International Journal of Electronic Commerce

ISSN: 1086-4415 (Print) 1557-9301 (Online) Journal homepage: http://www.tandfonline.com/loi/mjec20

Design of Free-to-Play Mobile Games for the Competitive Marketplace

Ismail Civelek, Yipeng Liu & Sean R. Marston

To cite this article: Ismail Civelek, Yipeng Liu & Sean R. Marston (2018) Design of Free-to-Play Mobile Games for the Competitive Marketplace, International Journal of Electronic Commerce, 22:2, 258-288, DOI: 10.1080/10864415.2018.1441755

To link to this article: https://doi.org/10.1080/10864415.2018.1441755

Published online: 27 Mar 2018.

Design of Free-to-Play Mobile Games for the Competitive Marketplace

Ismail Civelek, Yipeng Liu, and Sean R. Marston

ABSTRACT: Dramatic improvements in high-speed and mobile connectivity have been changing the way people enjoy games. In-game purchases, virtual currency, game feature design for heterogeneous consumers, and strong competition are key challenges for game providers. This study addresses the determination of optimal game design strategies for game providers in the presence of heterogeneous players and copycat competitors. Specifically, the study incorporates pricing of virtual goods/currency into the free-to-play (F2P) mobile game design for both monopoly and duopoly cases and characterizes the optimal strategies for game providers in terms of pricing of virtual goods/currency and the game challenge level. In both cases, we derive optimal pricing and game challenge levels for game providers. In a monopoly setting, it is always in the game provider's best interest to make the game as challenging as possible. In a duopoly setting, a reasonable first mover advantage in the form of discounted value to copycat games is required for the original providers to create original games. Our results provide useful guidelines for mobile game developers facing a threat from copycat competitors.

KEY WORDS AND PHRASES: Free-to-play, in-app purchases, microtransactions, mobile games, online games, online pricing, virtual currency, virtual goods.

Mobile devices are becoming the dominant way for information services to be delivered. Worldwide smartphone sales reached 1.606 billion units in 2016, which is an increase of 12 percent from 2015 [19]. The amount of time users spend on the Internet on mobile devices exceeds time spent using the traditional desktop in 2014 [41]. While most consumers use the mobile devices to access content and information, 35 percent of consumers use mobile devices to play games [30]. According to a study conducted in 2015 [18], 47 percent of Americans playing games prefer mobile devices, which are the most popular platform for players. Furthermore, another report shows that the global mobile game market is expected to double from $17.5 billion in 2013 to $35.4 billion by 2017 [5].

The digital game industry is growing at a very fast rate; in fact, the market brought in $83.6 billion in 2014 and was expected to increase by 19.1 percent to $99.6 billion in 2016 [8, 20]. To put this in perspective, the global box office for films reached $38.6 billion in 2016 [49], whereas the digital game industry brought in more than double box office film revenues. The way digital games are played has evolved during the past few years as the sales of mobile devices have increased dramatically. While PC gaming and console gaming are still leaders in the way that digital games are played, the mobile gaming segment (tablets and smart phones) has been increasing steadily. As of 2015 the total market

International Journal of Electronic Commerce / Vol. 22, No. 2, pp. 258–288.

ISSN 1086–4415 (print) / ISSN 1557–9301 (online)
DOI: https://doi.org/10.1080/10864415.2018.1441755

segment for mobile gaming was 24 percent and it is expected to increase to 34 percent by 2019 [5].

Interest in mobile gaming is immense with 966 million players worldwide [5], bringing in revenues of $34.8 billion, which accounts for 85 percent of all mobile application revenue [39]. Top mobile games can be very successful in generating significant revenue, Supercells games' Clash of Clans and Hay Day generated $2.4 million a day [47]. The dominant way for mobile games to earn revenue has been shifting from the traditional pay outright for the game to a free to play (F2P) model, which earns revenue through micro transactions. According to a study in 2016 [27], players who bought virtual products/currency in mobile games spent an average of $87 on F2P mobiles compared to consumers playing PC and console games who spent an average of $5. Moreover, 64 percent of paying players in the F2P mobile market make at least one purchase while 6.5 percent make five or more purchases [22].

