doi: 10.17221/202/2016-AGRICECON

A conjectural variation approach to vertical integration in agricultural cooperatives

Yung-Chang WANG*

Department of Banking and Finance, Chinese Culture University, Taipei, Taiwan

*Corresponding author: ycwwang@yahoo.com.tw

Wang Y.-C. (2017): **A conjectural variation approach to vertical integration in agricultural cooperatives**. Agric. Econ. – Czech, 63: 228–233.

Abstract: Under the assumption that agricultural cooperative is a form of vertical integration, this paper, using conjectural variations, solves the profit-maximizing problem faced by the members in the multi-plant firm model in which they are vertically integrated with the agricultural cooperative. The average principle, the marginal principle, and the linear combination principle are derived for the competitive behaviour, collusive behaviour, and Cournot behaviour, respectively. The Nash equilibrium and economic efficiency in the cooperative system are then discussed. Finally, the model is numerically solved in an illustration. The marginal principle ensures the cooperative system to remain socially optimal in the competitive market.

Keywords: collusive behaviour, Cournot behaviour, Nash equilibrium, multi-plant firm

The statement on the Cooperative Identity ICA (International Cooperative Alliance) suggests seven guidelines by which cooperatives put their values into practice. They include the voluntary and open membership, democratic member control, member economic participation, autonomy and independence, education, training and information, cooperation among cooperatives, and concern for community.[1] The one-member-one-vote principle is the main theme of the democratic member control. The proportionality principle and the limited compensation on capital are the main themes of the member economic participation. The proportionality principle implies that profit sharing in a cooperative is no more proportionate to shares. Instead, with a negligible compensation on capital, the cooperative distributes its earnings to the members in proportion to their patronages with the cooperative. This paper attempts to address the debate on the marginal principle and the average principle in agricultural cooperatives in the 1950s and 1960s, applying the conjectural variation approach to the multi-plant firm model in which the members are vertically integrated with the agricultural cooperative.[2] It is justified that the members seek to maximize the sum of the profit earned by their own farms and the earnings distributed in proportion to their patronages with the agricultural cooperative which they own and operate.

LITERATURE REVIEW

Staatz (1987) indicates that there has been much of the debate in the cooperative theory focused on whether cooperatives represented a pure form of vertical integration by firms, that is, an extension of firms, or whether cooperatives were organizations having scope for the decision making independent of members. Rehber (1998) argues that the cooperative organization is one worldwide way of vertical

[1]The values and principles of a cooperative are given by the International Cooperative Alliance (http://ica.coop/en/whats-co-op/co-operative-identity-values-principles).

[2]The agricultural cooperative has other purposes than being a vertically integrated plant, such as securing stable prices, maintaining long-term contracts, and increasing regional employment among others (LeVay 1983). Some agricultural cooperatives are organized to enhance the bargaining power. For discussion about the bargaining power of an agricultural cooperative, see Clodius (1957), Ladd (1974), and Lee (1989).

doi: 10.17221/202/2016-AGRICECON

integration and the other three ways are coordination without any contract (open market patronage), contract farming, and ownership integration. Soboh et al. (2009) classify the cooperatives into three types: vertical integration of firms, independent enterprise, and coalition of firms. Rebelo and Caldas (2015) argue that a cooperative will only be effective if its members/patrons are able to get higher net economic benefits than through other alternative forms of vertical integration like spot market, contract farming, quasi-integration or ownership integration.

Nilsson (2001) argues that many co-operatives function well for their members because of their vertical integrated character in order to counteract market failures ion product markets. Salazar and Górriz (2011) investigate the factors that affect the agricultural cooperatives decision of downstream vertical integration into the transformation of the products supplied by their members and analyse the effect of vertical integration on efficiency. Evidence shows that those cooperatives with actualization mechanisms of social capital, high dedication to agricultural activity, and high rate of capacity utilization are more likely to integrate within the cooperative another stage of the production cycle and, furthermore, cooperatives with a higher level of the downstream vertical integration are most efficient. Ratinger and Bošková (2013) find that the dairy firms' organizations in the Czech Republic intermediate 70% of milk sales to dairy industry and thus they represent a significant bargain power. Hanisch et al. (2013) show that dairy cooperatives have a pro-competitive effect and that exemptions for cooperatives from the anti-trust regulation may be justified based on a study of the member states of the EU-27 over the period of 2000–2010.

