHAPLEY VALUES OF A FARMER IN DIFFERENT COOPERATION STATES

States	I	IM	IS	IMS
$v(s)$	0.5×10^{-3}	0.7×10^{-3}	21×10^{-3}	21×10^{-3}
$v(s\|i)$	0	0.2×10^{-3}	20×10^{-3}	19.7×10^{-3}
$v(s)$-$v(s\|i)$	0.5×10^{-3}	0.5×10^{-3}	1×10^{-3}	1.3×10^{-3}
|s|	1	2	2	3
$w(\|s\|)$	0.33	0.17	0.17	0.33
$w(\|s\|)[v(s)$-$v(s\|i)]$	0.165×10^{-3}	0.085×10^{-3}	0.17×10^{-3}	0.429×10^{-3}
$\eta_1(v)$	0.849×10^{-3}(¥/g)			

TABLE IV. THE SHAPLEY VALUES OF A COOPERATOR IN DIFFERENT COOPERATION STATES

States	M	MI	MS	MIS
$v(s)$	0.2×10^{-3}	0.7×10^{-3}	19.7×10^{-3}	21×10^{-3}
$v(s\|i)$	0	0.5×10^{-3}	20×10^{-3}	21×10^{-3}
$v(s)$-$v(s\|i)$	0.2×10^{-3}	0.2×10^{-3}	-0.3×10^{-3}	0
|s|	1	2	2	3
$w(\|s\|)$	0.33	0.17	0.17	0.33
$w(\|s\|)[v(s)$-$v(s\|i)]$	0.066×10^{-3}	0.034×10^{-3}	-0.051×10^{-3}	0
$\eta_2(v)$	0.049×10^{-3}(¥/g)			

TABLE V. THE SHAPLEY VALUES OF A SUPERMARKET IN DIFFERENT COOPERATION STATES

States	S	SI	SM	SIM
$v(s)$	20×10^{-3}	21×10^{-3}	19.7×10^{-3}	21×10^{-3}
$v(s\|i)$	0	0.5×10^{-3}	0.2×10^{-3}	0.7×10^{-3}
$v(s)$-$v(s\|i)$	20×10^{-3}	20.5×10^{-3}	19.5×10^{-3}	20.3×10^{-3}
|s|	1	2	2	3
$w(\|s\|)$	0.33	0.17	0.17	0.33
$w(\|s\|)[v(s)$-$v(s\|i)]$	6.6×10^{-3}	3.458×10^{-3}	3.315×10^{-3}	6.699×10^{-3}
$\eta_3(v)$	20.099×10^{-3}(¥/g)			

An analysis of the results of the above example shows that, in general, the overall benefit of cooperation between members is greater than the income of members operating alone. But when the benefit of the "*IS*" model is equal to that of the "*IMS*" model, the operation stability of the "*IMS*" model begins to disintegrate, which means that the supermarket or farmer have no incentive to bring in any processor to participate in their alliance. In terms of the Shapley values, the farmer 's earnings rises from 0.5×10^{-3}¥/*g* before the partnership to 0.849×10^{-3}¥/*g* , an increase of 69.8%; the processor 's earnings rises from 0.2×10^{-3}¥/*g* before the partnership to 0.049×10^{-3}¥/*g* , an decrease of 75.5%; the supermarket 's earnings rises from 20×10^{-3}¥/*g* before the partnership to 20.099×10^{-3}¥/*g* , an increase of 0.495%. The proportion of income distribution varies from 2.4%, 1% and 96.6% to 4%, 0.3% and 95.7% after cooperation. The above sample results show that the processor plays a very important role in coordinating the income allocation relationship between the farmer and the big supermarket in this model. But the ubiquitous situation of the supply chain income allocation of shell-egg industry is universal, in which the large supermarket dominates the alliance relationship, who holds pricing rights and controls sales channels. While the farmer and processor are at a disadvantage, which means that it is easy to bear the greater risk and cost and the income ratio obtained is low. If such shell-egg industry supply chain income allocation could not be changed, it is not conducive to the development of the entire shell-egg industry in the long run.

VI. Management Enlightenments

The supply chain quality and price monitoring system of shell-egg industry need to be established and improved. And the factors that affect the income allocation of shell-egg industry supply chain alliance should be deeply analyzed, such as: number of participants in the alliance, the weighting factor, the state subsidy, the income, fixed cost, variable cost, shell-egg weight, loss, chick, rooster, feed, etc. According to the basic principle of supply chain benefit distribution and the characteristics of shell-egg industry supply chain, the alliance coordination mechanism for the innovation and upgrading of shell-egg industry supply chain is designed.

The state should formulate perfect shell egg grade standard and detect the quality of quarantine shell eggs, starting from the basic work of laws and regulations or industry standards, to solve the problems of transaction risk, quality risk and income risk existing in the supply chain of shell-egg industry, and realize the cost, risk and benefit sharing of the whole supply chain of modern shell- egg industry.

