



Chain-to-chain competition on product sustainability



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ABSTRACT

This paper studies the game model of two sustainable supply chains under competition in product sustainability, derives the equilibrium structures of the two-chain system and generates the managerial insights. When the supplier and manufacturer within the reverse supply chain are competitive, the sustainability degrees, demands and profits under three structures of this two-chain system are analyzed. It is found that although vertical integration is always a Nash equilibrium, it is Pareto optimal only when the competition degree is low. On the other hand, a more generalized case for the former model is investigated when the supplier and manufacturer are cooperative in bargaining the wholesale price, and the effects of bargaining power to the sustainability degrees, demands, and chain member profits are studied. It is further shown that the structure of vertical integration channels is not an equilibrium unless the two sustainable supply chains are independent.

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1. Introduction

The importance of product sustainability in business practice has been increasingly acknowledged by both academy and industry. Many reports and researches have suggested that the image of product sustainability can improve companies' competitiveness, e.g., through the more efficient/green use of materials and energy, higher employee motivation, access to new market segments (such as green consumers), etc. In other words, companies can “do well by doing good” since consumers have strong willingness to purchase the more sustainable products (e.g., Porter and Kramer, 2006; Luchs et al., 2010; Grimmer and Bingham, 2013; Salimifard and Raeesi 2014).

This point of view is also upheld by industrial practitioners. Market force is driving companies to invest in sustainability and provide green information to the market to gain competitive edge and expand market share. For example, in the fashion apparel industry, companies such as H&M, Marks & Spencer, and Levis have taken many approaches to minimize carbon emission in its production process by adopting new technologies (Dong et al., 2014). Coca Cola and its bottling partners have also announced that 100% of their new vending machines and coolers will be HFC (hydro-fluoro-carbon) free by 2015 (cn.mobile.reuters.com). Giant Retailers such as Tesco and Walmart have also initiated the newest

sustainability programs such as carbon labeling and sustainable product index. A growing number of companies are using public announcements of sustainability goals as a means of signaling their commitment to become sustainability leaders, and to compete for superior positioning versus their rivals.

Motivated by the above facts, this paper explores a system of two supply chains under competition of product sustainability. Each supply chain consists of a supplier and a manufacturer. The product demand is increasing in the product sustainability of the particular supply chain while decreasing with its opponent. The market is supposed to be fully competitive so the product prices are regarded as given parameters for both supply chains. In a decentralized supply chain, the supplier offers a wholesale price contract under which the manufacturer determines the product sustainability to maximize his own profit. On the other hand, the supplier can offer a coordination contract and thus the whole system profit is maximized within the integrated supply chain. In combination of the above cases, three chain-to-chain structures are established and analyzed. It is found that although vertical integration is always Nash equilibrium, it is Pareto optimal only when the competition degree of product sustainability is low. When the competition degree is relatively high, the two-chain system falls into prisoner dilemma. When the competition degree is extremely high, decentralization for both chains is not only Pareto optimal but also Nash equilibrium. Therefore, from the perspective of sustainable supply chain governance, supply chain vertical coordination can only be effective when the chain-to-chain competition is of a low degree,

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otherwise the vertical integration cannot emerge as a stable coalition between supply chain members in such a dynamic and competitive business environment.

Furthermore, we also consider a more generalized scenario of the former model when the supplier and manufacturer are cooperative in bargaining the wholesale price. The methodology of Nash bargaining model is adopted, with the objective of maximizing the product of the power function of the profits for the two supply chain members. The analytical solutions of the product sustainability and system profits are obtained, with the unique Nash equilibrium derived and the effects of bargaining power studied. It is shown that the structure of vertical integration channels is not an equilibrium unless the two supply chains are totally independent. Therefore, from the perspective of sustainable supply chain governance, a contract stimulates proper profit allocation after bargaining, rather than a coordination scheme, is more appropriate for the sustainable supply chain under competition.

Our study is particularly related to those considering chain-to-chain competition. A seminal work in this field is [McGuire and Staelin \(1983\)](#), which considers a price competition between two suppliers each selling through an independent retailer and explores the effect of the level of product substitutability on optimal retailer distribution. A major result is that when products are highly substitutable the decentralization of supply chain is preferable by both manufacturers. [Coughlan \(1985\)](#) extends this research to a more general demand function and applies it to the electrical industry while [Moorthy \(1988\)](#) further explains the reason why supply chain decentralization can lead to higher profits and links it to the concept of strategic interaction. [Wu and Chen \(2003\)](#) consider a quantity competition of a duopoly where each chain includes a single manufacturer and two retailers facing a newsvendor demand. [Baron et al. \(2008\)](#) incorporate wholesale price bargaining into a two-chain competing system and show that both the traditional two-chain structures are special cases of Nash Bargaining on the wholesale price. [Wu et al. \(2009\)](#) further extend the work of [Baron et al. \(2008\)](#) to include uncertain demand and show that integration in both chains is the unique Nash Equilibrium over one period decision, while decentralization or bargaining on the wholesale price for both chains may be Nash equilibrium over infinitely many periods.