Under the assumption that the agricultural cooperative is a form of downstream vertical integration by firms, this paper solves the profit-maximizing problem for individual members in the multi-plant firm model with conjectural variations. The marginal principle, the average principle, and the linear combination principle are derived on the assumptions of the competitive behaviour, collusive behaviour, and Cournot behaviour. This paper thus reconciles the average principle with the marginal principle as the decision rules in agricultural cooperatives, which was a debate in the 1950s and 1960s (Phillips 1953; Aresvik 1955; Trifon 1961). The Nash equilibrium and economic efficiency in the cooperative system are then discussed. Finally, the model is numerically solved in an illustration.

MODEL

Suppose that n profit-maximizing firms organize and run an agricultural cooperative, which purchases the input X from these firms, processes it into the output Y and, then, markets the output Y in the final product market.[3] The total revenue and total cost associated with processing and marketing are allocated among the n firms in proportion to their patronages with the cooperative. It is assumed, for the ease of exposition, that the cooperative's marketing technique can turn a unit of X into a unit of Y. The profit-maximizing problem faced by the firm i is given by

$$\begin{aligned} &Max \quad R(Y)\frac{X_i}{X} - C(Y)\frac{X_i}{X} - C_i(X_i) \\ &\{X_i\} \\ &s.t. \quad X = Y \text{ and } X = \sum_{j=1}^{\cdot\cdot} X_j \end{aligned} \tag{1}$$

The $R(Y)$ and $C(Y)$ denote the total revenue and the total cost of the cooperative, X_i/X denotes the proportion of the firm i's patronage to the total patronage with the cooperative, $C_i(X_i)$ denotes the firm i's production cost function. The objective function in the profit-maximizing problem is the firm i's profit equation, which is the difference between the revenue and the costs allocated to and incurred by the firm. The first-order condition for Equation (1) is given by

$$AR(X) + \frac{X_i dAR(X)}{dX}\frac{dX}{dX_i} = AC(X) + \frac{X_i dAC(X)}{dX}\frac{dX}{dX_i} + mc_i(X_i) \tag{2}$$

The $AR(X)$ and $AC(X)$ denote the average revenue and the average cost, respectively, and $mc(X_i)$ denotes the firm i's marginal production cost.

Since the revenue and cost are allocated among members in proportion to their patronages with the agricultural cooperative, a change in the firm i's patronages has an impact on the revenue and cost allocated to the others through changing the cooperative's average revenue and average cost.[4]

[3]This is the forward or downstream vertical integration. A similar analysis can be applied to the backward or upstream vertical integration.

doi: 10.17221/202/2016-AGRICECON

The other firms would thus respond to this change. However, the firm i does not know in advance how they would respond to this change. The firm i can only guess other firms' changes in their patronages with the cooperative. This is referred to as the conjectural output variation, denoted by $k = dX/dX_i$, or the conjectural variation for short.[5] Equation (2) is, therefore, rewritten as

$$AR(X) + kX_i \frac{dAR(X)}{dX} = AC(X) + kX_i \frac{dAC(X)}{dX} + mc_i(X_i) \quad (3)$$

What is the firm i's conjecture about the changes the other firms would make in response to its own change? We make three assumptions about the other firms' behaviour. They include $k = 0$, $k = X/X_i$ and $k = 1$.