The main difference between mobile F2P and console games is that there is no free trial for players; instead players download the entire game for free [9]. Hence, there are no barriers for players to download and start playing an F2P mobile game. In addition to the lack of a free-trial option, mobile F2P games do not offer pay-to-unlock options, such as new content. The most unique feature of F2P games is that developers offer the entire mobile game free to attract more customers, and then they focus on selling virtual goods and/or virtual currency for real money. Players can still play the entire game without spending real money, but many players are willing to buy virtual currency or virtual goods to speed up their game progression. In today's mobile game market, F2P game developers prefer as many players as possible present in the game due to network effects. Therefore, these mobile games are totally free to download without any free trial period.

In this study, we focus on F2P mobile games generating revenue from selling virtual currency (i.e., diamonds, crystals that can be used to purchase armor, equipment, or faster leveling in game) or virtual goods. We acknowledge that there are also other ways for F2P games to generate revenue: for example, Niantic is planning to charge around €3,000 for a business to become a Pokéstop or gym [43]. However, it is expected by 2017 that in-app purchases will account for 48.2 percent of mobile app revenue, approximately $37 billion. In-app purchases will be the number-one revenue source for mobile apps while paid apps will account for 37.8 percent and ad-based revenue will account for 14 percent [29]. Additionally, the gaming market is expected to account for 80 percent of global app revenue as of 2017 [21]. Thus, our study focuses only on revenue generated by selling virtual currency/goods in F2P mobile games. Our main contribution is providing a framework for a game provider facing strong competition and heterogeneous players. This study incorporates pricing of virtual goods/currency into the F2P mobile game design for both monopoly and duopoly cases. Additionally, we characterize the optimal strategies for game providers in terms of pricing of virtual goods/currency and the game challenge level. In the monopoly setting, if an F2P mobile game is not expected to be very rich in content, the optimal game challenge level does not exist. A monopoly game provider may choose to develop a small F2P mobile game at any challenge level to target a specific type of player base (e.g., casual, moderate, or hardcore gamers). However, if the game is expected to be very rich in content, we present closed-form solutions for the optimal price and the challenge level. As for the duopoly case, we investigate a commonly observed practice, where the copycat game providers compete against the original game providers through duplicating the game mechanism of the original game. We reveal the optimal pricing and game design strategies for both the original and copycat game providers engaged in a duopoly competition. In addition, we show that there should be a reasonable first-mover advantage for the original game provider to create original games.

Literature Review

This study examines microtransactions in digital games, specifically in F2P mobile games. The study is positioned at the interface of information systems, e-commerce, and economics literature.

The pricing strategies of experience goods has been extensively studied in literature. Considering free offering or minimal pricing of goods to attract consumers, and then making money on upgrades, accessories, and so on, there are numerous studies in marketing and industrial economics (e.g., [2, 7, 13, 40]). Varian [50] concludes that the pricing of information goods should be done using differential pricing and along with Bakos and Brynjolfsson [6], and Fishburn, Odlyzko, and Siders [16] that bundling information's goods is desirable. Sundararajan [48] examines the pricing of information goods in the presence of positive transaction costs and concludes that sellers should use fixed fee pricing for unlimited usage in combination with usage-based pricing.

The freemium business strategy is a model that generates revenue on a small percentage of users who will access premium features (additional functions, exclusive features, or virtual goods) while the remainder of consumers will use the product free [11]. While freemium can be associated with most products and services, it is typically associated with digital services or software. There are four common freemium strategies in practice: limited function, time-locked, hybrid (limited and time-locked), and free offering with an annoyance/slow-down mechanism. In the information systems literature, numerous theoretical and empirical studies compare these freemium strategies in the software industry (e.g., [9, 12, 31, 32, 33, 34, 46, 52]). Among well-known examples of freemium services include Hootsuite, Flicker, and Dropbox. Each of these products offers products for free with a premium paid service. Zhang et al. [55] use a game theoretical approach to analyze the impact of freemium strategy on competition between two firms and show that the optimal strategy to offer a free product or bundling depends on the quality of the core product in the presence of network effects.

The freemium strategy has become a popular model in the mobile apps market as well. Liu, Au, and Choi [35] show that the freemium strategy in the android marketplace has a positive impact on sales volume and revenue of the premium version. The main difference between freemium software and F2P games is the existence of micro-transactions, which allow consumers to buy virtual goods via virtual currency in F2P games. The freemium model has become a dominant strategy of revenue generation for mobile devices: 69 percent of gross revenue for iOS devices and 75 percent of gross revenue for Android devices came from freemium games in 2014 [37]. This was mainly done through direct monetization, also known as an in-app purchase. Therefore, the development of mobile freemium games has significantly increased over the past few years and professional game developers see freemium games as a favorable model with a bright future.

