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ORIGINAL ARTICLE

Benefits of sourcing alternative inputs of manufacturers for suppliers

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Abstract

A downstream manufacturer can procure high-quality inputs from its upstream raw material supplier to produce finished products with high quality. The manufacturer may also have the option to source alternative cheaper low-quality inputs to partially replace the inputs from its supplier to produce finished products of lower quality. That is, the manufacturer can use a mixture of the supplier's inputs and alternative ones in product design such that product quality depends on the proportion of each input used in products. We endogenize this product quality decision in a simple analytical model to study the impact of this option on the supplier's profits. Intuitively, the option of sourcing alternative inputs could hurt the supplier in two ways: It sells fewer inputs, and it needs to set a lower wholesale price due to competitive pressure. However, our study reveals an opposite finding: The supplier can benefit not only by selling more inputs but also by setting a higher wholesale price when the manufacturer has the option of sourcing alternative low-quality inputs. This interesting finding is due to the *wholesale price push-up effect*: The upstream supplier may deliberately raise the wholesale price when sourcing alternative inputs is an option for the downstream manufacturer. This increased wholesale price encourages the manufacturer to use a higher proportion of alternative cheaper inputs in its product design; as a result, the manufacturer's marginal cost is reduced, which leads to a decrease in its retail price. Therefore, consumer demand for the manufacturer's products becomes higher, which in turn results in higher manufacturer demand for the supplier's inputs. Moreover, we show that despite this higher wholesale price, the manufacturer can earn higher profits by optimally charging a lower retail price. Furthermore, we find that the wholesale price of the supplier's inputs can exceed the manufacturer's retail price, thereby leading to a negative profit margin for the manufacturer from using the supplier's inputs. Finally, we demonstrate the robustness of our findings under several model extensions.

KEYWORDS
dual sourcing, product design, strategic competition, supply chain management

1 | INTRODUCTION

The extant literature on dual sourcing (e.g., Chen & Guo, 2014; Johnson, 2007) mainly focuses on settings in which a downstream firm uses the inputs from only one of the two upstream sources in its manufacturing process. In this scenario, product quality is simply exogenous quality of the inputs from a single source. In practice, though, there are many occasions where a downstream firm uses a mixture of the inputs from both upstream sources in product design. In this scenario, product quality depends on the endogenous proportion of each input used in product design. The above two scenarios vary substantially, and in response, this paper focuses on the latter scenario that so far has received little attention from the literature.

Specifically, we are concerned with the following scenario in this study. A downstream manufacturer can procure high-quality inputs from its upstream raw material supplier to produce finished products with high quality. This manufacturer may also have the option to source alternative cheaper

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low-quality inputs to partially replace the inputs from its supplier to produce finished products with lower quality. The above situations of sourcing alternative inputs in product design (i.e., choosing a mixture of high- and low-quality inputs) arise frequently in practice. For instance, cooking oil manufacturers can source cheaper low-quality ingredients (e.g., canola oil) to substitute expensive high-quality ingredients (e.g., olive oil). One example is the brand Corto that offers a product that blends olive oil and canola oil.[1] Whiskey producers may also have the option to use economical grains (e.g., wheat) as their base to substitute for traditional malted barley.[2] Such an example is from Hedonism, which is a blended grain Scotch whiskey.[3] Moreover, even for energy products, fuel producers, like SC Fuels, are now mixing high-performance biodiesel with standard petrodiesel to create blended fuels.[4] To offer further examples, clothing manufacturers can blend low-end (e.g., synthetic fabrics) into high-end materials (e.g., cashmere) when making suits; cosmetic manufacturers produce facial masks without always using superior ingredients like hyaluronic acid, and in many cases nutritional supplement manufacturers do not offer fish oil containing 100% pure DHA and EPA.

A key research question arises naturally in this dual source setting: Does a dual sourcing strategy by the downstream manufacturer hurt the upstream supplier? Despite its practical importance, this question has not been adequately addressed in the dual sourcing literature (e.g, Chen & Guo, 2014; Johnson, 2007) that mainly focuses on how a downstream firm benefits from its dual sourcing. A downstream manufacturer would want to source alternative low-quality inputs in product design as they are cheaper in comparison to its upstream supplier's high-quality ones. As a result, one could intuit that such a manufacturer's dual sourcing strategy may harm its supplier in two ways. First, the supplier may sell fewer inputs because its downstream manufacturer may replace high-quality inputs with low-quality substitutes. Second, the supplier may also have to cut the wholesale price of its inputs to mitigate the manufacturer's incentives to purchase cheaper alternative inputs. This paper, however, finds in fact that the supplier can actually benefit when the manufacturer sources alternative inputs. This is achieved by the supplier not only by selling more of its inputs but also by setting a higher wholesale price.

To address the key question raised above and other related questions, we develop a game-theoretic model to explicitly study the impact of sourcing alternative inputs by a downstream manufacturer on a supply chain members' profits and consumers' surplus. The novel element in our framework that differs from the related literature (e.g., Chen & Guo, 2014) is investigating a new dual sourcing context in which a downstream manufacturer makes the product design decision by choosing a mixture of high-quality inputs from its upstream supplier and alternative low-quality inputs. This decision depends critically on the wholesale price of the supplier's inputs and the procuring cost of alternative inputs. Our model is particularly relevant to the settings where the quality of a manufacturer's products depends on the proportion of each input used in the products. For instance, the amount of superior ingredients (e.g., olive oil) is a pivotal factor that influences cooking oil quality. After analyzing the model, we identify that whether the supplier can benefit from sourcing alternative inputs by its manufacturer depends on its marginal cost. The detailed results of our model and their rationales are as follows.

Initially, when its marginal cost is low, the upstream supplier that wishes to boost demand for its high-quality inputs focuses more on encouraging its downstream manufacturer to choose a higher proportion of its inputs to be used in product design. This objective can be reached as long as the cost difference for the manufacturer between purchasing the supplier's inputs and alternative ones is small. This can occur when the supplier's marginal cost is low enough such that it can set a low wholesale price, while in the meantime the supplier is also competing with cheaper alternative inputs. Hence, to entice its manufacturer to use a higher proportion of its inputs to be used in product production, the supplier has to cut down its wholesale price, unlike the case where sourcing alternative inputs is not an option for the manufacturer. As a result, a decrease in wholesale price makes the supplier less profitable.

Alternatively, when its marginal cost is high, the upstream supplier that wants to enhance the manufacturer's demand for its high-quality inputs would instead encourage its downstream manufacturer to set a lower retail price that helps spur consumer demand for the manufacturer's products. This occurs because the wholesale price of the supplier's inputs would be sufficiently higher than the cost of purchasing alternative inputs, meaning that it would be unrealistic for the supplier to push its manufacturer to use a higher proportion of its inputs in product design. As a consequence, the supplier would instead compel the manufacturer to stimulate consumer demand for the manufacturer's products, through which the manufacturer demand for its inputs can correspondingly increase. Interestingly, this goal can be achieved if the supplier strategically sets a higher wholesale price compared to the case where sourcing alternative inputs is not an option for the manufacturer. We term this strategic effect a *wholesale price push-up effect*. Naturally, when the wholesale price of a supplier's inputs increases, its manufacturer will choose a lower proportion of its inputs in product design. This choice greatly reduces the manufacturer's marginal cost and thus its retail price, thereby increasing consumer demand for the manufacturer's products by a large extent. As a result, the supplier may enjoy higher manufacturer demand for its inputs due to this expanded consumer demand for its manufacturer's products, although charging a higher wholesale price causes a lower proportion of its inputs used in product design. Because of this, the supplier may benefit not only by selling more of its inputs, but also by setting a higher wholesale price when its manufacturer has the option to source alternative inputs.

We also tackle other important research questions, such as how a manufacturer's sourcing alternative inputs influences its product design, retail price, and profits. We find that despite the higher wholesale price of the supplier's inputs and the lower retail price of final products, interestingly, the manufacturer can make greater profits from sourcing alternative inputs because of the resulting lower marginal cost of the manufacturer. The reason for this finding is that in our model, the manufacturer's production cost is endogenously determined by its product design choice, namely, the proportion of each input used in final products. In this way, the supplier can exert a significant influence on the manufacturer's sourcing decisions by strategically setting the wholesale price. Although the wholesale price of the supplier's superior inputs can be higher, surprisingly, the manufacturer's production cost can remain lower by using more of alternative cheaper inputs, thereby resulting in a higher profit for the manufacturer. In a nutshell, we show that despite the induced higher wholesale price, sourcing alternative inputs by the manufacturer can benefit the entire supply chain's members. Consumers also benefit from the resulting lower retail prices.