The assumption of $k = 0$ implies the competitive behaviour. If the firm i believes that the cooperative's average revenue and average cost would not be affected by the change in its own patronage with the cooperative, then Equation (3) reduces to

$$AR(X) = AC(X) + mc_i(X_i) \quad (4)$$

This is exactly the average principle argued by Aresvik (1955) and Trifon (1961). They claim that the average principle is the profit-maximizing condition for vertical integration by the firm i. When the change in the firm i's patronage with the cooperative is negligible, the incremental revenue associated with an additional unit of output is the average revenue and the incremental cost associated with the same unit is the average cost.

Equation (4) is also written as

$$NAR(X) = mc_i(X_i) \quad (5)$$

$NAR(X)$, the net average revenue of the agricultural cooperative, is defined as the difference between the average revenue and the average cost. Equation (5) indicates that the firm i will adjust its patronage with the cooperative until its own marginal cost equals the cooperative's net average revenue. It is evident that the total income received by each of the firms results exclusively from its own farm. The cooperative's profit vanishes since the NAR(X) equals the input price determined by $mc_i(X_i)$, the marginal production cost of the input incurred by firm i. Moreover, it is noted that the output level marketed to the consumers by the cooperative is maximized.

The assumption of $k = X/X_i$ implies the collusive behaviour. If the firm i believes that the other firms would change their patronages with the cooperative proportionately, then Equation (3) reduces to

$$MR(X) = MC(X) + mc_i(X_i) \quad (6)$$

This is exactly the marginal principle argued by Phillips (1953). Phillips (1953) claims that the marginal principle is the profit-maximizing condition for the cooperative vertical integration by the firm i. This is analogous to the profit-maximizing condition for the ownership vertical integration discussed in the conventional microeconomic textbooks. When the change in the firm i's patronage with the cooperative induces the other firms to adjust their patronages proportionately, the incremental revenue associated with an additional unit of output is the marginal revenue and the incremental cost associated with the same unit is the marginal cost.

Equation (6) is also written as

$$NMR(X) = mc_i(X_i) \quad (7)$$

$NMR(X)$, the net marginal revenue of the agricultural cooperative, is defined as the difference between the marginal revenue and the marginal cost. Equation (7) indicates that the firm i would adjust its output until its marginal production cost equals the cooperative's net marginal revenue. The total income received by each of the firms has two components, namely the firm's own profit and its share in the cooperative's profit referred to as the surplus rebate. Following the marginal principle, the member firm earns the maximum total income among the three operating principles.

The assumption of $k = 1$ implies the Cournot behaviour. If the firm i believes that there would be no changes in the other firms' patronages with the cooperative, that is, the change in the total patronages is exactly the same as that in the firm i's patronage with the cooperative, then Equation (3) becomes[6]

[4]The fewer the member firms are, the closer the interdependence among them is.

[5]Conjectural variations are used to observe the firm's behavior in the oligopoly market. To guess how the industry output would respond to a change in a given firm's output is referred to as the conjectural industry output variation or, for short, the conjectural variation.

[6]Setting $k = 1$, we rearrange the left-hand side of Equation (3) and obtain $AR + (Xi/X)((X/dX)dAR + AR - AR)$. Substituting $MR = (X/dX)dAR + AR$ into the above expression yields the left-hand side of Equation (8). Similarly, the

doi: 10.17221/202/2016-AGRICECON

$$\frac{X_i}{X}MR(X)+(1-\frac{X_i}{X})AR(X)=\frac{X_i}{X}MC(X)+(1-\frac{X_i}{X})AC(X)+mc_i(X_i) \quad (8)$$

Equation (8) indicates that, when the other firms do not respond to this change, the incremental revenue and cost associated with the change in the firm i's patronage with the cooperative are a linear combination of the marginal revenue and the average revenue as well as a linear combination of the marginal cost and average cost with X_i/X and $1 - X_i/X$ as the weights, respectively. We may refer to Equation (8) as the linear-combination principle, which is somewhere between the average principle and the marginal principle. If X_i/X approaches 0, that is, the firm i's patronage with the cooperative is negligible as compared with the total patronages, then Equation (8) will reduce to Equation (4), which is the average principle claimed by Aresvik (1955) and Trifon (1961). On the contrary, if X_i/X approaches 1, that is, the firm *i*'s patronage with the cooperative is almost as large as the total patronages, then Equation (8) will reduce to Equation (6), which is the marginal principle argued by Phillips (1953). It is evident that the average principle and the marginal principle are two extremities of the linear-combination principle.