Considering current research in digital games, most of the literature focuses on traditional computer and console games. Studies embracing virtual currency, game design, and competition among F2P game providers are very limited. In a recent article, Guo et al. [22] study a monopoly game provider's problem of selling virtual currency to players who enjoy leisure and earn virtual currency. They conclude that decreasing the virtual currency price and increasing the number of virtual goods will improve game providers' revenue. Finneran and Zhang [15] provide a review of promises and challenges of studying flow, a psychological state, in computer-mediated environments and caution researchers to investigate hidden assumptions of theories in other disciplines. Agarwal and Karahanna [1] use a structural equation analysis to examine cognitive absorption of information technology use based on temporal dissociation, focused immersion, heightened enjoyment, control, and curiosity. They propose that playfulness and personal innovativeness are key determinants of cognitive absorption. Liu, Li, and Santhanam [36] argue that competition is the key factor of game design that should be incorporated into organizational activity games such as employee training games.

This study focuses only on F2P games on mobile devices. Regarding game satisfaction and virtual currency in F2P games, researchers have been studying motivations for playing the games and the impacts of virtual currency and promotions. Yee [51] finds that achievement, social environment, and immersion components are the main reasons for playing video games. Ryan, Rigby, and Przybylski [44] demonstrate that game enjoyment, autonomy, competence, and relatedness are important factors for the intention to play video games. Besides players' intentions to play these video games, Moon et al. [40] propose ownership-enhancing and socialization-enhancing strategies to improve player commitment in playing the game. Considering virtual currency and promotions in video games, Guo and Barnes [23] model consumers' behavior buying virtual currency via a mixture of new constructs and established theories, including the theory of planned behavior, technology acceptance model, trust theory, and unified theory of acceptance and use of technology. Additionally, Hamari and Lehdonvirta [25] focus on the marketing of virtual goods for F2Ps due to the untapped potential for marketing of virtual goods and Hamari [24] investigates purchase behavior for virtual goods in three F2P game environments: social networking, first-person shooter, and social virtual world games.

Regarding consumer behavior and promotions in mobile games, current studies in literature mostly focus on surveys and structural equation models to investigate motivations in taking advantage of promotions and buying virtual currency. Lin and Sun [34] examine two key gaming elements—game complexity and game familiarity—nd their impact on user game engagement. They suggest that game designers could change game complexity or familiarity to establish user game engagement. Okazaki, Skapa, and Grande [42] study the adoption of mobile gaming on a global market using 432 responses to surveyd from the United States, Spain, and the Czech Republic. Their results suggest that perceived convenience is the strongest determinant of attitude toward mobile gaming. Furthermore, Wei and Lu [53] find that both network externalities and individual gratifications significantly influence the intention to play social games on mobile devices. They show that both number of players and a gamer's individual gratification influence playing mobile games.

In light of buying virtual currency in mobile games, Animesh et al. [3] study how technological and spatial environments in virtual worlds influence participants' virtual experiences, and how experiences subsequently affect their intention to purchase virtual products. Wu, Li, and Rao [54] survey 253 online game players and found that online game story, graphics, length, and control are highly related to enjoyment, and that enjoyment has a significant impact on behavioral intention even with the presence of control variables. Moreover, Ke et al. [28] study how the unique virtual goods permission settings and other factors are associated with virtual goods prices via using data from Second Life. They find that permissions for virtual goods are not random, as creators strategically set the permissions for their virtual creations, and the copy and transfer permissions are significant factors associated with virtual goods prices. In a more recent study, Hanner and Zarnekow [26] use real data on paying users to study the purchasing behavior for conversion, retention, and monetization of customers in F2Ps by focusing on the marketing of virtual goods due to untapped potential for the marketing of virtual goods. They focus on the customer lifetime value (CLV) from marketing research to understand a small group of paying players in F2P games. Their data analysis suggests that players decide early whether they will be paying or nonpaying customers in the player's lifetime in an F2P game.