Moreover, we find that the wholesale price of the supplier's inputs can be higher than the retail price of the manufacturer's products. Although this implies that the manufacturer has a negative profit margin using the supplier's inputs, the manufacturer can rely solely on using alternative inputs to make all of its profits. In such a case, the gains made by sourcing alternative inputs could more than offset the potential losses incurred by the manufacturer's using more expensive, superior inputs from the supplier. That is to say, a manufacturer may utilize expensive inputs from its supplier to give its products an aura of superior quality, so that its products containing alternative low-quality inputs can still be sold at a higher price under the same assumption of superiority. Finally, we also extend the base model in several directions to verify the robustness of our findings and derive some additional new insights.

2 | RELATED LITERATURE

This paper has points of contact with three streams of the extant literature: (i) dual sourcing, (ii) product design, and (iii) exclusive dealing. However, this paper differs from each stream in some critical ways that offer several unique contributions to the extant literature.

First, this paper complements the literature on dual sourcing. The extant literature mainly focuses on studying the ways in which downstream firms can benefit from dual sourcing in comparison to single sourcing, including alleviating supply fluctuation (Johnson, 2007), raising rivals' cost (Arya et al., 2008), mitigating the supply chain efficiency due to yield uncertainty (Tang & Kouvelis, 2011), softening downstream competition (Chen & Guo, 2014), and intensifying upstream competition (Niu et al., 2019). Alternatively, single sourcing can also perform better than dual sourcing for downstream firms. For example, Dong et al. (2022) show that a downstream firm prefers single sourcing when yield correlation between upstream suppliers is highly positive.[5] Our paper contributes to the literature on dual sourcing by sharply contrasting with the above research in the following aspects. To begin with, the novel element in our framework is that product quality is an endogenous decision for the downstream firm, while the extant literature generally abstracts away this important decision variable by treating product quality as exogenous. In practice, as shown in the earlier examples, product quality in many cases depends on the proportion of each input used in product design. This product design issue has not received sufficient attention in the dual sourcing literature but is explored in detail in our paper, which we believe also generates original insights that can better inform related business practices. Next, the extant literature on dual sourcing also pays little attention to its impact on upstream suppliers' profits. The only exception is Niu et al. (2019), who show that the focal upstream supplier suffers from the downstream firm's dual sourcing due to intensified upstream competition. Our paper mainly pertains to the impact of a downstream firm's dual sourcing on supplier profits, making it distinct from the existing literature that mainly focuses on the impact of such dual sourcing on the manufacturer's profitability. This focus has profound business relevance, because a manufacturer's dual sourcing strategy inevitably affects supplier profits, and the supplier is also an important market player. Due to a lack of study from this point of view, there is also a keen need for a pragmatic examination of this type of impact. Our paper demonstrates interestingly that by selling more of its inputs and setting higher wholesale prices, the upstream supplier may still benefit from the downstream firm's dual sourcing even though it introduces upstream competition.

Second, this paper enriches the literature on product design. Researchers have examined how firms design product lines (e.g., Desai, 2001; Guo & Zhang, 2012; Li & Liu, 2019), product innovations (e.g., Hauser et al., 2006; Lauga & Ofek, 2009), horizontal attributes of products (e.g., Zhang, 2011), product upgrades (e.g., Fudenberg & Tirole 1998; Iyer & Soberman, 2016), and prominent attributes of products (e.g., Zhu & Dukes, 2017). In this literature stream, our paper is most closely related to analytical research that focuses on the vertical quality level of product. For example, Iyer and Soberman (2016) show how manufacturers design the social harm of products when consumers are concerned about social responsibility and social comparison in making purchase decisions. In addition, Jain and Li (2018) examine how manufacturers of vice goods, such as unhealthy food products, should design the healthiness of products and set prices to serve consumers who struggle with self-control problems when regulating consumption. Our research differs from these studies by examining how a manufacturer sets the quality level of its products based on the trade-off between the quality and cost of inputs from different sources. We show that with the manufacturer's endogenous product design decision, the presence of lower quality alternatives can benefit both the manufacturer and supplier offering high-quality inputs.

Third, the focus of this paper is also closely related to the literature on exclusive dealing, which prohibits a buyer that purchases a firm's product from buying products from the firm's rivals. Most studies focus on explaining the possible anticompetitive effects of exclusive dealing under different scenarios, such as entry deterrence (e.g., Aghion & Bolton, 1987; Miklós-Thal & Shaffer, 2016; Rasmusen et al., 1991) and the presence of adverse selection (e.g., Calzolari & Denicolò, 2013, 2015). In this paper, the case where the manufacturer has no option of sourcing alternative inputs resembles a situation where an exclusive deal is reached between the supplier and manufacturer, despite the absence of any contractual arrangement. Unlike the existing literature, which shows the profitability of exclusive dealing from the perspective of a dominant seller, we instead find that a dominant supplier may be reluctant to engage in an exclusive relationship with a manufacturer. Our key mechanism, which highlights the importance of the supplier's cost structure in affecting the supply chain efficiency, also differs from the existing literature.

Finally, it is worth noting that using multiple inputs in product design in this paper is distinctly different from product bundling in the literature (e.g., Adams & Yellen, 1976; Banciu et al., 2006; Bhargava, 2012; Venkatesh & Kamakura, 2003). In the prevailing literature, using multiple inputs in product design is motivated by the supply side, in that the cost of purchasing each input is different for a manufacturer, given that consumer preference about each input (if deemed as a product) is homogeneous. To the contrary, we find that product bundling is driven by the demand side, as consumer preference about each product is heterogeneous such that they would prefer a bundle of products over individual component products.

3 | MODEL SETUP

We consider a supply chain setting that consists of an upstream supplier that sets its wholesale price for its high-quality inputs, and a downstream manufacturer that procures the supplier's inputs but may also have an option of sourcing alternative inputs.

In the model, an upstream supplier offers high-quality inputs with quality q_H at a marginal cost c_H, and a downstream manufacturer can procure the supplier's inputs at wholesale price w to produce finished products with high quality. The manufacturer may also have the option to source alternative low-quality inputs with quality q_L ($< q_H$) at a marginal cost c_L from a perfectly competitive market, in order to partially replace some inputs from the supplier for producing products with lower quality. In the model extension, we also consider the scenario where alternative inputs are not provided competitively to allow a specific rival to influence the price of alternative inputs by its pricing power.

When sourcing an alternative input in product design is an option, the manufacturer makes two decisions: (1) the proportion of its supplier's high-quality inputs used in product design $\rho \in [0, 1]$, which is the novel element that differs from the existing literature (e.g., Chen & Guo, 2014), and (2) the retail price of its products p. The manufacturer's product quality q depends on the quality levels of the supplier's high-quality inputs, alternative low-quality inputs, and the proportion of its supplier's inputs used in product design, that is, $q = \rho q_H + (1 - \rho)q_L$. This is to capture the fact that the quality of products will improve with the increase of the proportion of high-quality inputs used in product design.

Consumer demand for the manufacturer's products is $N(q, p)$, which is a function of retail price p and product quality q. We assume that $\frac{\partial N}{\partial p} < 0$, $\frac{\partial N}{\partial q} > 0$ and $\frac{\partial^2 N}{\partial (q)^2} < 0$. This assumption conveys two messages. First, the demand curve is downward sloping. Second, the demand function is increasing and concave in the product quality. Specifically, we assume the demand function as $N = f(q) - p$, where $f'(\cdot) > 0$ and $f''(\cdot) < 0$. Essentially, this demand function can be derived from a micro-founded structure. Suppose there is a unit mass of consumers, each of whom wants to purchase one unit of products at most. Consumer utility from consuming products is $f(q)$, which satisfies $f'(\cdot) > 0$ and $f''(\cdot) < 0$. Moreover, each consumer incurs a transportation cost s to buy products, where s is uniformly distributed over an interval [0,1]. Then, it can be readily verified that the consumer demand for the manufacturer's products is exactly $N = f(q) - p$ as consumers will make a purchase as long as their transportation cost is smaller than $f(q) - p$. Note that a consumer will be indifferent between purchasing and not purchasing when the consumer's transportation cost equals $f(q) - p$. This consumer utility specification is consistent with a similar assumption adopted in the literature (e.g., Besanko et al., 1987; Goering, 1985; Tellis & Wernerfelt, 1987) that consumer utility is concave in product quality such that marginal utility from product quality is decreasing. For exposition, we assume that $f(q) = \sqrt{q}$ in the base model. In the Supporting Information Appendix, we consider a more generalized demand function (i.e., $f(q) = Aq^r$) and find that our results remain robust with this complication. In addition, without loss of generality, we normalize $q_L = 0$ and $c_L = 0$ in the base model. We have generalized both q_L and c_L in the Supporting Information Appendix, showing that the key insights derived in the base model are not qualitatively affected.

