# Evaluation of agricultural supply chain collaboration operation effectiveness base on DEA and ICA-DEA

Recebimento dos originais: 29/02/2020
Aceitação para publicação: 21/07/2020

**Kaijun Yu**
PhD in Engineering
Institute: Library, Shanghai University of Medicine &Health Sciences
Address: No. 279, Zhouzhu Highway, Pudong New Area, Shanghai, CHINA
E-mail: yukj@sumhs.edu.cn

**Song Luo**
Institute: Department of Equipment, The Affiliated Hospital of Guizhou Medical University
Address: No. 28, Guiyi Street, Guiyang, Guizhou, CHINA
E-mail: luoosong@163.com

**Xuejun Zhou**
Institute: Department of Equipment, The First People's Hospital of Nantong
Address: No.6, Hai'erxiang North Road, Nantong, Jiangsu, CHINA
E-mail: zhouxuejun66@126.com
(Corresponding author)

**Abstract**

Along with the advance of technology and transportation, produce demand and supply is no longer restricted to various countries or certain areas. The guarantee of the quality, completeness, safety, diversity, and relevant service information of produce is urgent. The effective grasp of pulsation and prospect of agriculture relies on the grasp of speed and efficiency. The rapid development of new technology drives the emergence of new economy and changes the past pure linear relationship between suppliers and customers into collaborative operation to develop closer collaborative partnership, through contractual supply relationship and structure the supply chain with close integration of production, supply, and marketing. DEA and ICA-DEA are utilized in this study to estimate the agricultural efficiency of 9 prefecture-level cities in Fujian Province. The research results and suggestions are proposed according to the results, expecting to achieve the mutual cooperation and work specialization among enterprises in the agriculture system and create stronger industrial competitive advantage for the supply chain system.

**Keywords**: Agriculture. Supply chain collaboration. Effectiveness evaluation.

## 1. Introduction

Along with rising consumer awareness and globally competitive environment, the product life cycle is shortening and consumers are increasing the requirement for quality. To satisfy consumer demands, firms gradually replace traditional artificial production with more precise and expensive automated production. Besides, due to the advance of information and logistics, firms, in face of global markets, constantly pursue market expansion and enhance market share that the flexible and rapid responses could not be easily completed by a single firm. The structure of supply chain systems is therefore applied to share the pressure of costs and production capacity so that firms could focus on the specialty to form work specialization. Nevertheless, when many supply chain management programs focus on the development of information technology, CPFR proposes a brand-new thinking and advocates solving the discrepancy between supply and demand, thoroughly making overall consideration of business partners' business models to reduce all supply and demand uncertainties down to the lowest. It results in significant effectiveness on reducing inventory, increasing sales, enhancing collaborative operation efficiency, and improving cash flow and return on investment. In the collaboration system, a performance management system is necessary. After the system receives orders, the optimal order planning program is sought from various practicable programs to achieve customer needs, provide customers with high-quality and reasonable production price products, and cope with the changeable environment to shorten delivery and rapid responses.

The acceleration of global competition, reduction of profits, short product life cycle, and increase in customer requirements reflect the shortening time for responding to demands. The grasp of market demand and rapid response to demand become extremely important. Along with the advance of technology and transportation, the demand and supply of produce are no longer restricted to various countries or certain areas. It is urgent to guarantee the quality, completeness, safety, diversity, and relevant service information of produce. The pulsation and prospect of agriculture could be effectively grasped by the grasp of speed and efficiency. The rapid development of new technology drives the emergence of new economy, changes past pure linear relationship between suppliers and customers into mutually collaborative operation, and develops the contractual supply relationship into closer collaborative partnership to structure the overall supply chain with tight connection among production, supply, and marketing. In this case, the agricultural supply chain collaboration operation effectiveness is evaluated in this study, expecting to achieve the mutual cooperation and work specialization among enterprises in the agriculture system and create stronger industrial competitive advantage for the supply chain system.