To the best of our knowledge, ours is the first study that incorporates the pricing of virtual goods/currency into the F2P mobile game design

Table 1. Comparison of Existing Literature on Digital Games and Virtual Items

Authors	F2P	User behavior	Competition among game providers	Mobile games	Key game design features (Challenge level)	Pricing of virtual items	One time or multiple purchases of virtual items	Research methodology and objectives
Guo et al. [22]	x	x		x		x	Single	Uses classic labor-leisure model to capture the dual experience of enjoying leisure and earning virtual currency for game players.
Guo and Barnes [23]							Single	Attempts to understand users' decision to purchase virtual goods through the use of inductive, qualitative data from focus groups and expert interviews; and deductive, quantitative survey data.
Agarwal and Karahanna [1]		x					N/A	Uses structural equation models and empirical methods to examine the relationship between cognitive absorption and five dimensions of temporal dissociation.
Liu, Li, and Santhanam [35]		x			x		N/A	Examines the relationship between cognitive absorption and five dimensions of temporal dissociation through tournament theory.
Hamari and Lehdonvirta [25]		x			x		N/A	Examines game design for marketing virtual goods using segmentation and differentiation modeling.
Ke et al. [28]		x				x	Single	Reviews the relationship between permission rights of virtual goods and their prices using fixed-effects models.
Hanner and Zarnekow [26]	x	x					Multiple	Looks at the purchasing behavior of players in F2P games and the potential use in the application of games and usage of CLV models using data analysis.
This study	x		x	x	x	x	Multiple	Incorporates pricing of virtual goods and game challenge level into F2P mobile game design for both monopoly and duopoly cases using a Stackelberg model.

for both monopoly and duopoly cases. Table 1 illustrates the position of this study vis-à-vis similar studies in the literature. This study also characterizes the optimal strategies for game providers in terms of pricing of virtual goods/currency, game challenge level, and threat from copycat game providers.

Original Game Provider: A Monopoly Case Analysis

We present a model to analyze two cases based on the game provider's competition: monopoly and duopoly. In both cases, the study presents the optimal structure for the model. In the monopoly case, the original game provider creates an F2P game that does not have a similar competing F2P game in the mobile marketplace. Hence, the game provider's problem in the monopoly case is to assure that there is a market for the game and that players are willing to buy the virtual goods/currency. In the F2P mobile games, players can fast-track character leveling, acquire improvements or buffs, or decrease time constraints with in-game virtual currency like diamonds, rubies, crystals, and so on. The use of virtual currency or goods by a player will decrease the overall challenge level of the game. Therefore, the game providers sell virtual currency or goods (armor, equipment, etc.) for real money in app stores. In this study, we assume that selling virtual goods/currency through in-app microtransactions is the only revenue source for the game provider [4].

The monopoly game provider's decision problem is modeled as a two-stage game, as shown in Figure 1. In Stage 1, the monopoly game provider announces the game challenge level γ and the unit price for the virtual goods/currency p. In Stage 2, players decide whether to participate in the game, and if a player chooses to play, he or she chooses the amount of virtual goods/currency G to purchase.

In real life, we observe that the amount of virtual goods purchased by consumers varies from player to player. To model the "free to play" virtual game scenario, we first require that consumers be heterogeneous in their gaming challenge level preferences. Let θ represent an individual player's preference about the challenge level of the game, which is assumed to be distributed uniformly between 0 and 1. Thus, the population density is normalized at 1. Players are heterogeneous in θ, as follows from Shapiro's [45] classic treatment of consumers'