Equation (8) is also written as

$$\frac{X_i}{X}NMR(X)+(1-\frac{X_i}{X})NAR(X)=mc_i(X_i) \quad (9)$$

Equation (9) indicates that the firm *i* would adjust its output until its own marginal production cost equals the weighted average of the net marginal revenue and the net average revenue of the agricultural cooperative. Each of the firms obtains its total income from two sources as it does in Case 2, that is, its own profit from the farm and its share in the cooperative's profit. The profit earned from the farm here is larger than that that in Case 2, while the cooperative's profit is smaller than that in Case 2. However, the sum of the earnings from the farms and the cooperative's profit is larger than that in Case 1, but smaller than that in Case 2.[7]

EQUILIBRIUM AND EFFICIENCY

From Equations (5), (7), and (9), we know that the firm i could not be in disequilibrium while the other firms are all in equilibrium. In the case of the linear-combination principle, the conditions for all firms to attain equilibrium are

$$\frac{X_i^*}{X^*}NMR(X^*)+(1-\frac{X_i^*}{X^*})NAR(X^*)=mc_i(X_i^*) \quad i=1,\ldots,n \quad (10)$$

X_i^* and X^* denote the firm *i*'s optimal patronage and the optimal total patronages with the cooperative, respectively. If the *n* equations in Equation (10) are mutually independent, then the equilibrium values for the *n* unknowns $X_1^*, X_2^*, \ldots, X_n^*$ can be solved. The firms with higher marginal costs would be more in equilibrium with smaller patronages than those with lower marginal costs.

Given that *n* equals 2 and the two firms are identical, Equation (10) is thus written as

$$\frac{1}{2}NMR(X^*)+\frac{1}{2}NAR(X^*)=mc(X_1^*)=mc(X_2^*) \quad (11)$$

From which X^* is readily solved and $X_1^*=X_2^*=1/2X^*$.

Three principles have been so far derived to determine the optimum input level in the agricultural cooperative by using the conjectural variation approach. They include the average principle, the marginal principle, and the linear-combination principle. Which of the three principles is preferred from the viewpoint of economic efficiency? Economic efficiency is obtained at the equality between the marginal social benefit and marginal social cost, thereby the welfare of the society being maximized. The efficiency condition is thus given by

$$AR(X) = MC(X) + mc_i(X_i) \quad (12)$$

$AR(X)$ denotes the marginal social benefit and $MC(X) + mc_i(X_i)$ denotes the marginal social cost.[8] It is apparent that none of the three principles meets the condition for the economic efficiency. However, in the competitive market the demand curve is horizontal

right-hand side of Equation (8) is derived from the right-side of Equation (3) when it is rearranged with $MC = (X/dX)\,dAC + AC$ substituted.

[7]On the other hand, if the behaviour of an agricultural cooperative is analyzed in the context of the cooperative firm, in addition to the traditional profit maximization, the objectives include the maximum net average revenue, the maximum surplus rebate per unit of input, the maximum producer surplus plus profit and the maximum input subject to a no loss constraint. For detail, see LeVey (1983) and Vitaliano (1977).