The sequence of the game proceeds as follows. At stage 1, the upstream supplier sets the wholesale price for its high-quality inputs, charged to the downstream manufacturer. At stage 2, the downstream manufacturer determines the proportion of its upstream supplier's inputs used in product design, as well as determining the retail price of its finished products. This game sequence is to reflect the fact that the downstream manufacturer makes its decisions based on the observed prices of the inputs. At stage 3, the market clears and payoffs for all parties are realized.

4 | EQUILIBRIUM ANALYSIS

We are interested in the impact of a downstream manufacturer's option of sourcing alternative inputs on the profits of its upstream supplier and the payoffs of other parties. To this end, we first study a case where the manufacturer has no option to source alternative inputs and then examine a case where it does have such an option.

4.1 | No sourcing alternative inputs

In this subsection, we study the benchmark case where the manufacturer has no option to source alternative inputs. This could occur if an exclusive contract signed between the supplier and manufacturer prohibits the manufacturer from using any inputs other than the supplier's in product design. In this case, clearly, $\rho = 1$, and the only decision that the manufacturer makes is the retail price of its products. Hence, the product quality is $q = q_H$; that is, the only inputs contained in the products are the supplier's, and thus the quality of products is simply reduced to that of these inputs. Therefore, the consumer demand for the manufacturer's products N equals the manufacturer demand for the supplier's inputs N_S, that is, $N = N_S$.

We solve the model by backward induction. At stage 2, the manufacturer's problem is to choose the retail price of its products (p) to maximize its profit (Π_M), given the specific wholesale price (w):

$$\max_p \Pi_M = (p - w)(\sqrt{q_H} - p). \tag{1}$$

Hence, the optimal retail price of its products is given by

$$p = \begin{cases} \dfrac{\sqrt{q_H} + w}{2}, & \text{if } w \leq \sqrt{q_H}; \\ \sqrt{q_H}, & \text{if } w > \sqrt{q_H}. \end{cases} \tag{2}$$

The corresponding consumer demand for the manufacturer's products can be expressed as

$$N = \begin{cases} \dfrac{\sqrt{q_H} - w}{2}, & \text{if } w \leq \sqrt{q_H}; \\ 0, & \text{if } w > \sqrt{q_H}. \end{cases} \tag{3}$$

The manufacturer will only purchase inputs from the supplier when its wholesale price is low (i.e., $w < \sqrt{q_H}$). Otherwise, it will not purchase any inputs, as doing so cannot be profitable.

At stage 1, anticipating that its manufacturer purchases $N_S = N$ units of its inputs, the supplier's problem is to set the wholesale price of its inputs to maximize the profit (Π_S):

$$\max_w \Pi_S = (w - c_H)N, \tag{4}$$

where N is given by (3). It is expected that, if $c_H > \sqrt{q_H}$, the supplier cannot make any profits as its manufacturer will not purchase any inputs because of the high wholesale price. In contrast, if $c_H \leq \sqrt{q_H}$, the manufacturer is able to earn profits and the optimal wholesale price is $w^{no*} = \frac{\sqrt{q_H}+c_H}{2}$. Note that we use the superscript *no* to denote the case in which sourcing alternative inputs is not an option for the manufacturer. Therefore, to make the analysis meaningful, we only focus on the scenario $c_H \leq \sqrt{q_H}$ throughout the entire paper. We can then obtain other equilibrium variables, including the retail price (p^{no*}), consumer demand (N^{no*}), and profits of the supplier and manufacturer (Π_S^{no*} and Π_M^{no*}). The following lemma formally summarizes the equilibrium outcome.

Lemma 1. *Suppose the manufacturer has no option to source alternative inputs. At equilibrium,* $w^{no*} = \frac{\sqrt{q_H}+c_H}{2}$, $p^{no*} = \frac{3\sqrt{q_H}+c_H}{4}$, $N^{no*} = \frac{\sqrt{q_H}-c_H}{4}$, $\Pi_M^{no*} = \frac{(\sqrt{q_H}-c_H)^2}{16}$, *and* $\Pi_S^{no*} = \frac{(\sqrt{q_H}-c_H)^2}{8}$.

4.2 | Sourcing alternative inputs

Next, we study a case where the manufacturer is able to source alternative inputs in product design. To carry out such a dual sourcing strategy, the manufacturer has two instruments to take control of: the proportion of its supplier's inputs used in product design (ρ) and the retail price of its products (p).

With this in mind, at stage 2, upon observing the wholesale price of the supplier's inputs, the manufacturer's profit is

$$\Pi_M = (p - \rho w)(\sqrt{\rho q_H} - p). \tag{5}$$

Note that one unit of the product contains ρ unit of the supplier's inputs and $1 - \rho$ unit of alternative inputs. As a result, ρw is the marginal cost of the manufacturer, which accounts for its marginal costs of purchasing both the supplier's inputs and alternative ones. It can be shown that the optimal ρ is determined by[6]

$$\rho = \begin{cases} 1, & \text{if } w \leq \dfrac{\sqrt{q_H}}{2}; \\ \dfrac{q_H}{4w^2}, & \text{if } w > \dfrac{\sqrt{q_H}}{2}. \end{cases} \tag{6}$$

Intuitively, the manufacturer wants to source alternative inputs only when the cost of purchasing the supplier's inputs is high (i.e., $w > \frac{\sqrt{q_H}}{2}$). Otherwise, the manufacturer purchases only the supplier's inputs due to their quality advantage over alternative inputs. In addition, it can be readily verified that the manufacturer selects a higher proportion of alternative inputs used in product design as the wholesale price of its supplier's inputs increases. Conditional on the above ρ, the optimal retail price is further determined as follows

$$p = \frac{\sqrt{\rho q_H} + \rho w}{2} = \begin{cases} \frac{\sqrt{q_H} + w}{2}, & \text{if } w \le \frac{\sqrt{q_H}}{2}; \\ \frac{3q_H}{8w}, & \text{if } w > \frac{\sqrt{q_H}}{2}. \end{cases} \tag{7}$$

In addition, the consumer demand for the manufacturer's products can be written as

$$N = \frac{\sqrt{\rho q_H} - \rho w}{2} = \begin{cases} \frac{\sqrt{q_H} - w}{2}, & \text{if } w \le \frac{\sqrt{q_H}}{2}; \\ \frac{q_H}{8w}, & \text{if } w > \frac{\sqrt{q_H}}{2}. \end{cases} \tag{8}$$

At stage 1, the supplier chooses w to maximize the following profit, taking into account that the manufacturer's optimal choices of ρ and N are given by (6) and (8):

$$\Pi_S = (w - c_H)\rho N = \begin{cases} (w - c_H)\frac{\sqrt{q_H} - w}{2}, & \text{if } w \le \frac{\sqrt{q_H}}{2}; \\ (w - c_H)\frac{q_H^2}{32w^3}, & \text{if } w > \frac{\sqrt{q_H}}{2}. \end{cases} \tag{9}$$

Notably, unlike the previous case where sourcing alternative inputs is not an option for the manufacturer, here the manufacturer demand for the supplier's inputs N_S depends on two components: (i) the proportion of the supplier's inputs used in product design ρ, and (ii) the consumer demand for the manufacturer's products N. That is, more specifically, $N_S = \rho N$. Solving the supplier's profit maximization problem, we obtain the equilibrium results.

We use the superscript o to denote the case in which the manufacturer has the option to source alternative inputs. We further obtain all equilibrium variables, including the wholesale price (w^{o*}), the proportion of the supplier's inputs used in product design (ρ^*), retail price (p^{o*}), consumer demand (N^{o*}), manufacturer demand for the supplier's inputs (N_S^{o*}), profits of the supplier and manufacturer (Π_S^{o*} and Π_M^{o*}), profit margin of the manufacturer (m_M^{o*}), and profit margins of using the supplier's inputs and alternative inputs of the manufacturer (m_{MS}^{o*} and m_{MA}^{o*}). The following lemma formally summarizes the equilibrium outcome.

