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The effect of risk sensitivity on a supply chain of mobile applications under a consignment contract with revenue sharing and quality investment

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ABSTRACT

The paper provides a thorough investigation of the revenue sharing contract format typically used in the mobile applications (Apps) industry. The platform provider sets the level of revenue sharing, and the App developer determines the investment in quality and the selling price of the App. The demand for an App, which depends on both price and quality investment, is assumed to be uncertain, so the risk attitude of the supply chain members has to be considered. Specifically, we focus on how risk-sensitive behavior of supply chain members affects chain performance. The members' equilibrium strategies are analyzed under different attitudes toward risk: averse, neutral and seeking. We show that the retailer's utility function has no effect on the equilibrium strategies, and suggest schemes to identify these strategies for any utility function of the developer. We find that (i) the revenue sharing contract circumvents the double marginalization effect associated with vertical competition and therefore yields the best selling price for the customer; (ii) a decentralized supply chain sometimes performs better than a centralized one; and (iii) a risk-seeking developer may obtain a higher expected profit than does a risk-neutral developer.

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1. Introduction

Mobile applications (Apps) are software programs designed to run on smartphones and tablets. They are commonly downloaded through application distribution platforms, such as the Apple (iTunes) App Store, Google Play, the Windows Phone Store and BlackBerry App World. These platform distributers have achieved substantial success in terms of sales volume and revenue. According to analyst Horace Dediu of Asymco, over the last four years Apple's annual revenue from iTunes, which in 2013 was about $12 billion, has risen steadily at a rate of 32% to 38% per year. Dediu's analysis further indicates that over 800 applications are downloaded from iTunes per second (http://www.asymco.com/2013/01/09/a-more-complete-picture-of-the-itunes-economy/). In addition, according to a study released by App Annie, the year-to-date growth for the Google Play store was 311% in November 2012 (http://www. forbes. com/sites/timworstall/2012/11/30/google-plays-smaller-but-growing-faster-than-apples -app-store/).

The platform distributor (i.e., the App retailer) and the App developer (the supplier) constitute a two-echelon supply chain, whose business relationship is formed by a contract. In many cases, the platform distributor proposes a consignment contract to App developers, based on a revenue sharing policy (Gans, 2012). In this type of contract, the developer continues to own the mobile App and typically bears sole responsibility for determining its selling price. For every App sold, the platform distributor charges an agreed percentage of the selling price (Hsieh and Hsieh, 2013). For example, iTunes App Store and Google Play Store keep 30% of the revenues from sold Apps, and the developer receives 70% (see http://www.foraker.com/ios-app-distribution-options and https://support.google.com/ googleplay/android-developer/answer/112622?hl=iw).

This paper analyzes pricing and quality investment strategies in a two-echelon supply chain of mobile applications (Apps) under a consignment contract with revenue sharing. According to Wasserman (2010), the qualities that are most relevant to mobile applications are performance (efficient use of device resources, responsiveness, scalability), reliability (robustness, connectivity, stability), quality (usability, installability), and security. Ghose and Han (2014) indicate that quality is an important driver of demand in a mobile App setting. In particular, we study the impact of risk-sensitive behavior of supply chain members on the performance of the chain. We further explore the advantages and disadvantages of a consignment contract with revenue sharing, in comparison with a wholesale price contract.

Consignment contracts with revenue sharing have been studied in the literature. Wang et al. (2004) modeled decision-making in a two-echelon supply chain as a non-cooperative leader-follower game. They showed that the decentralized chain cannot be perfectly

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coordinated by this contract, i.e., that the profit of the supply chain is less than the profit achieved under the centralized system. Li and Hua (2008) and Li et al. (2009), on the other hand, modeled decision-making as a cooperative bargaining model and showed that in this case the revenue sharing contract can perfectly coordinate the supply chain. Zhang et al. (2010) analyze consignment contracts that contain bonus or side payment terms, and examine whether they can promote better coordination between the supplier and the retailer. Ru and Wang (2010) studied two different consignment arrangements that differed with respect to which channel member makes the decision on inventory or service level. Chen et al. (2011) carried out equilibrium analysis comparing a centralized chain with a decentralized supply chain under three types of contracts: fixed, price-increasing, and price-decreasing revenue sharing percentage.

The contribution of this paper to the literature is threefold: First, the papers cited above deal with tangible products; we, in contrast, consider mobile Apps, which are virtual products (Chernonog and Avinadav, 2014). Such products require a different supply chain modeling approach, as they are characterized by a negligible unit distribution cost and ample capacity to fulfill demand, meaning that holding and shortage costs are not relevant. Second, while the above-cited papers use demand models that are solely price-dependent, we include quality investment as a demnd accelerator. Our underlying assumption is that higher quality investment implies higher App quality, which, in turn, yields higher demand (see, for example, Huang et al., 2013). Third, whereas the papers discussed above implicitly assume that the parties adopt risk-neutral behavior, we study how the decision-makers' sensitivity to risk affects all stakeholders of the supply chain (developer, retailer, customers and social planner).