[8]It is here assumed that there are no externalities.

doi: 10.17221/202/2016-AGRICECON

Table 1. Equilibrium values of selected variables for the three operating principles

Operating Principle	X, Y (1)	$AR = P_y$ (2)	$mc(Xi)$ (3)	NAR (4)	NMR (5)	π_c (6)	PS_f (7)	PS_c (8)	CS (9)	(7) + (8) + (9) = (10)
Marginal	22.2	77.8	11.1	45.4	11.1	762.7	123.5	987.7	246.9	1358.0
Average	37.6	62.4	18.8	18.8	–50.4	0	353.6	225	707.1	1285.7
Linear Combination	27.4	72.6	13.7	37.0	–9.7	638.2	187.7	863.2	375.3	1426.2
Maximum Social Welfare	28.6	71.4	14.3	35.0	–14.3	591.3	204.1	816.3	408.2	1428.6

and, hence, the $AR(X)$ equal to $MR(X)$. Equations (6) and (12) turn to be identical. The marginal principle, therefore, ensures the cooperative system to remain socially optimal in the competitive market.

NUMERICAL ILLUSTRATION

Suppose that two identical firms producing X organize and run an agricultural cooperative. The cooperative purchases X from the firms as an input, transforms a unit of input X into a unit of output Y by processing, and then markets the output Y to the consumers. The cost and revenue functions relevant to the cooperative are given by

Cost function of output: $C(Y) = Y^2 + 225$

Average cost: $AC(Y) = Y + \frac{225}{Y}$

Marginal cost: $MC(Y) = 2Y$

Demand function for Y: $P_y = AR(Y) = 100 - Y$

Marginal revenue of output: $MR(Y) = 100 - 2Y$

Net average revenue of input:

$$NAR(Y) = 100 - 2Y - \frac{225}{Y}$$

Net marginal revenue of input: $NMR(Y) = 100 - 4Y$

The cost functions relevant to the firms are given by

Cost function of input: $C(X_i) = \frac{1}{2} X_i^2$, $i = 1, 2$

Marginal cost of input: $mc(X_i) = X_i$

For each of the operating principles, we calculate the equilibrium values of the input and output (X, Y), the price or average revenue of output ($AR = P_y$), marginal cost of input ($mc(X_i)$), net average revenue of the output (NAR), the net marginal revenue of the output (NMR), cooperative's profits (π_c), the firms' producer surplus or profits (PS_f), the cooperative's producer surplus (PS_c), the consumer surplus (CS), and the social welfare measured as the sum of the producer surplus and consumer surplus ($PS_f + PS_c + CS$). The results are summarized in Table 1.[9]

22.2 units of output are marketed and the firms earn a maximum income of 886.1 (= 762.7 + 123.5) if the marginal principle is used to determine the output level in the cooperative. 37.6 units of output are marketed and the firms earn a maximum producer surplus or profit of 353.6 if they follow the average principle. It is noted that their total income is also 353.6 because the cooperative is operating at the break-even point. However, the consumer surplus is maximized at a level of 707.1 in this case. 27.4 units of output are marketed and the firms earn the total income of 825.8 (= 187.7 + 638.2) if they run the cooperative with the linear combination principle as their decision rule. The least deadweight loss is incurred in this case because the associated welfare of society rises to 1426.2, only next to the maximum level of 1428.6 when the firms take the decision rule in Equation (12).

CONCLUSION

The agricultural cooperative is treated as a joint plant owned and operated by the cooperating firms. The revenue and cost resulting from the operation in the cooperative are allocated among the firms in proportion to their patronages with the cooperative. It implies that a change in any firm's patronage with the cooperative would affect the other firms' benefits through its effect on the revenue and cost of the cooperative. The member firms are thus mutually interdependent. Each firm in the cooperative chooses a level of patronage with the cooperative so that its total income, the profit earned from its own farm and the profit sharing in the agricultural cooperative might be maximized. Without the assumption about the other firms' reaction to a firm's change in its patronage with the cooperative, it would be impossible to determine the firm's profit-maximizing patronage in the cooperative system. The conjectural variation

[9]The cooperative's producer surplus is larger than its profit (π_c) by 225 which is the fixed cost in the cost function. For the two firms, their income earned from the farm is equal to their producer surplus due to absence of fixed costs in their cost function.

doi: 10.17221/202/2016-AGRICECON

approach is thus used to solve the optimization problem faced by the firm in the multi-plant firm model.