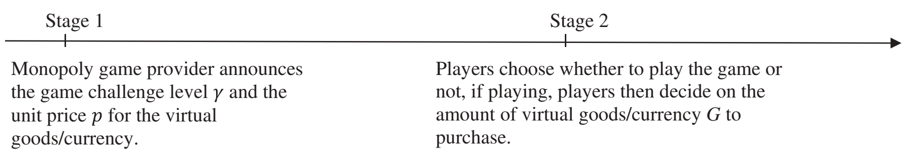

Figure 1. Timing of the Two-Stage Game in a Monopoly

Table 2. Summary of Notation

	Decision Variables
γ	The actual game challenge level/difficulty level set by the game provider.
G	The amount of the virtual goods/currency purchased by the individual game player, determined by the unit price p of the virtual goods/currency and the individual player's type θ.
p	The price paid by the player for a single unit of the virtual goods/currency. This price is set by the game provider.
	Other Variables
θ	Individual player's preference for the game challenge level. Uniformly distributed between [0 and1]
$U(\theta)$	Individual player's overall utility as a function of θ.
θ_L	Indifference player type between playing the game or not playing the game.
θ_U	Indifference player type between purchasing the virtual goods/currency or not.
R	The overall revenue for the game provider through selling the virtual goods/currency.
	Parameters
V	The gross utility of a game, determined by the content offered in the game.
c	Unit fit cost associated with the mismatch between the individual player's preference for the game challenge level and the actual challenge level of the game.
s	The discounted utility for the copycat game.

heterogeneous tastes for product qualities. Players may consume different amounts of virtual goods/currency depending on the actual game challenge level relative to the individual player's personal preference. This is also the point of departure of our model from the existing literature (e.g., [22, 23, 28]), where players are often assumed to consume either zero or one quantity of the game's virtual goods/currency. Obviously, a consumer might not play the game at all if the game is deemed too difficult for a beginner or too easy for a more experienced player. Thus, the actual game challenge level has an impact on the potential market size for the game. Therefore, we treat the actual game challenge level γ as one of the two decision variables of the monopoly game provider in addition to the unit price p for the virtual goods/currency. Our notation is summarized in Table 2.

Player's Decision Problem in Stage 2

This monopoly game is solved by backward induction. First a player's decision is made in Stage 2 assuming a given p and γ. A player's utility function is determined by his or her preference about the challenge level of the game, θ, and the actual game challenge level $\gamma \in [0, 1]$, which is set by the game provider. Let c denote the unit fit cost when a player's preferred challenge level θ is different from the actual game challenge level γ. Note that the game challenge level will cause disutility to a player in both directions when $\theta \neq \gamma$. When a game fails to meet a player's preconception, either by being too easy or too challenging for that player, it often causes frustration to the player's game experience [14, 38]. Lowering the challenge level to "Easy" can feel humiliating to a self-titled "hardcore" player, as raising the challenge level to "Hard" would be unthinkable to a "casual" one. When the game challenge level γ is higher than a player's preferred challenge level θ (i.e., $\gamma > \theta$), the player may choose to purchase a certain amount of virtual goods/currency G (at a cost of pG) to align the game's challenge level with the player's preferred challenge level and therefore improve the player's utility. Meanwhile, if the game challenge level is lower than a player's preferred challenge level (i.e., $\gamma < \theta$), then the player will not purchase any virtual goods/currency as doing so will only decrease a player's utility.

Let V, which is assumed to be equal for all players, denote the gross utility for a game. Note that the gross utility of an F2P mobile game is often determined by the total amount of the content offered in a game, and is thus equivalent for all players who play the game. Combining all these factors, a player's utility function is therefore given by Equation (1):

$$U(\theta) = V - c(\gamma - \theta - G)^2 - pG. \tag{1}$$

The effect of the squared term in Equation (1) above is twofold. First, it captures the diminishing effect of the virtual goods/currency in lowering the game challenge level. This assumption is consistent with our observation in real F2P games. Purchasing a small amount of virtual goods/currency, we often observe that a game's challenge level can be lowered immediately at the beginning of games, but a significant amount of virtual goods/currency is often needed to lower the game challenge level by a moderate amount as the game progresses. Second, the squared term also captures the game challenge level relative to an individual player's personal preference, which causes disutility to a player in both directions. A player will only play a game if he or she has a positive utility, $U(\theta) > 0$.

There are two game challenge level preference thresholds, θ_U and θ_L, which segment players of the game. The indifference point for a player to play the game or not is given by θ_L, which is determined by $U(\theta_L) = 0$ as shown in Equation (2).

$$\theta_L = \gamma - \frac{V}{p} - \frac{p}{4c}. \tag{2}$$

Players with $\theta \leq \theta_L$ will choose not to play the game because the game is too challenging for them relative to V, or because purchasing virtual goods to lower the game challenge level is too expensive. Players whose type is between the two thresholds, that is, $\theta_L \leq \theta \leq \theta_U$, will play the game and purchase virtual goods/currency to lower the game challenge level. Additionally, a player whose challenge level preference θ is greater than θ_U, that is, $\theta \geq \theta_U$, will play the game but choose not to purchase any virtual goods/currency because they deem virtual goods/currency to be unnecessary for them, that is, $G = 0$. This is because they either enjoy playing challenging games or because they have enough time to play the game without the help of