Another stream of research related to our paper is the study on sustainable supply chain. [Du et al. \(2011\)](#) examine a two-echelon supply chain in which the emission-dependent manufacturer trades with emission permit supplier under the cap-and-trade regulation. [Swami and Shah \(2013\)](#) study a two-echelon supply chain in which both supply chain members can design the greening effort, and find that a two-part tariff contract can coordinate the supply chain. [Zhang and Liu \(2013\)](#) investigate a supply chain in which the market demand correlates with the green degree of green product and find that the revenue sharing contract can coordinate the supply chain. [Dong et al. \(2014\)](#) study the sustainability investment on sustainable product with emission regulation consideration for decentralized and centralized supply chains. In addition, [Amin and Zhang \(2014\)](#) propose a mixed-integer linear programming model to configure a closed-loop supply chain network including multiple products, plants, recovery technologies, demand markets, and collection centres. Please see [Alzaman \(2014\)](#) for a recent literature review of this research stream.

Different from the above research, this paper contributes to the literature by constructing a model of two sustainable supply chains competing product sustainability and exploring the equilibrium structures for such a two-chain system. It is found that decentralization can prevail over integration when the competition degree is high, when the supplier and manufacturer act in a non-cooperative pattern. In addition, integration is never an equilibrium structure

under competition when the chain members bargain on wholesale price. Hence, the coordination mechanisms that induce sustainable supply chains to act as if they are vertically integrated, such as [Swami and Shah \(2013\)](#) and [Zhang and Liu \(2013\)](#), should be treated with caution.

This paper is organized as follows. In Section 2, we propose the two-chain competition model. Section 3 derives optimal solutions for the sustainability degrees, demand, and supply chain member profits. Section 4 compares the equilibrium results among different structures and provides managerial insights. Section 5 incorporates Nash bargaining on wholesale price into the model and Section 6 concludes the paper.

2. Two-chain competition model

Consider that two supply chains, each one consisting of a supplier and a manufacturer. In each supply chain, the supplier provides raw material to the manufacturer who produces and sells substitutable product to market. The two chains compete on the sustainability degree of the product, which is invested in the process of product manufacturing and determined by the manufacturer. That is, the demand of the product is increased with its sustainability degree and decreased with the sustainability degree of its opponent product sold by the competing supply chain. This reflexes the fact that the consumers' environmental awareness raises their purchase willingness for more sustainable and eco-friendly products, and thus the product sustainability competition is emphasized. Since our main focus is on the competition on product sustainability and to highlight more on this core issue, the paper considers that the demand is only related on the competition on sustainability level and the market prices are given. This is for the tractability of our model and comparison of different channel structures. Moreover, this assumption is also rational in practice since markets in many resource-intensive industries have become almost price-deterministic and the competition nowadays is more on product brands, which closely relates to sustainability. The above actions of H&M in apparel industry and Coca Cola in food industry are fair examples since they have been grappling with sustainability issues for brand image while their product prices are very stable at the meantime.

Specifically, the demands for supply chain $i = 1, 2$ are.

$$q_i = 1 + s_i - \theta s_j, \quad i = 1, 2; \quad j = 3 - i. \quad (1)$$

In the above equation, 1 is the normalized market base, s_i is the sustainability level of product i and θ in $[0, 1]$ denotes the competition degree of the two products on sustainability; $\theta = 0$ implies two independent supply chains without any sustainability competition. Such linear demand functions regarding the sustainability level have been adopted by [Swami and Shah \(2013\)](#) and [Dong et al. \(2014\)](#). The sustainability level here, is a rather general concept that can be any eco-friendly factor or improvement embedded in the product. For example, s_i can represent the total amount of improvement of carbon emissions emitted per unit expressed in equivalent tons of carbon dioxide (CO₂), which can be labeled as carbon footprint on the product. Such factor is relevant to the consumers' purchase willingness and can influence the market demand for the product. In addition, we also assume symmetry between the two supply chains. This is for the simplicity of the solution calculation of our model without loss of any generalization.

For notation convenience we assume the prices are same and denoted asp , but it can be relaxed to two different prices and all results generated will still apply. The unit cost for making raw material is c_s for the supplier. For the manufacturer, the unit

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