## 2. Literature Review

### 2.1. Collaboration

Cho et al. (2017) indicated that, along with the development of supply chain management, future competition was no longer the competition among enterprises, but the competition among supply chains. To integrate supply chains to be more competitive in the fiercely changing environment, a common goal was necessary and the system members' power should be integrated. Aiming at supply chain management, Wunderlich & Beck (2017) pointed out an important premise that all value chain members should change the conflict with the goal of supply chain management to assist in the supply chain management, i.e. traditionally emphasized short-term effectiveness. In fact, trust and exchange were the cores between supply chain management suppliers and buyers. Benitez et al. (2018) mentioned that, along with the public emphasis on JIT, total quality management, and supply chain management, the relationship between buyers and suppliers gradually changed from mutual competition to mutual cooperation to strengthen the competitive advantage of the entire system. Besides, evaluations were not made on a single supplier, but on all collaborative partners to consider the overall performance of the supply chain. Kim & Schoenherr (2018) stated that a manufacturer, in order to successfully achieve the innovation of supply chain system, had to regard suppliers as a part of the enterprise for continuous improvement and find out long-term collaborative partners through supplier development and evaluation. Gregory et al. (2018) indicated that traditional supplier-buyer relationship focused on individual position, but not utilize close cooperation to create higher profits. Xian et al. (2018) mentioned that traditional focus on multiple sources, price competition, and mutual restraint with short-term contracts revealed the characteristic of mutual hostility that the selection of suppliers tended to short-term product quality and price, but ignored suppliers' long-term ability. In this case, purchasers and suppliers would seek for the lowest production cost in the transaction. Yan et al. (2016) stated that the relationship between both parties also focused on short-term contracts. Such price-driven transaction caused limited communication in the transaction, the hostility resulted in little trust among firms, and little technological information would be shared before purchasers completing norms.

## 2.2. Supply chain collaboration

Hao & Song (2016) indicated that supply chain collaboration system members were linked to cooperatively complete customer demands through the outsourcing of orders; besides, increasing collaborative partners made it become more complicated. In this case, when analyzing manufacturing process, the order information process should be understood and production firms was regarded as a single analysis unit expanding to the entire supply chain collaboration in order to correctly reflect the overall system information. Ataseven & Nair (2017) proposed that a supply chain collaboration system was composed of a center plant and all collaborative partners so that the ability of the supply chain was the integrated ability of the center plant and all collaborative partners. From the interview with firms in precision machine industry, Maestrini et al. (2017) indicated that the center plant would plan and be responsible for the product manufacturing process, from the receipt of orders to delivery, and the contact with customers in the period was in charge by the center plant. Fuchs et al. (2018) stated that, once an order was received, the center plant would immediately evaluate the relative information and the production capacity, separate it into work orders or outsourcing orders for production departments in the plant or contractors; contractors, after accepting the orders, would also separate the orders into work orders or outsourcing orders, according to the order information and the production capacity. Yu et al. (2017) indicated that contractors, according to the order information and the production capacity, could transfer work orders to contractors; meanwhile, the assembly quantity and parts required for various processes in the manufacturer would be started the production according to the BOM information of products in the accepted order.

### 2.3. Performance evaluation

Social resources are limited. The optimal utilization of limited resources has been the focus of managers. Efficiency and effectiveness, as the key points in performance evaluation, are often used for measuring the ability of an organization utilizing resources and the goal achievement. Chae et al. (2018) regarded efficiency as doing the thing right, which stressed on the use of correct means and mainly measured the effective application of resources in an organization in short period. By discussing the relationship between inputs and outputs, the most output was acquired with the least inputs; or, by finding out the way to reduce production costs to enhance the cost effectiveness of resources, the results were used as the improvement reference for evaluating organizational productivity. Peng et al. (2016) regarded effectiveness as doing the right thing, revealing the ability of an organization, under the premise of customers acquiring the maximal value, generating revenue through operation, where the measurement of ends was emphasized. It aimed to discuss whether an organization could effectively achieve the set goal within a period of time.

Liu et al. (2016) indicated that efficiency could be the performance on transforming inputs into outputs, which stressed on the effective utilization of existed production resources. In economics, the concept of Pareto Optimality could be used for the explanation. From the aspect of input orientation, it referred to an organization, with the same output amount, not being able to increase outputs without increasing input resources or reducing the yield of other outputs. In this case, the organization was efficient. From the aspect of output orientation, an organization, with the same inputs, could not reduce inputs without reducing the yield or increasing other input resources. In this case, the organization was efficient.