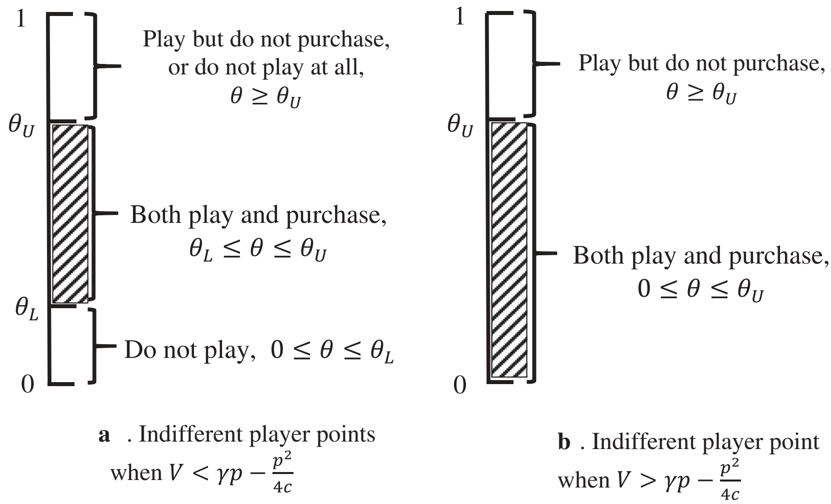

Figure 2. The Distribution of Players in a Monopoly

the virtual goods/currency to fast-track the game's progression. Thus, the game provider will not generate revenue by selling virtual goods/currency to these players. As shown in Equation (3), the indifference point θ_U for a player to purchase virtual goods/currency or not, is therefore determined by $G(\theta_U) = 0$.

$$\theta_U = \gamma - \frac{p}{2c}. \tag{3}$$

Figure 2a illustrates the distribution of the players in a monopoly under this scenario. The shaded area of Figure 2a corresponds to those players who would play the game and purchase the virtual goods/currency. Since we assume that selling virtual goods/currency is the only source of revenue for the game provider, the shaded area also represents the targeted player base for the monopoly game provider. Note that it is also possible to have a segment of players with extremely high preferences for challenge such that they find the given challenge level too low and decide not to play the game at all. However, since players within this segment will not play the game they do not contribute to the game provider's revenue base. Our model thus treats these players the same way as those players who would play the game but not purchase.

Figure 2b illustrates another possible scenario for the monopoly game provider. When an F2P mobile game offers rich content to players, that is, when $V > \gamma p - \frac{p^2}{4c}$, all consumers would derive positive utility by playing the game, that is, $U(\theta) > 0$ for any $\theta > 0$. Since all players find the game interesting enough for them to play, θ_U becomes the threshold between players who purchase or do not purchase virtual goods/currency. Consequently, the shaded area in Figure 2b between $0 \leq \theta \leq \theta_U$ becomes the targeted player base for the monopoly game provider.

Regardless of how rich an F2P mobile game's content is, a player within the shaded area of Figure 2 always faces the same problem—deciding the optimal amount of the virtual goods/currency G to purchase—which maximizes his or her overall utility. Moreover, a player is indifferent to playing or not playing the game if he or she receives zero or negative utility from the game, that is, $U \leq 0$. A player whose $\theta \leq \theta_U$ will select an optimal amount of virtual goods/currency G that maximizes the player's overall utility. Since a player's utility function is concave in G, the first-order condition about the utility function U with respect to G, that is, $\frac{\partial U}{\partial G} = 0$, provides the optimal G^* for a player:

$$G^*(\theta) = \gamma - \theta - \frac{p}{2c}. \tag{4}$$

Note that the optimal amount of the virtual goods/currency G^* purchased by an individual player is independent of the game's gross utility parameter V, but dependent on the two decision variables γ and p set by the monopoly game provider in Stage 1. This result is consistent with our observations in real F2P mobile games. Popular games with either a very limited amount of content (e.g., Flappy Bird, Fruit Ninja, Minecraft, etc.) or very rich content (e.g., Real Racing, Grand Theft Auto, Pokémon Go, etc.) could generate comparable amounts of revenue. In this study, since we do not take the cost of game development into consideration, we therefore consider the gross utility parameter V as exogenously given instead of considering a decision variable set by the monopoly game provider. Also, note that G^* is a function of θ, suggesting that different types of players would purchase different amounts of virtual goods/currency in equilibrium.

