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Interfaces with Other Disciplines

Optimal quality and quantity provisions for centralized vs. decentralized distribution: Market size uncertainty effects

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ABSTRACT

We provide insights on how market size uncertainty affects the optimal quality (quantity) provision in distribution channels when consumers are heterogeneous in their willingness to pay for product quality. In this context, we denote the difference between the manufacturer's optimal quality (quantity) provision for a centralized channel and its optimal analog for a decentralized channel as the quality (quantity) differential. We find that market size uncertainty creates or increases the quantity differential, but it does not affect the differential's polarity. In contrast, market size uncertainty decreases the quality differential and it does so to the extent that, depending on the level of consumer heterogeneity, it reverses the differential's polarity. Moreover, we find that the higher the inherent uncertainty level, the more pronounced are the effects. We likewise find that the effects of market size uncertainty are amplified if the notion of consumer heterogeneity is replaced with retail-level competition.

1. Introduction

A manufacturer's optimal product quality provision as well as its correspondingly optimal product quantity provision depend on whether it sells its product in a centralized channel structure or in a decentralized channel structure. In this context, product quality refers to one or more product attributes that are such that all consumers agree on the direction of preference, as is the case for example with processing speed and storage capacity in a computer, with driving range per unit of fuel in an automobile, or with thread count in an apparel product. A decentralized channel structure refers to the situation in which a manufacturer exclusively sells its product to an independent retailer that, in turn, sells to end consumers; and a centralized channel refers to the alternative situation in which a manufacturer exclusively sells its product directly to end consumers. Examples of decentralized distribution channels include companies such as North Face and Benetton in the apparel industry and LG in the electronics industry. Examples of centralized distribution channels, in contrast, include such companies as the apparel manufacturers Zara and Gap and the appliance manufacturer Kenmore. Accordingly, scholars in marketing and economics have studied how channel structure affects a manufacturer's product quality provision. One standard result, for example, prescribes an optimal quality provision for a decentralized channel that is lower than its analog for a centralized channel when market size is deterministic and consumers are uniformly heterogeneous in their willingness to pay for product quality (see, for example, Economides (1999)).

However, regardless of whether a manufacturer sells its product in a given market through a centralized or a decentralized channel structure, it typically is the case not only that individual consumers within the market differ in their willingness to pay per unit quality, but also that uncertainty surrounds the overall population size of the market. For example, again in the electronics and apparel industries, not only is it typical for consumers to differ vertically in their willingness to pay for product quality, but also is imprecise forecasting a hallmark, especially for new product introductions ranging from Apple's iPod innovations (Gibson, 2004) to Microsoft's Surface RT (Reed, 2013) to essentially any seasonal introduction in fashion and apparel (Desai, Koenigberg, & Purohit, 2007; Fisher, Hammond, Obermeyer, & Raman, 1994; Foster, Golder, & Tellis, 2004; He, Marklund, & Vossen, 2008; Kuksov & Wang, 2013; Ofek & Turut., 2013). Indeed, due to the long lead times involved, manufacturers in the apparel industry including, for example, Zara (which sells its product directly to end consumers through a centralized channel structure) and Benetton (which sells its product to retailers through a decentralized channel structure) must decide on both their product quality and their production quantity sev-

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eral months before their selling seasons start (Ghemawat & Nueno, 2006). Hence, market size uncertainty is another important factor to consider in addition to consumer heterogeneity in determining optimal quality and quantity provisions within a given distribution channel structure.

Thus, in this paper, we study how market size uncertainty impacts the standard effect that channel structure has on a manufacturer's optimal product quality and quantity provisions. In particular, we compare a manufacturer's optimal quality (quantity) provision given that the manufacturer sells its product exclusively through a decentralized channel structure to the manufacturer's optimal quality (quantity) provision given that it instead sells its product exclusively through a centralized channel structure, and we assess how market size uncertainty affects the direction and magnitude of that comparison. For purpose of comparison, we denote the difference between the manufacturer's optimal quality (quantity) provision in centralized distribution and its optimal quality (quantity) provision in decentralized distribution as the channel differential with respect to quality (quantity). For shorthand, we refer to this difference as the *quality differential* (*quantity differential*). Toward that purpose, we adopt a well-established game-theoretic model of consumer utility in which consumers are defined to be uniformly heterogeneous in their willingness-to-pay for product quality but we incorporate a random variable to capture market size uncertainty. We then determine the manufacturer's optimal quantity and quality provisions for centralized distribution, followed by its optimal decisions for decentralized distribution, analyze how market uncertainty affects the quantity and quality differentials, and develop insights accordingly. We also explore the scope of our results first by expanding our initial uniform definitions of consumer heterogeneity and market uncertainty to non-uniform dispersions, and second by replacing our definition of consumer heterogeneity with the notion of retail-level competition.

