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## A negotiation-based algorithm to coordinate supplier development in decentralized supply chains

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## ABSTRACT

In this paper, we study supplier development in a decentralized supply chain with a single manufacturer and a single supplier. Because supplier development usually requires relationship-specific investments, the allocation of investment costs is a critical issue faced by participating firms. Referencing the relational view, we first investigate the effects of relationship-specific investments on the efficiency and effectiveness of supplier development. Next, we formulate and solve a continuous time optimal control model characterizing the decision to invest in supplier development and show that the supplier's incentive to participate in supplier development critically depends on the manufacturer's share of investment costs. The findings of our numerical analysis indicate that although the subsidy can lead to significant improvement in supply chain performance, subsidizing a constant share of investment costs is not always economically reasonable from the manufacturer's point of view. Thus, we provide a negotiation-based algorithm that assists the manufacturing firm in gradually increasing the share of investment costs to ensure an efficient level of subsidy, resulting in both perfect supply chain coordination and a win-win situation.

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## 1. Introduction

Because manufacturing firms increasingly focus on their core competencies, capable supplier networks play a paramount role in generating competitive advantage. However, suppliers too often lack the capability to perform adequately. In response, manufacturers across a wide range of industries develop closer relationships with their suppliers and initiate supplier development programs (Wagner, 2010). Within the automotive industry, Toyota initially began providing on-site assistance to help supplying firms implement lean manufacturing concepts for technological and organizational changes (Marksberry, 2012; Sako, 2004). Other automobile manufacturers have followed this collaborative approach to improve supply chain performance, including Chrysler, Daimler, Ford, General Motors, Honda, Nissan, and Volkswagen (Praxmarer-Carus, Sucky, & Durst, 2013; Talluri, Narasimhan, & Chung, 2010). Further examples of supplier development programs applied by companies outside the automotive industry can be found, among others, at

Boeing, Dell, General Electric, Hewlett-Packard, Motorola, Siemens, and Walmart (Routroy & Pradhan, 2013; Wagner, 2006a).

Supplier development is broadly defined as “any effort by a buying firm to improve a supplier's performance and/or capabilities to meet the manufacturing firm's short- and/or long-term supply needs” (Krause, 1999, p. 206). Following this definition, supplier development activities are typically initiated, designed, and administered by the manufacturing firm. Moreover, it is usually assumed that suppliers are eagerly willing to adapt and implement supplier development activities imposed by the manufacturer (Mortensen & Arlbjørn, 2012). However, despite the potential benefits resulting from such participation, supplier development may not always be a paying proposition for the supplier (Kim & Netessine, 2013; Krause, Handfield, & Tyler, 2007).

Indeed, there are sound arguments why suppliers might refrain from joining in supplier development. Because resources committed to supplier development are most often relationship-specific and therefore difficult or even impossible to redeploy outside the particular business relationship, suppliers may see such investments as vulnerable to opportunistic expropriation (Wang, Li, Ross, & Craighead, 2013; Williamson, 1979). Therefore, suppliers might be reluctant to modify or improve internal processes, and instead pursue their own objectives while participating in supplier

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development (Bai & Sarkis, 2014). Because supplier development is a reciprocal approach that requires mutual recognition, misaligned objectives and the hazards of opportunistic behavior could cause inefficiency in or, even worse, the premature abandonment of the supplier development process (Blonska, Storey, Rozemeijer, Wetzels, & de Ruyter, 2013; Iida, 2012).

Given this background, the purpose of our research is to examine the alignment of the supply chain partners' objectives to enhance the supplier development process. We seek to answer the following questions: How does the risk of partner opportunism affect the supplier's willingness to participate in manufacturer-initiated supplier development? Are bilateral relationship-specific investments a viable incentive to induce desirable supplier behavior, while simultaneously facilitating value generation within supplier development? Additionally, how should the mutual investment decision be arranged to improve supply chain coordination, while both the supplier and the manufacturer increase their respective profit?

By answering these questions, our paper makes a threefold contribution. First, in reference to the relational view as a theoretical framework, we investigate the effect of relationship-specific investments on the efficiency and effectiveness of supplier development and show that the deployment of bilateral relationship-specific investments might be an important source of competitive advantage. Second, considering a decentralized supply chain consisting of one manufacturer and one supplier, we formulate a continuous time optimal control model characterizing the supplier development investment decision. Using this model, we find that the supplier's incentive to participate in supplier development critically depends on the manufacturer's share of investment costs. We then carry out an extensive numerical analysis and demonstrate that although the manufacturer's subsidy leads to significant improvement in supply chain performance, subsidizing a constant share of investment costs is not always economically reasonable from the manufacturing firm's perspective. Given the fact that for an ongoing collaborative business relationship, supply chain coordination must result in enhancing the profitability of both the manufacturer and the supplier, we third present a negotiation-based algorithm that assists the manufacturing firm in gradually increasing the share of investment costs to ensure an efficient level of subsidy. The proposed coordination scheme can be employed as a guideline to realize perfect supply chain coordination while both the manufacturer and the supplier increase their respective profit in each iteration, leading to a win-win situation.