## 3. Research Design

### 3.1. Selection of input/output

In order to combine the selection of inputs/outputs with expert opinions, reduce input costs, and avoid fuzziness in the survey process, Modified Delphi Method is applied to select inputs and outputs in this study. Based on special considerations for some part of the study, brainstorming open-ended questionnaire is omitted. After referring to numerous literatures, the structured questionnaire is developed for the first run of questionnaire survey. It is Modified Delphi Method, which directly uses the structured questionnaire for the first run of survey, could save much time and have the experts focus on the research topic, without making guess on open-ended questionnaire. Total 30 copies of questionnaire are distributed for this study, and 24 valid copies are retrieved, with the retrieval rate 80%. Prefecture-level cities in Fujian Province are studied, and the variable data are acquired from open statistical data.

Definition of variable:

Input variable:

(1) Operating expense: Expenses in the process, including R&D expenditure, selling expense, expense for administration, and general expense.

(2) Number of employees: Total number of employees.

Output variable:

(1) Net income: Revenue acquired from product sales or labor provision in regular business activity deducting sales returns and allowances in operating revenue.

(2) Number of firms: Number of firms participating in supply chain collaboration.

### 3.2. Efficiency evaluation analysis

ICA is first used for data transformation, i.e. separating independent signals from observation, and the separated independent signals are integrated into DEA model at the second stage in order to understand the relative efficiency of decision-making units. Since independent components (IC) extracted with ICA are used as the variable for DEA, the estimated difference analysis value should be transformed to really understand the improvement of units with low efficiency. The effectiveness of ICA-DEA proposed in this study simulates variable values with different correlations in the experiment and the coefficients estimated by ICA-DEA and other methods (e.g. DEA) are compared. DEA represents to ignore the correlations among variables, but directly estimate with DEA. ICA-DEA, on the other hand, deals with the correlations among input variables with Independent Component Analysis and substitutes extracted independent components into DEA to become new input variables for efficiency estimation with DEA.

## 4. Empirical Analysis of Agricultural Supply Chain Collaboration Operation

### 4.1. Analysis of agricultural supply chain collaboration operation effectiveness

DEA and ICA-DEA are used in this study for estimating the agricultural efficiency of 9 prefecture-level cities in Fujian Province. DEA stands for purely estimating efficiency with DEA, while ICA-DEA represents to extract input and output variables with Independent Component Analysis, and the extracted independent components are regarded as new input and output variables for efficiency estimation with DEA.

The analysis results with DEA and ICA-DEA are organized in Table 1 and Table 2. According to the data in the tables, the number of efficient DMUs estimated with ICA-DEA is smaller than it estimated with DEA. The research result reveals that ICA-DEA could actually solve the problems caused by high correlations among variable data as well as effectively enhance the discrimination of DMUs on the efficiency order.

**Table 1: Relative efficiency of agricultural supply chain collaboration operation**

| | DEA | ICA-DEA |
|---|---|---|
| Maximal efficiency | 1.00 | 1.00 |
| Minimal efficiency | 0.81 | 0.77 |
| No. of efficient DMU | 2 | 1 |
| Total DMU | 9 | 9 |
| Percentage of efficient DMU | 22% | 11% |

**Table 2: Relative efficiency of agricultural supply chain collaboration operation**

| prefecture-level city | DEA | | | ICA-DEA | | |
|---|---|---|---|---|---|---|
| | overall efficiency | technical efficiency | scale efficiency | overall efficiency | technical efficiency | scale efficiency |
| Xiamen | 1.00 | 1.00 | 1.00 | 0.98 | 0.97 | 0.99 |
| Fuzhou | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Putian | 0.90 | 0.90 | 0.90 | 0.88 | 0.87 | 0.89 |
| Sanming | 0.87 | 0.86 | 0.87 | 0.85 | 0.85 | 0.86 |
| Quanzhou | 0.98 | 0.97 | 0.99 | 0.96 | 0.95 | 0.96 |
| Zhangzhou | 0.96 | 0.96 | 0.96 | 0.92 | 0.91 | 0.93 |
| Nanping | 0.85 | 0.84 | 0.86 | 0.83 | 0.81 | 0.84 |
| Longyan | 0.89 | 0.88 | 0.90 | 0.86 | 0.86 | 0.86 |
| Ningde | 0.81 | 0.81 | 0.82 | 0.77 | 0.76 | 0.78 |