Lemma 2. *Suppose the manufacturer has the option to source alternative inputs. At equilibrium,*

- *when $c_H \le \frac{\sqrt{q_H}}{3}$, the manufacturer does not purchase any alternative inputs, that is, $\rho^* = 1$. In addition, $w^{o*} = \frac{\sqrt{q_H}}{2}$, $p^{o*} = \frac{3\sqrt{q_H}}{4}$, $N^{o*} = \frac{\sqrt{q_H}}{4}$, $m_M^{o*} = \frac{\sqrt{q_H}}{4}$, $\Pi_M^{o*} = \frac{q_H}{16}$, and $\Pi_S^{o*} = \frac{\sqrt{q_H}}{4}(\frac{\sqrt{q_H}}{2} - c_H)$;*
- *when $c_H > \frac{\sqrt{q_H}}{3}$, the manufacturer purchases alternative inputs, that is, $\rho^* = \frac{q_H}{9c_H^2}$. In addition, $w^{o*} = \frac{3c_H}{2}$, $p^{o*} = \frac{q_H}{4c_H}$, $N^{o*} = \frac{q_H}{12c_H}$, $N_S^{o*} = \frac{q_H^2}{108c_H^3}$, $m_M^{o*} = \frac{q_H}{12c_H}$, $m_{MS}^{o*} = \frac{q_H}{4c_H} - \frac{3c_H}{2}$, $m_{MA}^{o*} = \frac{q_H}{4c_H}$, $\Pi_M^{o*} = \frac{q_H^2}{144c_H^2}$, and $\Pi_S^{o*} = \frac{q_H^2}{216c_H^2}$.*

5 | EQUILIBRIUM RESULTS

Based on the above equilibrium analysis, we next examine the impact of the manufacturer's sourcing alternative inputs on the manufacturer, supplier, channel, and consumers. This is studied by mainly comparing the equilibrium market outcomes of Lemmas 1 and 2 derived earlier, which are summarized in Table 1. For brevity, we use the abbreviations NSAI and SAI to denote the cases of no sourcing alternative inputs and sourcing alternative inputs, respectively.

5.1 | Impact of SAI on manufacturer's product design, retail price, product demand, profits, and profit margins

In this subsection, we explicitly study how the manufacturer's sourcing alternative inputs influences its own product design, retail price, product demand, profits, and profit margins in that order.

We first derive how the manufacturer makes product design decision (i.e., choosing the proportion of each type of inputs) when it has the option of sourcing alternative inputs. The supplier can exert a significant influence on its manufacturer in determining whether and how much to source alternative inputs by strategically setting the wholesale price. That is, the manufacturer's sourcing decisions are not independent of the supplier but largely influenced by the supplier's pricing decisions. The reason is that the difference between the wholesale price of the supplier's inputs and the cost of purchasing alternative inputs is the key to the manufacturer's incentives for sourcing alternative inputs. As a result, given $c_L = 0$ in the base model, whether the manufacturer undertakes such a dual sourcing strategy depends on the equilibrium wholesale price, which is positively associated with the supplier's marginal cost of production.

The following proposition formally states how the manufacturer's choice of the proportion of its supplier's inputs used in product design depends on the supplier's marginal cost of production.

Proposition 1. *When $c_H \le \frac{\sqrt{q_H}}{3}$, ρ^* is constant as 1; when $c_H > \frac{\sqrt{q_H}}{3}$, $0 < \rho^* < 1$ and ρ^* decreases with c_H.*

TABLE 1 Equilibrium market outcomes under NSAI and SAI

	c_H	ρ	p	N	Π_M	w	N_S	Π_S
NSAI	$c_H \le \sqrt{q_H}$	1	$\frac{3\sqrt{q_H}+c_H}{4}$	$\frac{\sqrt{q_H}-c_H}{4}$	$\frac{(\sqrt{q_H}-c_H)^2}{16}$	$\frac{\sqrt{q_H}+c_H}{2}$	$\frac{\sqrt{q_H}-c_H}{4}$	$\frac{(\sqrt{q_H}-c_H)^2}{8}$
SAI	$c_H \le \frac{\sqrt{q_H}}{3}$	1	$\frac{3\sqrt{q_H}}{4}$	$\frac{\sqrt{q_H}}{4}$	$\frac{q_H}{16}$	$\frac{\sqrt{q_H}}{2}$	$\frac{\sqrt{q_H}}{4}$	$\frac{\sqrt{q_H}}{4}\left(\frac{\sqrt{q_H}}{2}-c_H\right)$
	$c_H > \frac{\sqrt{q_H}}{3}$	$\frac{q_H}{9c_H^2}$	$\frac{q_H}{4c_H}$	$\frac{q_H}{12c_H}$	$\frac{q_H^2}{144c_H^2}$	$\frac{3c_H}{2}$	$\frac{q_H^2}{108c_H^3}$	$\frac{q_H^2}{216c_H^2}$

When its marginal cost is low (i.e., $c_H \le \frac{\sqrt{q_H}}{3}$), the supplier sets a low wholesale price, which leads the manufacturer to purchase its inputs only. In contrast, when its marginal cost is high (i.e., $c_H > \frac{\sqrt{q_H}}{3}$), the supplier charges a high wholesale price, which induces the manufacturer to source cheaper alternative inputs in product design. In the latter case, the manufacturer uses a larger proportion of alternative inputs, as the marginal cost of purchasing high-quality inputs becomes higher.

We then move to explore how the manufacturer's retail price, product demand, and profits are determined by its option of sourcing alternative inputs. The results are summarized in the following proposition.

Proposition 2. *The manufacturer's sourcing alternative inputs decreases the retail price, and increases the product demand and its own profit. Formally,* $p^{o*} < p^{no*}$, $N^{o*} > N^{no*}$, *and* $\Pi_M^{o*} > \Pi_M^{no*}$.

Recall that under NSAI, the manufacturer demand for the supplier's inputs (N_S) equals the consumer demand for the manufacturer's products (N). Under SAI, however, the manufacturer demand for the supplier's inputs depends not only on this consumer demand but also on the proportion of the supplier's inputs used in product design (ρ). In other words, the supplier can adjust its wholesale price to influence the manufacturer demand for its inputs from the manufacturer so as to maximize its profits.

Proposition 2 first presents the impact of the manufacturer's sourcing alternative inputs on its retail price. It says that the retail price under SAI is always lower than that under NSAI, regardless of the supplier's marginal cost. This is due to the resulting lower marginal cost of the manufacturer. When the marginal cost of the supplier is low ($c_H \le \frac{\sqrt{q_H}}{3}$), the manufacturer has no interest in sourcing alternative inputs (as shown in Proposition 1). In this case, the decrease in marginal cost of the manufacturer is a result of a lower wholesale price from the supplier due to the competitive pressure from cheaper alternative inputs. In contrast, when the supplier's marginal cost is high ($c_H > \frac{\sqrt{q_H}}{3}$), the decrease in marginal cost of the manufacturer is from sourcing cheaper alternative inputs given that ρ^* is smaller than 1 (as indicated by Proposition 1). As a result, given that the retail price under SAI is always lower than that under NSAI, consumer demand for the manufacturer's products in the former case is generally higher than that in the latter case.

Proposition 2 then shows how the option of sourcing alternative inputs by the manufacturer affects its own profits. Comparing Π_M^{o*} with Π_M^{no*}, we obtain that $\Pi_M^{o*} > \Pi_M^{no*}$ always holds regardless of c_H. That is, interestingly, this dual sourcing strategy makes the manufacturer strictly better off, even though the wholesale price of its supplier's inputs can be higher (see Proposition 4 shown latter) and its retail price is generally lower (see Proposition 2 shown earlier). This result defies the common wisdom that the manufacturer earns lower profits when the wholesale price rises and its retail price declines. The main reason for this result is that the production cost for the manufacturer is endogenously determined in our model instead of being exogenously fixed, as in the existing literature (e.g., Chen & Guo, 2014), because our framework allows the manufacturer to make product design decision by choosing the proportion of each input used in final products. Recall Proposition 1 where when the marginal cost of the supplier is low such that $c_H \le \frac{\sqrt{q_H}}{3}$, the manufacturer does not purchase any alternative inputs. In this case, the manufacturer benefits from a lower wholesale price of its supplier's inputs, which reduces its own marginal cost. In contrast, when the supplier's marginal cost is high such that $c_H > \frac{\sqrt{q_H}}{3}$, the manufacturer does source alternative inputs, as shown in Proposition 1. In this case, the marginal cost of the manufacturer is also reduced due to sourcing cheaper alternative inputs, which in turn improves its profits. Our research also confirms the intuition that the manufacturer should be better off if it has more leverage in dealing with its supplier, such as a choice of alternative inputs.

Finally, to gain additional insights into sourcing alternative inputs for the manufacturer, let us examine profit margins of the manufacturer under such a dual sourcing regime based on Lemma 2. We restrict our attention to the case in which the marginal cost of the supplier is high such that $c_H > \frac{\sqrt{q_H}}{3}$, as the manufacturer purchases only alternative inputs in this parameter range. The following proposition states the results.