The remaining of this paper is structured as follows. First, the related literature is briefly reviewed in Section 2 before some theoretical background on the performance implications of supplier development is provided in the subsequent Section 3. Then, the basic optimal control problem is described in Section 4 before a reference solution is computed in Section 5 assuming a centralized decision-making process. Next, two cases of a decentralized decision-making process are considered: indirect supplier development in Section 6 and direct supplier development in Section 7. Subsequently, a negotiation-based coordination algorithm is proposed and numerically analyzed in Section 8. Finally, an extension to a scenario with multiple suppliers is briefly sketched before conclusions are drawn in Section 9.

## 2. Related literature

The topic of supplier development has received considerable attention from researchers in the past two decades (Talluri et al., 2010). Previous research on supplier development demonstrates that manufacturing firms use a variety of activities to develop suppliers' performance and/or capabilities. With few exceptions (e.g., Hartley & Jones, 1997; Sánchez-Rodríguez, Hemsforth, &

Martínez-Lorente, 2005), supplier development activities are classified by the manufacturer's level of commitment to a specific supplier (e.g., Humphreys, Cadden, Wen-Li, & McHugh, 2011; Krause, 1997; Krause, Scannell, & Calantone, 2000; Monczka, Trent, & Callahan, 1993; Wagner, 2006b). Accordingly, we distinguish two types of supplier development activities in this paper, indirect and direct supplier development.

In the case of indirect supplier development, the manufacturing firm commits no or only limited resources to a specific supplier. Instead, indirect supplier development may encompass activities such as evaluating suppliers' operations, setting performance goals, providing performance feedback, instilling competitive pressure, promising future business based on goal attainment or recognizing suppliers' progress by designating them as preferred suppliers (Krause et al., 2000; Wagner, 2010). These activities might encourage suppliers to take additional efforts to better comply with the manufacturer's requirements, resulting in unilateral deployment of relationship-specific investments.

In contrast to indirect supplier development, the manufacturer plays a more active role in the case of direct supplier development. Direct supplier development might include activities such as training given to suppliers' personnel by manufacturing firm representatives, furnishing temporary on-site support to enhance further interaction, providing equipment and tools, or even dedicating capital resources to suppliers (Monczka et al., 1993; Wagner & Krause, 2009). Thus, direct supplier development presents a more collaborative approach based on frequent manufacturer-supplier exchanges, resulting in bilateral deployment of relationship-specific investments.

Empirical research generally supports the notion that supplier development plays a critical role in driving performance and/or capabilities improvement on the part of the supplier and contributes strategically to strengthen the manufacturer's competitiveness. However, Krause and Ellram (1997) note that manufacturers' success in supplier development varies and that those who are more satisfied with the outcome of supplier development activities appear to communicate more effectively with and invest more time and resources in suppliers than do less-satisfied companies. As indicated by Krause, Handfield, and Scannell (1998), suppliers are unlikely to embrace fully a set of changes required for improvement unless there is tangible evidence that the manufacturing firm will support the supplier's efforts with matched resources. Thus, successful supplier development apparently requires bilateral deployment of resources, not only inputs from the supplying firm (Krause, 1999). Similar results are found by Krause et al. (2000), Wen-li, Humphreys, Chan, and Kumaraswamy (2003), Humphreys, Li, and Chan (2004), Krause et al. (2007), Humphreys et al. (2011) and Wagner (2011), who all state that direct support by a manufacturing firm is of major significance in determining supplier performance and/or capabilities improvement, thus enhancing the manufacturer's competitiveness.

Although direct involvement by the manufacturing firm seems to be an important antecedent of successful supplier development, mounting anecdotal evidence indicates that the majority of manufacturers are generally very hesitant to commit considerable resources to external, independent suppliers. As Monczka et al. (1993) determine, manufacturers are reluctant to conduct direct supplier development activities when they fear that competitors may benefit from the supplier's capability improvements. Furthermore, Krause (1997) reports that relationship-specific investments in suppliers' operations are rarely used compared with indirect supplier development activities. In line with this, Krause and Scannell (2002) state that manufacturers' commitment appears to be non-existent when a need for direct investments arises in the context of supplier development. Similar results are found by Wagner (2006a), Carr and Kaynak (2007), and Wagner and Krause (2009).

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