## 4.2. Malmquist productivity index analysis

Table 3 shows the Malmquist efficiency analysis in 2018-2019. From Table 3, total factor productivity of Fuzhou is higher than 1, while the rest prefecture-level cities appears smaller than 1, revealing the reduction of productivity. In terms of pure technical efficiency change, the efficiency of all prefecture-level cities is improved. Regarding scale efficiency in two periods, Fuzhou is moving towards long-term optimal scale, while the rest prefecture-level cities, with smaller than 1, show the future management getting far away from long-term optimal scale. Moreover, the production techniques of all prefecture-level cities in technical changes in two periods are improved.

**Table 3: Malmquist efficiency analysis**

| prefecture-level city | technical changes in two periods TECHCH | pure technical efficiency change PECH | scale efficiency in two periods SECH | total factor productivity change TFPCH |
|---|---|---|---|---|
| Xiamen | 0.98 | 1.00 | 0.98 | 0.99 |
| Fuzhou | 1.03 | 1.02 | 1.00 | 1.01 |
| Putian | 1.00 | 0.98 | 0.94 | 0.98 |
| Sanming | 1.00 | 1.00 | 0.95 | 0.94 |
| Quanzhou | 1.03 | 1.02 | 0.97 | 0.93 |
| Zhangzhou | 1.07 | 1.06 | 0.92 | 0.95 |
| Nanping | 1.07 | 1.04 | 0.90 | 0.94 |
| Longyan | 1.18 | 1.11 | 0.94 | 0.96 |

| | | | | |
|---|---|---|---|---|
| Ningde | 1.11 | 1.08 | 0.96 | 0.90 |

Data source: Self-organized in this study.

## 5. Conclusion

From the efficiency acquired from DEA and the information of various variables, 1 DMU, about 11% of all DMUs, presents strong-form efficiency, with the efficiency=1, revealing the better agricultural supply chain collaboration operation effectiveness, 3 DMUs, about 33% of all DMUs, show the efficiency in 0.9-1, as marginal inefficient, revealing that the agricultural supply chain collaboration operation effectiveness could be more easily promoted, and 5 DMUs, about 56% of all DMUs, appear the efficiency smaller than 0.9, as obvious inefficient, where Ningde shows the lowest agricultural supply chain collaboration operation effectiveness. Apparently, supply chain collaboration among agricultural enterprises should be started from internal agricultural enterprises to establish the partnership with mutual trust. Besides, the corporate culture among agriculture cooperation enterprises must be highly compatible in order to ensure the permanent cooperation. The coordination and integration of departments in an agricultural enterprise and the collaboration among external partners might appear management inconvenience and mess due to numerous cooperation objects. In this case, the integration ability and full support of high-level supervisors would be important. The composition of an agricultural team should present professional knowledge and understand the operation process of agriculture in order to make adjustments when facing supply chain collaboration impacts. Moreover, the background of information technology for planning software/hardware, network systems, and work platforms is necessary. Regarding the organizational behavior and communication, the operation process and communication tools should be improved to enhance the collaboration among departments in an agricultural enterprise and prompt organizational changes with incentive systems, innovation ability, and brainstorming to reduce the risk resulted from the collaboration among agricultural enterprises. An open platform with integrity and expansibility is an important issue for the development agricultural supply chain collaboration environment with complete fundamental communication network and safe & stable technologies, connection with upstream and downstream cooperation partners, and direct and safe data transmission and exchange among systems. Network technology could ensure the speed and correctness of transaction as well as allow the information offered by agricultural enterprises in the supply chain collaboration being public and transparent. In this case, agricultural enterprises have to present complete

Internet technology to successfully establish the supply chain collaboration system.

## 6. Recommendation

Aiming at the operation of agricultural supply chain collaboration, the following suggestions are proposed in this study.