Our stylized analysis makes a technical contribution by incorporating uncertainty effects into the literature realm focused on assessing the impact of distribution channel structure on marketing strategy. In so doing, we establish that, in contrast to the standard quality-decreasing effect of decentralization that otherwise would prevail absent the uncertainty, market size uncertainty fuels an opposing quality-increasing effect that potentially reverses the polarity of the quality differential from positive to negative, depending on whether consumer heterogeneity is moderate or extreme. In particular, we find that if consumer heterogeneity is moderate, then market size uncertainty decreases the quality differential that would exist without uncertainty, but it does not affect the polarity of that differential. However, if consumer heterogeneity is either low or high, then market size uncertainty reverses the polarity of the differential such that the optimal quality provision in the decentralized channel becomes higher than that in the centralized channel. This happens because uncertainty produces the functional equivalent of an increased marginal cost of quality production per unit sold, which drives down the corresponding optimal quality provision in either distribution channel. But this downward pressure is mitigated in a decentralized channel relative to its centralized analog because double marginalization reduces product availability, thus translating into a comparatively lower marginal cost of quality per unit sold. Accordingly, if consumer heterogeneity is either low or high, then market size uncertainty creates a negative quality differential that otherwise would not exist; but if consumer heterogeneity is intermediate, then market size uncertainty serves only to decrease the positive quality differential that otherwise would exist.

In a similar vein, we find that if consumer heterogeneity is comparatively low, then market size uncertainty creates a quantity differential that otherwise would not exist; and if consumer heterogeneity is comparatively high, then market size uncertainty increases the quantity differential that otherwise would exist. Moreover, we find, the higher is the market size uncertainty, the larger is the quantity differential. This happens because uncertainty creates a need to supplement a target market decision with a product availability decision to mitigate the risk of supply and demand mismatch that is introduced, and double marginalization amplifies that decision in a decentralized channel.

This paper fills a gap situated between two related streams of literature. The first stream, which is concentrated in the marketing and economics literature, is that which studies the polarity of a manufacturer's quality differential. See, for example, Jeuland and Shugan (1983), Villas-Boas (1998), Economides (1999), Xu (2009), Zhao, Atkins, and Liu (2009), Shi, Liu, and Petruzzi (2013), Chen, Liang, Yao, and Sun (2017) and Zhu and He (2017). Within this stream, Jeuland and Shugan (1983), Villas-Boas (1998), and Economides (1999) study market conditions that lead to a positive quality differential, while Xu (2009) and Shi et al. (2013) characterize market conditions without uncertainty that lead to a negative quality differential. We complement this literature stream by demonstrating how market uncertainty, rather than skewed heterogeneity among consumer willingness to pay, can drive the polarity of the quality differential negative.

The second stream, which is concentrated in the operations management literature, is that which studies the effects of uncertainty on the manufacturer's optimal pricing, quantity, or quality provision. See, for example, Gerchak and Mossman (1992), Federgruen and Heching (1999), Petruzzi and Dada (1999), Lariviere and Porteus (2001), Bernstein and Federgruen (2004), Wang (2006), Geng (2007), Carlton and Dana (2008), He et al. (2008), Allon and Federgruen (2007; 2008; 2009), Qi, Chu, and Chen (2016), Rong, Chen, and Shen (2015), and Jiang and Tian (2016). Among these, the following are especially relevant to the analytical underpinnings of our model. Carlton and Dana (2008) apply a newsvendor framework to study the related problem of product line design and show that uncertainty can drive down a manufacturer's optimal product quality when consumer preferences are homogeneous. Geng (2007) complements Carlton and Dana (2008) by exploring the effects of uncertainty on a manufacturer's jointly optimal pricing and quality decisions for different aggregate demand functions; and Bernstein and Federgruen (2004) and Allon and Federgruen (2007; 2008; 2009) extend these analyses by considering competition effects. In a related vein, Rong et al. (2015) study the effects of demand uncertainty on a manufacturer's optimal product line design in a market consisting of two segments of consumers, each with different willingness to pay for product quality. However, unlike our paper, these studies do not consider any underlying effects of the distribution channel structure on the manufacturer's optimal quality and quantity provisions.

One notable exception is Jerath, Kim, and Swinney (Forthcoming), who study the effects of production cost, price postponement, and distribution channel structure on a manufacturer's optimal quantity and quality provisions. They show in their context that quality and inventory are substitutes, channel decentralization may lead to higher product quality, and a wholesale price contract cannot coordinate the channel. Our work thus complements theirs: We study the interplay between consumer heterogeneity, market size uncertainty, and ex ante pricing to examine how market uncertainty affects the manufacturer's quality differential, to explore the generalizability of the effects to broader distributions of either consumer heterogeneity or market uncertainty, and to compare and contrast the effects to similar effects arising from retail-level competition.

This paper also indirectly relates to the vast literature on dual-channel supply chains in which product quality is defined to be ei-