Proposition 3. *Suppose* $c_H > \frac{\sqrt{q_H}}{3}$ *and the manufacturer has the option to source alternative inputs. The manufacturer's profit margin* m_M^{o*} *decreases with* c_H. *Specifically, the* *manufacturer's profit margins of using the supplier's inputs and alternative ones, that is, m_{MS}^{o*} and m_{MA}^{o*}, decrease with c_H; furthermore, the former margin is negative if $c_H > \frac{\sqrt{6q_H}}{6}$ while the latter margin is always positive.*

Recall Lemma 2, the manufacturer's profit margins from using the supplier's inputs and alternative ones m_{MS}^{o*} and m_{MA}^{o*} are $p^{o*} - w^{o*}$ and p^{o*}, respectively. As a result, the (overall) profit margin of the manufacturer m_M^{o*} is $\rho^* m_{MS}^{o*} + (1 - \rho^*) m_{MA}^{o*} = p^{o*} - \rho^* w^{o*}$, which is decreasing in c_H. Although the manufacturer's profit margin from using alternative inputs is always positive, its profit margin from using the supplier's inputs can be negative, as the wholesale price of the supplier's inputs is higher than the retail price of the manufacturer's products when the marginal cost of the supplier is high ($c_H > \frac{\sqrt{6q_H}}{6}$). This means that the manufacturer may gain from using alternative inputs but lose from using its supplier's inputs. Therefore, utilizing alternative inputs is the only conduit to making profits for the manufacturer, even though it also uses the supplier's inputs. Essentially, the manufacturer wants to take advantage of the cost difference between purchasing its supplier's inputs and alternative ones in operating its business. Although the wholesale price of the supplier's inputs is relatively high, the manufacturer may continue to purchase some of them. The purpose of purchasing these expensive inputs for the manufacturer is solely to add an air of superiority to its products, such that its products can be sold at a higher price under the guise of high-quality inputs.

5.2 | Impact of SAI on supplier's wholesale price, input demand, and profits

In this subsection, we are interested in the impact of sourcing alternative inputs by the manufacturer on the supplier's wholesale price, input demand, and profits. We first look at how such a dual sourcing strategy affects the wholesale price of the supplier. The following proposition summarizes the results.

Proposition 4. *The manufacturer's sourcing alternative inputs decreases the wholesale price of the supplier when the marginal cost of the supplier is low, while such a dual sourcing strategy increases this wholesale price when this cost is high. Formally, when $c_H \le \frac{\sqrt{q_H}}{2}$, $w^{o*} \le w^{no*}$; when $c_H > \frac{\sqrt{q_H}}{2}$, $w^{o*} > w^{no*}$.*

Proposition 4 shows that the impact of sourcing alternative inputs of the manufacturer on the wholesale price of the supplier relies on the marginal cost of the supplier. We illustrate this result in Figure 1. First, when the marginal cost of the supplier is low ($c_H \le \frac{\sqrt{q_H}}{2}$), the wholesale price under SAI is lower than that under NSAI. In this scenario, the optimal proportion of the supplier's inputs used in product design ρ^* is high, as shown in Proposition 1. This means that under SAI, the supplier is able to appropriate high demand for its inputs by working to induce its manufacturer to choose a high proportion of its inputs in product design. To realize this objective, facing the competitive pressure from cheaper alternative inputs, the supplier needs to cut its wholesale price in comparison to that under NSAI.

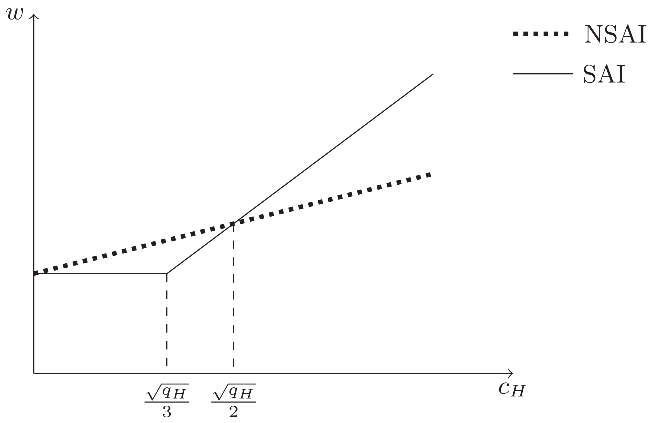

FIGURE 1 Equilibrium supplier's wholesale price

Proposition 4 also says that the wholesale price under SAI is higher than that under NSAI when the marginal cost of the supplier is large ($c_H > \frac{\sqrt{q_H}}{2}$). Recall Proposition 1 where, if the supplier's marginal cost is large, the optimal proportion of the supplier's inputs used in product design (ρ^*) is low. In this case, the supplier instead cares more about encouraging the consumer demand for the manufacturer's products, through which the manufacturer demand for its inputs can be raised in comparison to the case where sourcing alternative inputs is not an option for the manufacturer. Interestingly, this growth can be achieved if the supplier strategically sets a higher wholesale price compared to that under NSAI. We term this strategic effect the *wholesale price push-up effect*. The rationale behind this result is as follows: When the wholesale price of the supplier becomes higher, the manufacturer is induced to opt for a lower proportion of its supplier's inputs used in product design, which greatly reduces its marginal cost. The manufacturer subsequently decreases the retail price of its products, thereby encouraging increased consumer demand for its products, which in turn helps the supplier secure higher manufacturer demand for its high-quality inputs.

Next, we focus on the impact of the manufacturer's sourcing alternative inputs on the manufacturer demand for the supplier's inputs. The following proposition states the results.

Proposition 5. *The manufacturer's sourcing alternative inputs decreases the manufacturer demand for the supplier's inputs when the marginal cost of the supplier is moderate, while such a dual sourcing strategy increases this demand when this cost is low or high. Formally, when $0.394\sqrt{q_H} \le$*

$c_H \le 0.958\sqrt{q_H}$, $N_S^{o*} \le N_S^{no*}$; *when* $c_H < 0.394\sqrt{q_H}$ *or* $c_H > 0.958\sqrt{q_H}$, $N_S^{o*} > N_S^{no*}$.

The consumer demand for the manufacturer's products under SAI is always higher than that under NSAI, as described in the previous subsection. However, it is not clear whether the manufacturer demand for the supplier's inputs under SAI is lower or higher than that under NSAI, because the latter demand is also dependent on the proportion of the supplier's inputs used in product design.

When the marginal cost of the supplier is low ($c_H < 0.394\sqrt{q_H}$), the manufacturer demand for the supplier's inputs under SAI is higher than that under NSAI, as the proportion of the supplier's inputs used in product design remains high enough for it to benefit from the expanded consumer demand for the manufacturer's products. When the supplier's marginal cost falls into an intermediate range ($0.394\sqrt{q_H} \le c_H \le 0.958\sqrt{q_H}$), the manufacturer demand for the supplier's inputs under SAI is lower than that under NSAI, as the manufacturer demand loss, due to the diminished proportion of the supplier's inputs used in product design, outweighs the consumer demand gain due to a decrease in the retail price of the products. However, when the marginal cost of the supplier becomes high ($c_H > 0.958\sqrt{q_H}$), the manufacturer demand for the supplier's inputs under SAI can be higher than that under NSAI, as the consumer demand gain due to the reduced retail price can more than override the manufacturer demand loss due to the diminished proportion of the supplier's inputs used in product design. This is because the consumer demand for the manufacturer's products can be considerably increased when its marginal cost is sufficiently low due to a significant decrease in the retail price, which is a result of a larger decrease in the proportion of the supplier's inputs used in product design.

Finally, we derive how the manufacturer's sourcing alternative inputs affects the supplier's profits. Comparing Π_S^{o*} with Π_S^{no*}, we obtain that $\Pi_S^{o*} > \Pi_S^{no*}$ if $c_H > \tilde{\theta}\sqrt{q_H}$, where $\tilde{\theta} = \frac{3+\sqrt{9-4\sqrt{3}}}{6} \approx 0.74$. The following proposition formally presents the result.

Proposition 6. *The supplier loses from the manufacturer's sourcing alternative inputs when its marginal cost of production is low, while it benefits from such a dual sourcing strategy when this cost is high. Formally, when* $c_H \le 0.74\sqrt{q_H}$, $\Pi_S^{o*} \le \Pi_S^{no*}$; *when* $c_H > 0.74\sqrt{q_H}$, $\Pi_S^{o*} > \Pi_S^{no*}$.

The supplier's profit is determined by two factors: its wholesale price and the manufacturer demand for its inputs. Table 2 summarizes whether the supplier makes higher profits if its manufacturer has the option to source alternative inputs by integrating the effects of such a production strategy on these two factors based on Propositions 4 and 5.