In the case of competitive behaviour, we derive a profit-maximizing condition for the firm i that is exactly the average principle proposed by Aresvik as the equilibrium condition for the cooperative vertical integration. However, in the case of collusive behaviour, we derive a profit-maximizing condition for the firm i that is exactly the marginal principle proposed by Phillips. In the case of Cournot behaviour, we derive a weighted average of the former two cases. It is referred to as the linear combination principle. It is easy to find that the average principle and the marginal principle are both the extreme cases of the linear combination principle. The debate on whether the average principle or the marginal principle is the equilibrium condition in the cooperative system in the 1950s and 1960s can be readily reconciled by using the conjectural variations to solve the multi-plant firm model.

The concept of the Nash equilibrium is applicable to the three cases since the firm i cannot be in equilibrium while the other firms are not. It implies that the cooperative system is in equilibrium if and only if each of the members is optimally behaving. Facing the negatively-sloped demand curve for the final product, the agricultural cooperative cannot produce output at a socially optimum level no matter whether the average principle, the marginal principle or the linear combination principle is undertaken. However, in the competitive market where the demand curve is horizontal to the individual firms, the cooperative would remain socially optimal with the marginal principle undertaken.

REFERENCES

Aresvik O. (1955): Comments on "economic nature of the cooperative association". Journal of Farm Economics, 37: 140–144.

Clodius R.L. (1957): The role of cooperatives in bargaining. Journal of Farm Economics, 39: 1271–1281.

Hanisch M., Rommel J., Müller M. (2013): The cooperative yardstick revisited: panel evidence from the European dairy sectors. Journal of Agricultural & Food Industrial Organization, 11: 151–162.

Ladd G.W. (1974): A model of a bargaining cooperative. American Journal of Agricultural Economics, 56: 509–519.

Lee S.C. (1989): Opportunism, Vertical Integration, and Exclusive Dealing Contracts in Cooperative Organizations. Unpublished Dissertation. Ohio State University.

LeVay C. (1983): Agricultural co-operative theory: A review. Journal of Agricultural Economics, 34: 1–44.

Nilsson J. (2001): Organizational principles for co-operative firms. Scandinavian Journal of Management, 17: 329–356.

Phillips R. (1953): Economic nature of the cooperative association. American Journal of Agricultural Economics, 35: 74–87.

Ratinger T., Bošková I. (2013): Strategies and effects of milk producers' organizations in the Czech Republic. Agricultural Economics, 59: 113–124.

Rebelo J., Caldas J. (2015): The economic role of the Portuguese agricultural cooperatives. Revista de Economia e Sociologia Rural, 53: 91–102.

Rehber E. (1998): Vertical Integration in Agriculture and Contract Farming. Working Paper 46. A Joint USDA Land Grant University Research Project, United States Department of Agriculture, Washington, DC.

Salazar I., Górriz G.C. (2011): Downstream vertical integration and efficiency implications in agricultural cooperatives. The B.E. Journal of Economic Analysis & Policy, 11: 1–26.

Soboh R.A., Lansink A.O., Giesen G., Van van Dijk G. (2009): Performance measurement of the agricultural marketing cooperatives: The gap between theory and practice. Review of Agricultural Economics, 31: 446–469.

Staatz J.M. (1987): Recent developments in the theory of agricultural cooperatives. Journal of Agricultural Cooperation, 2: 74–95.

Trifon R. (1961): The economics of cooperative ventures: Further comments. Journal of Farm Economics, 43: 215–235.

Vitaliano P. (1977): The theory of cooperative enterprise: Its development and present status. Agricultural Cooperatives and the Public Interest, 21–42.

Received June 29, 2016
Accepted August 4, 2016
Published online December 16, 2016