(1) Agricultural enterprises are suggested to focus on the benefits resulted from the supply chain collaboration and further emphasize the established trust and shared cooperation with suppliers; particularly, the purchase supply chain collaboration could precede strategic integration through the specific collaboration of provided by upstream, midstream, and downstream to develop the maximal collaboration effectiveness.

(2) Aiming at supply chain collaboration systems, knowledge education and training should be preceded in an agricultural enterprise, education and training plans and performance evaluation systems could be made, constant education and training could be preceded every month, and annual education and training plans for departments and agricultural enterprises should be made for both newcomers and in-service staff.

(3) An agricultural enterprise has to review and design operation process and consider the integration ability of existing systems in order to maximize the collaboration process and standard transaction techniques to further overcome the differences among agricultural enterprises in the supply chain upstream and downstream, efficiently exchange and deliver information, and make decisions. Healthy knowledge management could help agricultural enterprises develop knowledge, learn to share knowledge with others in the agricultural enterprise, and create more valuable knowledge.

## 7. Reference

ATASEVEN, C.; NAIR, A., Assessment of supply chain integration and performance relationships: A meta-analytic investigation of the literature. *International Journal of Production Economics*, v. 185, p. 252-265, 2017

BENITEZ, J.; GAUTAM RAY; HENSELER, J., Impact of information technology infrastructure flexibility on mergers and acquisitions. *Management Information Systems Quarterly*, v. 42, p. 25-43, 2018

CHAE, H.-C.; KOH, C. E.; PARK, K. O., Information technology capability and firm performance: Role of industry. *Information & Management*, v. 55, p. 525-546, 2018

CHO, B.; RYOO, S. Y.; KIM, K. K., Interorganizational dependence, information transparency in interorganizational information systems, and supply chain performance. *European Journal of Information Systems*, v. 26, p. 185-205, 2017

FUCHS, C.; BECK, D.; LIENLAND, B.; KELLNER, F., The role of IT in automotive supplier supply chains. *Journal of Enterprise Information Management*, v. 31, p. 64-88, 2018

GREGORY, R. W.; KAGANER, E.; HENFRIDSSON, O.; RUCH, T. J., IT consumerization and the transformation of IT governance. *Management Information Systems Quarterly*, v. 42, p. 1225-1253, 2018

HAO, S.; SONG, M., Technology-driven strategy and firm performance: Are strategic capabilities missing links? *Journal of Business Research*, v. 69, p. 751-759, 2016

KIM, Y. H.; SCHOENHERR, T., The effects of supply chain integration on thecost efficiency of contract manufacturing. *Journal of Supply Chain Management*, v. 54, p. 42-64, 2018

LIU, H.; WEI, S.; KE, W.; WEI, K. K.; HUA, Z., The configuration between supply chain integration and information technology competency: A resource orchestration perspective. *Journal of Operations Management*, v. 44, p. 13-29, 2016

MAESTRINI, V.; LUZZINI, D.; MACCARRONE, P.; CANIATO, F., Supply chain performance measurement systems: A systematic review and research agenda. *International Journal of Production Economics*, v. 183, p. 299-315, 2017

PENG, J.; QUAN, J.; ZHANG, G.; DUBINSKY, A. J., Mediation effect of business process and supply chain management capabilities on the impact of IT on firm performance: Evidence from Chinese firms. *International Journal of Information Management*, v. 36, p. 89-96, 2016

WUNDERLICH, N.; BECK, R., 25 years of CIO and it leadership – revisiting managerial roles in information systems research. The 21st Pacific Asia Conference on Information Systems, In Langkawi, Malaysia. 2017

XIAN, K. J.; SAMBASIVAN, M.; Abdullah, A. R., Impact of market orientation, learning orientation, and supply chain integration on product innovation. *International Journal of Integrated Supply Management*, v. 12 , p. 69-89, 2018

YAN, M. R.; CHIEN, K. M.; YANG, T. N., Green component procurement collaboration for improving supply chain man-agement in the high technology industries: A case study from the systems perspective. *Sustainability*, v. 8, p. 105, 2016

YU, W.; JACOBS, M. A.; CHAVEZ, R.; FENG, M., The impacts of IT capability and marketing capability on supply chain integration: A resource based perspective. *International Journal of Production Research*, v. 55, p. 4196-4211, 2017