When $c_H \le 0.394\sqrt{q_H}$, although sourcing alternative inputs raises the manufacturer demand for the supplier's inputs, it lowers its wholesale price largely, resulting in a net negative effect on the supplier's profits. When $0.394\sqrt{q_H} < c_H \le 0.5\sqrt{q_H}$, such a dual sourcing strategy reduces not only the wholesale price but also the manufacturer demand for the supplier's inputs, and thus it unambiguously lowers the supplier's profits. When $0.5\sqrt{q_H} < c_H \le 0.74\sqrt{q_H}$, sourcing alternative inputs diminishes the manufacturer demand for the supplier's inputs by a large extent, even though this raises its wholesale price, which causes decreased profits for the supplier. When $0.74\sqrt{q_H} < c_H \le 0.958\sqrt{q_H}$, the supplier benefits from sourcing alternative inputs because of a prominent increase in the wholesale price, despite selling fewer of its inputs. In particular, when $c_H > 0.958\sqrt{q_H}$, the supplier not only sells more of its inputs but also sets a higher wholesale price—the two benefits that jointly make it better off if its manufacturer purchases some alternative inputs. In a nutshell, the supplier can benefit from sourcing alternative inputs by its manufacturer when its marginal cost is high.

5.3 | Impact of SAI on channel profits and consumer surplus

We further evaluate the overall effect of the manufacturer's sourcing alternative inputs on the joint profit of both the supplier and manufacturer, as well as the surplus of consumers. On one hand, when the manufacturer has no option to source alternative inputs, the joint profit of the supply chain members is $\Pi^{no*} = \Pi_S^{no*} + \Pi_M^{no*} = \frac{3}{16}(\sqrt{q_H} - c_H)^2$. On the other hand, when sourcing alternative inputs is an option for the manufacturer, the joint profit becomes $\Pi^{o*} = \Pi_S^{o*} + \Pi_M^{o*}$. Comparing Π^{no*} with Π^{o*}, we find that $\Pi^{no*} > \Pi^{o*}$ when $\theta_1\sqrt{q_H} < c_H < \theta_2\sqrt{q_H}$, where $\theta_1 = \frac{5-\sqrt{5}}{6} \approx 0.461$ and $\theta_2 = \frac{1+\sqrt{5}}{6} \approx 0.539$. As indicated earlier, when $c_H > 0.74\sqrt{q_H}$, sourcing alternative inputs of the manufacturer always raises the profit of the supplier as well as that of the manufacturer, thereby improving the supply chain efficiency. Otherwise, the overall effect of sourcing alternative inputs of the manufacturer on the joint profit is ambiguous, which depends on whether the positive effect on the manufacturer's profit dominates the negative effect on the supplier's profit. We show that the overall effect can be negative only when the marginal cost of the supplier falls in the small range between $0.461\sqrt{q_H}$ and $0.539\sqrt{q_H}$.

Overall, despite the resulting higher wholesale price, sourcing alternative inputs of the manufacturer can promote the supply chain efficiency due to an increase in profits for all supply chain members. In addition, consumers surplus (CS) is higher when the manufacturer is able to engage in this dual sourcing strategy due to the induced lower retail price of the products. The following proposition summarizes the above results.

Proposition 7. *The manufacturer's sourcing alternative inputs decreases the channel profit when the marginal cost*

TABLE 2 Effects of sourcing alternative inputs on w, N_S, and Π_S

	$c_H \le 0.394\sqrt{q_H}$	$0.394\sqrt{q_H} < c_H \le 0.5\sqrt{q_H}$	$0.5\sqrt{q_H} < c_H \le 0.74\sqrt{q_H}$	$0.74\sqrt{q_H} < c_H \le 0.958\sqrt{q_H}$	$c_H > 0.958\sqrt{q_H}$
w	−	−	+	+	+
N_S	+	−	−	−	+
Π_S	−	−	−	+	+

of the supplier is moderate, while such a dual sourcing strategy increases the channel profit when this cost is low or high. Moreover, such a dual sourcing strategy always increases consumer surplus. Formally, when $c_H < 0.461\sqrt{q_H}$ *or* $c_H > 0.539\sqrt{q_H}$, $\Pi^{o*} > \Pi^{no*}$; *when* $0.461\sqrt{q_H} \le c_H \le 0.539\sqrt{q_H}$, $\Pi^{o*} \le \Pi^{no*}$. *In addition,* $CS^{o*} > CS^{no*}$.

6 | MODEL EXTENSIONS

In this section, we consider several model extensions to demonstrate the robustness of our key results and derive additional new insights. The detailed analyses and proofs of these model extensions are available in the Supporting Information Appendix.

6.1 | Alternative inputs are not competitively supplied

We have so far considered the case in which low-quality inputs are competitively supplied at marginal cost. In this subsection, we analyze an alternative scenario where low-quality inputs are supplied solely by a specific rival. This is to capture the idea that the price of alternative inputs can be influenced by market power. For instance, a firm that produces low-quality ingredients, such as canola oil, may also have some pricing power. Note that when the manufacturer has no option of sourcing alternative inputs, the equilibrium outcome will be identical to that in the base model.

Next, suppose the manufacturer is able to source alternative inputs for product design. For this scenario, we consider the following three-stage game in which we denote the supplier in the base model as the dominant supplier and alternative supplier as the small supplier. At stage 1, the dominant supplier sets the wholesale price w for its high-quality inputs and the small supplier simultaneously sets the wholesale price w_L for alternative low-quality inputs. At stage 2, the manufacturer determines both the proportion of each supplier's input to be used in product design and the retail price of its products. At stage 3, the market clears and payoffs for all parties are realized. The equilibrium outcome of this case is available in the Supporting Information Appendix. In particular, we have shown that the manufacturer wants to source only alternative inputs when $c_H > \frac{\sqrt{q_H}}{3}$, in which case the small supplier can make positive profits.

In the following proposition, by comparing equilibrium profits of the dominant supplier (Π_S^{o*} and Π_S^{no*}), we aim to show that as long as its marginal cost is high enough, the dominant supplier can be better off when the manufacturer sources alternative inputs than when it does not.

Proposition 8. *Suppose alternative low-quality inputs are supplied solely by a specific rival. When the dominant supplier's marginal cost is sufficiently high* ($c_H > 0.83\sqrt{q_H}$), *it benefits from the manufacturer's sourcing alternative inputs, that is,* $\Pi_S^{o*} > \Pi_S^{no*}$.

Proposition 8 shows that the dominant supplier can also benefit from the manufacturer's sourcing alternative inputs, even when these inputs are supplied solely by a specific rival. When the marginal cost of the dominant supplier is high ($c_H > \frac{\sqrt{q_H}}{3}$), the manufacturer has the incentive to source alternative inputs, enabling the small supplier to set the wholesale price for its low-quality inputs above its marginal cost. The dominant supplier, who cares about the manufacturer demand for its inputs, reacts to this increase in the wholesale price for alternative inputs by adjusting its wholesale price upward. Because of higher wholesale prices for both high- and low-quality inputs, the manufacturer produces lower quality products as compared to the case where low-quality inputs are competitively supplied. Hence, the dominant supplier also faces lower manufacturer demand for its high-quality inputs and thus is less likely to benefit from the manufacturer's sourcing alternative inputs in a less competitive input market.

6.2 | Direct production by supplier

In the base model, we assume that the supplier only makes profits by selling its inputs to the manufacturer, who in turn produces finished products for consumers in an indirect process. However, in certain scenarios, the supplier itself can also directly produce finished products by using its inputs. For instance, a supplier offering olive oil also directly sells its 100% pure olive oil to consumers in some marketplaces. A natural question is whether the product competition between direct and indirect channels can affect the manufacturer's incentives for sourcing alternative inputs. We consider an extended version of the base model by introducing the supplier's direct production of products to be sold to consumers.[7] That is, the supplier produces its products through a direct channel in addition to selling its inputs to the manufacturer, who may also source alternative inputs in product design through an indirect channel. Consumers choose which channel to purchase, knowing that products in the indirect channel may contain some alternative low-quality inputs.