We use utility functions to express the supply chain members' attitudes toward risk. Specifically, we investigate the linear and the exponential utility functions, which reflect risk-neutral and risk-sensitive (risk-averse/seeking) decision-makers, respectively. We suggest that mobile App developers are particularly likely to engage in risk-seeking behavior. Indeed, Chen et al. (2007) claim that risk seeking, or a "no venture no gain" attitude, is prevalent in the expanding electronic business environment. Astebro (2003) indicates that risk-seeking is one of several possible reasons why so many inventors proceed to develop their inventions, despite the fact that only a small fraction will profit from their efforts. Notably, only a few papers have investigated risk-seeking decision makers in a supply chain (e.g., Lee and Lodree, 2010; Hahn and Kuhn, 2012; Tse and Tan, 2012).

Our study shows that the risk attitude of the developer is crucial in determining the equilibrium values of the retail price, the level of investment in quality, the level of revenue sharing and, correspondingly, the supply chain profits. In contrast, the risk attitude of the retailer has no effect. Moreover, we find that a risk-seeking developer may obtain a higher expected profit than a risk-neutral developer does. Contrary to popular belief, we find that from the perspectives of the customer and the social planner, decentralized supply chains can perform better than centralized chains; specifically, this occurs when the developer is risk-sensitive.

In order to explore the advantages and disadvantages of a consignment contract with revenue sharing, we compare it to a wholesale price contract, in which the retailer receives a fixed payment (rather than a percentage of the price) for each unit sold. We observe that, in contrast to the wholesale price contract, a revenue sharing contract circumvents the double marginalization effect caused by vertical competition, and therefore yields the optimal selling price for the customer. On the other hand, the wholesale price contract yields higher App quality. Finally, we show that the retailer and the social planner benefit from a revenue sharing contract.

2. Model formulation

Consider a developer who distributes a mobile App to customers via a dominant retailer. As in the case of virtual product models (Chernonog and Avinadav, 2014), distribution of mobile Apps is characterized by a negligible unit distribution cost and ample capacity to fulfill demand. Therefore, our model does not include either holding or shortage costs, and the only relevant cost component is the investment in the quality of the App, K, whose value is determined by the developer. The developer also determines the selling price per unit, p, whereas the retailer demands a fraction of the selling price, denoted by η, for each sold unit (i.e., the "percentage margin").

Another characteristic of mobile Apps is that the retailer only provides a distribution platform for the developer, so that selling is actually carried out by consignment. Therefore, the decision variables of the developer, p and K, dictate the total profit of the supply chain, whereas the decision variable of the retailer, η, dictates the revenue sharing of the supply chain, yielding a revenue-sharing contract (see Gerchak and Wang, 2004; Giannoccaro and Pontrandolfo, 2004; Cachon and Lariviere, 2005; Li et al., 2009; and Pan et al., 2010).

We adopt the commonly used multiplicative effect of uncertainty (Petruzzi and Dada, 1999), which is characterized by a fixed coefficient of variation. Accordingly, the demand function is $\tilde{D}(p,K) = D(p,K)\varepsilon$, where $D(p,K)$ is the expected demand, which is influenced by price and quality investment, and ε is a non-negative random variable (noise) with cumulative distribution function (CDF) F_ε and expectation $E(\varepsilon) = 1$. As is common in economics, $D(p,K)$ is strictly decreasing in p and, by the law of diminishing marginal productivity, is strictly concave in K. Naturally, $D(p,K)$ is monotone increasing in K, at least up to a certain amount, otherwise there will be no investment in quality.

The profits of the retailer and the developer are, respectively,

$$\tilde{\pi}_r(\eta) = \eta p D(p,K)\varepsilon \tag{1}$$

and

$$\tilde{\pi}_d(p,K) = (1-\eta)pD(p,K)\varepsilon - K. \tag{2}$$

Due to the multiplicative effect of uncertainty, we can use the property known as stochastic dominance, which is commonly used in analysis of stochastic models to order random variables (Bulinskaya, 2004). By definition (Whitmore and Findlay, 1978; Shaked and Shanthikumar, 2007), a random variable X stochastically dominates a random variable Y (denoted $X \succ Y$) if $P(X \geq z) \geq P(Y \geq z)\ \ \forall z$. The importance of this domination order stems from the result (Rothschild and Stiglitz, 1971) that $X \succ Y$ if and only if every decision maker with any utility function will always prefer X over Y. In other words, risk preferences do not matter if a stochastic order has been established. Correspondingly, when an order cannot be established, the preferences of the decision maker matter (Chernonog and Kogan, 2013; Perlman, 2013; Chernonog and Avinadav, 2014). This property is exploited in the following theorem:

Theorem 1.

(i) The retailer's profit with the largest expectation stochastically dominates any other profit of the retailer.
(ii) For a given K, the developer's profit with the largest expectation stochastically dominates any other profit of the developer.
(iii) The developer's profits corresponding to various values of K, for a given p, are not stochastically ordered.

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