Shell-egg industry should encourage and support the development of farmers, establish cooperation between farmers and processors, promote the large-scale and deep processing of farmers, so as to improve the bargaining power of farmers. In order to realize the increase in the share of farmers in the supply chain of shell-egg industry, the corresponding agricultural machinery subsidies, shell egg breeding subsidies and other policies, which are beneficial to the further development, should be improved and implemented .

Shell-egg industry need to encourage and support the development of processors. Domestic processors are now facing the situation of high costs and little income. The rent, water, electricity, labor, machinery and technical support for processing plants is lacking by the government. In the China's future, through the signing of leasing contracts or purchasing contracts, the introduction of foreign large-scale intelligent shell-egg deep processing machinery would like to enjoy the policy land rent and dividends to ensure the benefits of processors.

The threshold for shell eggs to enter big supermarket should be lowered, and further the bargaining power and pricing rights of large supermarkets need to be standardized. The price of shell-egg products collected by supermarkets should be regulated to ensure the basic rights of consumers. Nowadays, more and more online sales channels are explored by the big supermarket, which further strengthens the proportion of big supermarket's rights and income distribution. It is not conducive to the upgrading of the supply chain of the shell and egg industry. The country should advocate and urge the online and offline sales of large supermarkets and big stores should be combined with processors and farmers to jointly develop steadily.

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REFERENCES

[1] FAO.FAOSTAT [DB/OL]. (2017-12-19). http : // www. fao. Org / faostat/ en/ # data.

[2] XinhuaNet. Several Opinions of the State Council of the CPC Central Committee on Increasing Reform and Innovation and Speeding up Agricultural Modernization Construction (full text) [EB/OL]. (2015-02-02). http : // www.mao.gov.cn / ztzl / yhwj2015 / zywj / 201502 / t20150202_4378754. htm.

[3] Tan S D, Liu Y C, Ma Y, et al.. Investigation and analysis on the breeding status of egg chicken in China [J]. China's Poultry , 2017(24):69-71.

[4] Yu H, Zhang, S Z, Yu L N. Review of egg production situation in 2016 and analysis of 2017 trend in China [J]. Poultry Science, 2017(2):14-17.

[5] Yang D Q, Zhong Y, Liu H G, et al. Present situation and development trend of egg production and trade in the world's main egg producing countries [J]. China's Poultry, 2013 , 35(18):57-60.

[6] Bai J, Cao J, Mi H B, et al.. Effect of different feeding methods on the production performance of hens [J]. China's Forage, 2018(7): 24-27.

[7] Li Z, Hu Z Q. Profit distribution mechanism of dairy industry chain in China [J]. Journal of Arid Land Resources and Environment , 2019 , 33(1): 77-83.

[8] Huang Y. Study on benefit distribution mechanism of pork supply chain based on Shapley value method [J]. Agricultural Technology Economy, 2017(2): 122-128.

[9] Hofman W J , Trienekens J H , Zuurbier P J P. Information and communication technology (ICT) for food and agribusiness.[M]. 2000.

[10] Clevenger T. Internet pharmacies: cyberspace versus the regulatory state.[J]. Journal of Law & Health , 2000 , 15(2):165-178.

[11] Oviedo P , Ruoti Cosp M , Mendoza L , et al. Does ICT Diffusion Increase Government Responsiveness in Autocracies? An empirical assessment of the political implications of China's Internet[J]. Journal of Contemporary China , 2015 , 24(96):1048-1069.

[12] Hollister K K , Koppel N B. Efficient allocation of IT resources.(Information technology)[J]. Hospitals , 1974 , 48(9):45-47.

[13] Yang C X , Xu W Q , Kong L Z , et al. Analysis on the allocation efficiency of science and technology resources of agricultural research institutes at the provincial level based on the panel data of 30 provinces in China.[J]. Journal of Southern Agriculture , 2015, 46(1): 170-174

[14] Chi T. Trading in strategic resources: Necessary conditions , transaction cost problems , and choice of exchange structure[J]. Strategic Management Journal , 1994, 15(4):271-290.

[15] Gode D K , Sunder S. What makes markets allocationally efficient?[J]. Quarterly Journal of Economics , 1997 , 112(2):603-630.

[16] Samarajeewa A D , Schiere H , Viets T , et al. Systems modelling in dairy development under coconut.[J]. Tropical Agricultural Research , 2000 , 80(S3):35-36.

[17] Samarajeewa S, Hailu G, Jeffrey S R, et al. Analysis of production efficiency of beef cow/calf farms in Alberta[J]. Applied Economics , 2012 , 44(3):313-322.

[18] Gallardo J M , Jiménez-Losada A. Comment on "A new approach of cooperative interval games: The interval core and Shapley value revisited"[J]. Operations Research Letters , 2018, 46(4): 434-437.