To model the imperfect competition between the two channels, we assume the following linear demand functions.[8] That is, the demand function for the manufacturer's products is

$$N_M = \begin{cases} \sqrt{\rho q_H} - p, & \text{if } p \le \dfrac{\gamma\sqrt{\rho q_H} - \sqrt{q_H} + p_H}{\gamma}; \\ \dfrac{\sqrt{\rho q_H} - \gamma\sqrt{q_H} + \gamma p_H - p}{1-\gamma^2}, & \text{if } \dfrac{\gamma\sqrt{\rho q_H} - \sqrt{q_H} + p_H}{\gamma} < p < \sqrt{\rho q_H} - \gamma\sqrt{q_H} + \gamma p_H; \\ 0, & \text{if } p \ge \sqrt{\rho q_H} - \gamma\sqrt{q_H} + \gamma p_H \end{cases} \tag{10}$$

and that for the supplier's product is

$$N_S = \begin{cases} \sqrt{q_H} - p_H, & \text{if } p_H \le \dfrac{\gamma\sqrt{q_H} - \sqrt{\rho q_H} + p}{\gamma}; \\ \dfrac{\sqrt{q_H} - \gamma\sqrt{\rho q_H} + \gamma p - p_H}{1-\gamma^2}, & \text{if } \dfrac{\gamma\sqrt{q_H} - \sqrt{\rho q_H} + p}{\gamma} < p_H < \sqrt{q_H} - \gamma\sqrt{\rho q_H} + \gamma p; \\ 0, & \text{if } p_H \ge \sqrt{q_H} - \gamma\sqrt{\rho q_H} + \gamma p. \end{cases} \tag{11}$$

Here the parameter $\gamma \in [0, 1)$ captures the substitutability between the two channels or between the two products offered by both firms. A higher γ means that consumers view these two products as closer substitutes.

We consider the following sequence of the game in this setting. At stage 1, the upstream supplier sets the direct price for its products p_H and the wholesale price of its inputs charged to the manufacturer w. At stage 2, the downstream manufacturer chooses the proportion of the supplier's inputs to be used in production ρ and its products' price p. At stage 3, consumers choose which channel to make a purchase, if any. We consider price competition between two channels that may offer differentiated products. We also assume that the supplier sets the price for products before the manufacturer does, which captures the fact that the upstream firm is typically the market leader.

We first characterize the equilibrium outcomes for the case where the manufacturer has no option to source alternative inputs and the case where it does have such an option, the detailed results are provided in the Supporting Information Appendix. When the manufacturer has no option to source alternative inputs, both firms sell two horizontally differentiated products with the same high quality. The supplier that acts as the market leader optimally chooses the wholesale price for its manufacturer and the retail price for its own product so as to extract the highest profit from both channels. The manufacturer also earns positive profits, reflecting the market power to set the retail price for its own product. The profits tend to vanish, however, as the degree of substitution between two channels becomes sufficiently high (i.e., γ goes to 1). By contrast, when the manufacturer has the option of sourcing alternative inputs, the equilibrium outcome becomes more complex and it relies on both the substitutability between the two channels and supplier's marginal cost of production. Nevertheless, we find that the supplier also wants to induce the manufacturer to source alternative inputs when its marginal cost of production is sufficiently high, the result of which is qualitatively consistent with that in the base model.

We further investigate the impact of the manufacturer's sourcing alternative inputs on the profits of the channel members. The result is summarized in the following proposition.

Proposition 9. *Suppose the supplier also sells its products through a direct channel,*

- $\Pi_S^{o*} > \Pi_S^{no*}$ *if and only if* $c_H > \bar{c}_H$, *where* $\bar{c}_H$ *depends on* γ;
- *when* $\gamma \le 0.52$, $\Pi_M^{o*} > \Pi_M^{no*}$; *when* $\gamma > 0.52$, $\Pi_M^{o*} \le \Pi_M^{no*}$ *only if* c_H *is moderate; otherwise,* $\Pi_M^{o*} > \Pi_M^{no*}$.

Proposition 9 shows that when the supplier sells its product through a direct channel, the manufacturer's sourcing alternative inputs also has a positive impact on the supplier's profit when the supplier's marginal cost of production is high. This result is consistent with that in the base model where the supplier does not offer its own products for sale. Compared to the case where there is no direct sale of products, the supplier is able to further limit the manufacturer's price by setting a lower price for its products in the direct channel. The supplier's ability to produce finished products directly further shifts surplus from the manufacturer to the supplier itself. As a result, the supplier tends to earn higher profits when it can sell through a direct channel.

Unlike the base model, the manufacturer may no longer benefit from its choice of sourcing alternative inputs. As shown in Proposition 9, when the degree of substitution between two products is high (i.e., $\gamma > 0.52$) and the marginal cost of the supplier is moderate, the manufacturer is indeed worse off when it has an option to source alternative inputs. The reason is that when the products sold by the supplier and manufacturer are close substitutes, the intensified price competition between the two channels tends to limit the supplier's ability to extract profits from its own direct channel. When the marginal cost of the supplier is moderate, the supplier does best by setting a sufficiently high wholesale price so as to prohibit the manufacturer from making sales. This enables the supplier to fully eliminate price competition so that it is able to obtain the monopoly profit from its own direct channel. Nevertheless, when $\gamma \leq 0.52$, with price competition not being the main concern, the supplier always wants to keep the manufacturer active in making sales. Hence, in this scenario, the manufacturer always benefits when it has an option to source alternative inputs regardless of the marginal cost of the supplier.

6.3 | Supplier offering both types of inputs

In the base model, we assume that the upstream supplier only offers high-quality inputs while alternative low-quality inputs are supplied in a perfectly competitive market. In this extension, we consider a different scenario in which the upstream supplier offers both high- and low-quality inputs, and is thus able to determine the wholesale prices for both types of inputs charged to the manufacturer. The sequence of the game is as follows. At stage 1, the upstream supplier chooses the wholesale price for high-quality inputs w and that for low-quality inputs w_L. At stage 2, the downstream manufacturer determines the proportion of high-quality inputs ρ based on the observed wholesale prices, and also sets the retail price p for final products.

Our analysis reveals that at equilibrium the supplier wants to induce its manufacturer to source alternative inputs when its marginal cost of production is high (i.e., $c_H > \frac{\sqrt{q_H}}{2}$). Intuitively, the manufacturer is concerned about the difference in the marginal costs of purchasing two inputs ($w - w_L$) in deciding whether to source alternative inputs or not. When the upstream supplier provides both inputs, it can always influence the manufacturer's choice of sourcing alternative inputs by adjusting the wholesale prices of both inputs accordingly. Intuitively, when the marginal cost of purchasing high-quality inputs is low, the supplier would want to set a sufficiently low wholesale price for high-quality inputs to prevent the manufacturer from sourcing alternative low-quality inputs that would diminish the quality of final products. As such, the equilibrium outcome exactly replicates the one in Lemma 1. On the contrary, when the marginal cost of purchasing high-quality inputs is high, the supplier would strategically make the wholesale price for high-quality inputs much higher than that of alternative low-quality inputs to induce the manufacturer to source the latter. The reason is that doing so can lead to a lower retail price for final products that benefits the supplier, a rationale that is similar to the one behind our main results in the base model.

We further discuss the impact on the supplier and manufacturer when the former is able to provide both types of inputs.[9] The result is formally summarized in the following proposition.

Proposition 10. *Comparing the model where the supplier offers both inputs with the base model,*

- $\Pi_S^* = \Pi_S^{no*}$ *and* $\Pi_M^* = \Pi_M^{no*}$ *when* $c_H \leq \frac{\sqrt{q_H}}{2}$; $\Pi_S^* > \Pi_S^{no*}$ *and* $\Pi_M^* > \Pi_M^{no*}$ *when* $c_H > \frac{\sqrt{q_H}}{2}$;
- $\Pi_S^* > \Pi_S^{o*}$ *and* $\Pi_M^* < \Pi_M^{o*}$ *for any* c_H.

The above proposition suggests the following new insights. First, the supplier is always no worse off when it can offer both high-quality and low-quality inputs than when it is faced with competitors who sell low-quality inputs. This result is fairly intuitive because when the supplier owns both types of inputs, it can always control the wholesale prices of both inputs rather than the wholesale price of high-quality inputs only as shown in the base model. Second, the manufacturer could either gain or lose when the wholesale prices of both inputs are solely determined by the supplier. On the one hand, the manufacturer can benefit as compared to the base model in which it has no option to source alternative inputs. The reason is that although the supplier may charge higher wholesale prices for both types of inputs, the manufacturer's choice of sourcing alternative inputs continues to reduce its effective marginal cost of production and thereby raises its profits as compared to the case of no sourcing alternative inputs in the base model. On the other hand, the manufacturer is unambiguously worse off as compared to the case in the base model for which sourcing alternative inputs is an option. This is because when the supplier owns both types of inputs, it would optimally adjust the wholesale price of high-quality inputs downward and that of low-quality inputs upward. This strategy induces the manufacturer to source more high-quality inputs, leading to higher quality of finished products. However, as its effective marginal cost increases by a larger extent due to the higher wholesale price of low-quality inputs, the manufacturer ends up with a lower profit than what it obtains in the base model.

