

## Optimization and Coordination of Organic Product Supply Chains under Competition: An Analytical Modeling Perspective

**Authors :** Mohammadreza Nematollahi, Bahareh Mosadegh Sedghy, Alireza Tajbakhsh

**Abstract :** The last two decades have witnessed substantial attention to organic and sustainable agricultural supply chains. Motivated by real-world practices, this paper aims to address two main challenges observed in organic product supply chains: decentralized decision-making process between farmers and their retailers, and competition between organic products and their conventional counterparts. To this aim, an agricultural supply chain consisting of two farmers, a conventional farmer and an organic farmer who offers an organic version of the same product, is considered. Both farmers distribute their products through a single retailer, where there exists competition between the organic and the conventional product. The retailer, as the market leader, sets the wholesale price, and afterward, the farmers set their production quantity decisions. This paper first models the demand functions of the conventional and organic products by incorporating the effect of asymmetric brand equity, which captures the fact that consumers usually pay a premium for organic due to positive perceptions regarding their health and environmental benefits. Then, profit functions with consideration of some characteristics of organic farming, including crop yield gap and organic cost factor, are modeled. Our research also considers both economies and diseconomies of scale in farming production as well as the effects of organic subsidy paid by the government to support organic farming. This paper explores the investigated supply chain in three scenarios: decentralized, centralized, and coordinated decision-making structures. In the decentralized scenario, the conventional and organic farmers and the retailer maximize their own profits individually. In this case, the interaction between the farmers is modeled under the Bertrand competition, while analyzing the interaction between the retailer and farmers under the Stackelberg game structure. In the centralized model, the optimal production strategies are obtained from the entire supply chain perspective. Analytical models are developed to derive closed-form optimal solutions. Moreover, analytical sensitivity analyses are conducted to explore the effects of main parameters like the crop yield gap, organic cost factor, organic subsidy, and percent price premium of the organic product on the farmers' and retailer's optimal strategies. Afterward, a coordination scenario is proposed to convince the three supply chain members to shift from the decentralized to centralized decision-making structure. The results indicate that the proposed coordination scenario provides a win-win-win situation for all three members compared to the decentralized model. Moreover, our paper demonstrates that the coordinated model respectively increases and decreases the production and price of organic produce, which in turn motivates the consumption of organic products in the market. Moreover, the proposed coordination model helps the organic farmer better handle the challenges of organic farming, including the additional cost and crop yield gap. Last but not least, our results highlight the active role of the organic subsidy paid by the government as a means of promoting sustainable organic product supply chains. Our paper shows that although the amount of organic subsidy plays a significant role in the production and sales price of organic products, the allocation method of subsidy between the organic farmer and retailer is not of that importance.

**Keywords :** analytical game-theoretic model, product competition, supply chain coordination, sustainable organic supply chain

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