6.4 | Manufacturer competition

In the base model, we focus on the case where the manufacturer is the monopoly supplier of final products in the downstream market. To demonstrate that our key findings are independent on this assumption, in this subsection we consider an extended model with competition among manufacturers. Suppose there are two manufacturers M_1 and M_2 who compete in the downstream market. Each of them may want to source high-quality inputs from the supplier or alternative low-quality ones from a perfectly competitive market like the base model.

To reflect the imperfect competition between two manufacturers M_1 and M_2, we assume that the demand function for each manufacturer takes the following linear form.[10] That is, the demand for M_1 is N_1 and that for M_2 is N_2, where

$$N_1 = \begin{cases} \sqrt{\rho_1 q_H} - p_1, & \text{if } p_1 \leq \dfrac{\gamma\sqrt{\rho_1 q_H} - \sqrt{\rho_2 q_H} + p_2}{\gamma}; \\ \dfrac{\sqrt{\rho_1 q_H} - \gamma\sqrt{\rho_2 q_H} + \gamma p_2 - p_1}{1-\gamma^2}, & \text{if } \dfrac{\gamma\sqrt{\rho_1 q_H} - \sqrt{\rho_2 q_H} + p_2}{\gamma} < p_1 < \sqrt{\rho_1 q_H} - \gamma\sqrt{\rho_2 q_H} + \gamma p_2; \\ 0, & \text{if } p_1 \geq \sqrt{\rho_1 q_H} - \gamma\sqrt{\rho_2 q_H} + \gamma p_2 \end{cases} \tag{12}$$

and

$$N_2 = \begin{cases} \sqrt{\rho_2 q_H} - p_2, & \text{if } p_2 \leq \dfrac{\gamma\sqrt{\rho_2 q_H} - \sqrt{\rho_1 q_H} + p_1}{\gamma}; \\ \dfrac{\sqrt{\rho_2 q_H} - \gamma\sqrt{\rho_1 q_H} + \gamma p_1 - p_2}{1-\gamma^2}, & \text{if } \dfrac{\gamma\sqrt{\rho_2 q_H} - \sqrt{\rho_1 q_H} + p_1}{\gamma} < p_2 < \sqrt{\rho_2 q_H} - \gamma\sqrt{\rho_1 q_H} + \gamma p_1; \\ 0, & \text{if } p_2 \geq \sqrt{\rho_2 q_H} - \gamma\sqrt{\rho_1 q_H} + \gamma p_1. \end{cases} \tag{13}$$

The parameter $\gamma \in [0, 1)$ captures the degree of substitution between the products offered by two manufacturers. A higher γ means that the two products are closer substitutes. In particular, when $\gamma = 0$, these products are independent and each manufacturer is a monopolist; when γ is sufficiently close to 1, the two products are perfect substitutes. Besides, each manufacturer may raise the consumer demand for its products by choosing a higher proportion of high-quality inputs.

The sequence of the game is as follows. At stage 1, the upstream supplier chooses the wholesale price w charged to both manufacturers. At stage 2, upon observing the wholesale price w, both downstream manufacturers simultaneously choose the proportions of high-quality inputs ρ_i and set the retail prices p_i for $i = 1, 2$.

After fully characterizing the equilibrium outcomes, we find that competition between manufacturers will not change the equilibrium outcome regardless of whether manufacturers have an option to source alternative inputs or not. This is because that competition does not affect manufacturers' incentives to source alternative inputs but only limits their pricing power. As a result, competition hurts each manufacturer as both tend to lose market power when the substitution between their products becomes sufficiently high (i.e., γ is close to 1). We further obtain the following proposition that shows the impact of the manufacturers' sourcing alternative inputs on the profits of the channel members.

Proposition 11. *Suppose two manufacturers are competing in the downstream market. We have $\Pi_i^{o*} > \Pi_i^{no*}$ for $i = 1, 2$. In addition, $\Pi_S^{o*} \leq \Pi_S^{no*}$ when $c_H \leq 0.74\sqrt{q_H}$, and $\Pi_S^{o*} > \Pi_S^{no*}$ when $c_H > 0.74\sqrt{q_H}$.*

The above proposition continues to suggest that the supplier may be better off when sourcing alternative inputs is an option for downstream manufacturers. Although competition between manufacturers tends to hurt both of them, it results in a downward shift in their profits to the same extent in both cases whether or not they have an option to source alternative inputs. As a result, the downstream competition has a neutral effect on how manufacturer profits are impacted by the decision to source alternative inputs. One implication from this finding is that the degree of competition in the downstream market may not be particularly relevant when the upstream supplier decides whether or not to allow its manufacturers to source alternative inputs.

7 | CONCLUSION

The extant literature on dual sourcing (e.g., Chen & Guo, 2014; Johnson, 2007) generally overlooks a practical scenario in which product quality may depend on the proportion of each input used in final products. Moreover, the extant literature pays little attention to the question of whether dual sourcing by a downstream manufacturer hurts an upstream supplier. Our paper closes this research gap by building this novel element into a game-theoretic model.

The practices of manufacturers sourcing alternative inputs besides their suppliers' for product design are widely observed in the market. In this paper, we show that such practices may not always hurt suppliers, but may benefit them via increases in both demand for their inputs and wholesale prices. Specifically, we find that this interesting result occurs when marginal costs of suppliers are relatively high. The underlying mechanism that centers on the result is that in this case, suppliers will strategically raise wholesale prices of their inputs (i.e., *wholesale price push-up effect*) such that their manufacturers choose a lower proportion of their inputs to be used in product design. As a result, manufacturers' effective marginal costs are reduced, which in turn leads to lower retail prices, thereby raising consumer demand for their products. Therefore, suppliers can benefit from selling more of their inputs due to this expansion of consumer demand, in addition to an increase in wholesale prices.

We also demonstrate that both manufacturers and consumers can be better off when manufacturers have the option to source alternative inputs. Moreover, wholesale prices of suppliers' inputs can be lower than retail prices of manufacturers' products. This suggests that manufacturers may profit only from using alternative inputs, with a manufacturer's sole goal in sourcing expensive inputs from a supplier merely an effort to cast a superior image of their products in order to price them higher. Finally, we show that the above results are robust in several model extensions.

To summarize, we find that upstream suppliers may strategically set higher wholesale prices that can make them sell more of their inputs when their downstream manufacturers have the option to procure alternative inputs in product design. As a result, the suppliers can benefit from their manufacturers' dual sourcing. However, despite an increase in the wholesale prices, the manufacturers can benefit by optimally charging lower retail prices. Consumer surplus is improved due to the resulting decrease in the products' retail prices. Therefore, sourcing alternative inputs by the manufacturers can benefit all market parties.

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ENDNOTES

[1] See https://corto-olive.com/products/51-49-evoo-canola-blend?variant=30347250401373 , accessed June 2, 2022.

[2] It is well-documented that blended whiskeys are of lower quality than single malt ones. See the following link for an example: https://whiskyanalysis.com/index.php/background/scotch-style-whiskies-single-malts-vs-blends/ , accessed June 2, 2022.

[3] See https://scotchwhisky.com/whiskypedia/2813/hedonism/ , accessed June 2, 2022.

[4] See https://www.scfuels.com/biodiesel-vs-diesel/ , accessed June 2, 2022.

[5] The extant literature also studies the problem of horizontal sourcing in which a downstream firm may have an option of sourcing components from a competing firm (e.g., Hu et al., 2022).

[6] The detailed analysis is relegated to the Supporting Information Appendix.

[7] Arya et al. (2007) consider a similar setting in which a firm sells its products through both direct channel and indirect retail channel.

[8] These linear demand functions can be derived from the following quadratic utility function of a representative consumer $U(q_M, q_S) = \sqrt{\rho q_H} q_M + \sqrt{q_H} q_S - \frac{1}{2}(q_M^2 + q_S^2 + 2\gamma q_M q_S)$, where q_M and q_S are quantities demanded for the products of the manufacturer and the supplier, respectively.

[9] When the supplier offers both inputs, we denote the equilibrium profits of the supplier and the manufacturer by Π_S^* and Π_M^*, respectively.

[10] These linear demand functions can be derived from the following quadratic utility function of a representative consumer $U(q_1, q_2) = \sqrt{\rho_1 q_H} q_1 + \sqrt{\rho_2 q_H} q_2 - \frac{1}{2}(q_1^2 + q_2^2 + 2\gamma q_1 q_2)$, where q_1 and q_2 are quantities demanded for the products of manufacturers M_1 and M_2, respectively.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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