Given the optimal amount of the virtual goods/currency, G^*, purchased by an individual player and the two threshold values that segments the market θ_L and θ_U, we are now ready to solve the monopoly's revenue maximization problem in Stage 1.

Monopoly Game Provider's Decision Problem in Stage 1

The game provider's strategies are created in Stage 1. As shown in Figures 2a and 2b, a game provider's revenue from selling virtual goods/currency depends on whether or not the market is fully covered. We therefore divide the monopoly game provider's revenue maximization problem into two scenarios regarding the value of V.

Scenario 1—Partially covered market: *When* $V < \gamma p - \frac{p^2}{4c}$:

When $V < \gamma p - \frac{p^2}{4c}$ (in our model, this value is determined by solving $\theta_L > 0$), a player will play the game if and only if his or her utility is nonnegative, which leads to a partially covered market as shown in Figure 2a. The revenue for the monopoly game provider is based on the number of players bounded by the two threshold values, that is, $\theta_L \leq \theta \leq \theta_U$ and the amount of virtual goods/currency purchased by each player. The revenue function of the monopoly provider is therefore given by Equation (5):

$$R = p\int_{\theta_L}^{\theta_u} G^*(\theta)d\theta. \tag{5}$$

In addition, requiring $0 < \theta_L < \theta_U$ also provides both an upper bound and a lower bound on the unit price of the virtual goods such that:

$$2\left(c\gamma - \sqrt{c(c\gamma^2 - V)}\right) < p < 2\sqrt{cV}. \tag{6}$$

Inequality (6) shows that the unit price for the virtual goods/currency can be neither too low nor too high. On the one hand, if the unit price is too low, all low-type players may derive positive utilities when playing the game by purchasing some virtual goods/currency at an almost negligible cost, which leads to a fully covered market (i.e., $\theta_L < 0$). On the other hand, if the unit price is too high, consumers will perceive that the virtual goods/currency are too expensive. They will either play the game or not play the game but will not purchase any virtual goods/currency (i.e., $\theta_U < \theta_L$) . We provide the analysis of the fully covered market later in this section.

When $V < \gamma p - \frac{p^2}{4c}$, the revenue maximization problem of the monopoly game provider in Stage 1 is presented in Equation (7):

$$\max_{p,\gamma} R = p\int_{\theta_L}^{\theta_u} G^*(\theta)d\theta = \frac{\left(p^2 - 4cV\right)^2}{32c^2p}, \tag{7}$$

Subject to:

$$2\left(c\gamma - \sqrt{c(c\gamma^2 - V)}\right) < p < 2\sqrt{cV}$$

$$0 \leq \gamma \leq 1.$$

A first look at the objective function of the maximization problem is shown in Equation (7), where it seems as if the game provider's revenue function is independent of the game's challenge level γ. A closer look at the revenue function, however, reveals that a monopoly game provider could design the game at any challenge level and then charge an optimal unit price, p^* , according to the game challenge level. The optimal unit price p^* will be determined by the game challenge level γ and therefore impacts the overall revenue for the game provider. In fact, this finding is consistent with our observation in the F2P mobile game industry. When game providers realize they cannot afford to develop large-scale games (i.e., $V > \gamma p - \frac{p^2}{4c}$) that offer rich content to attract all players, many providers develop small mobile games at various challenge levels to target different player bases. There are easy games for casual game players, intermediate games for moderate players, and very challenging games for hardcore gamers. In fact, if an "optimal game challenge level" really exists, then all games will be equally challenging and the targeted market would be the same for all providers, which is clearly counterintuitive. As a result, the optimal game challenge level does not exist for the monopoly game provider when $V < \gamma p - \frac{p^2}{4c}$. We summarize this finding as our first proposition below:

Proposition 1: When a mobile game is not expected to be very rich in content (i.e., $V < \gamma p - \frac{p^2}{4c}$), a monopoly game provider adjusts the game challenge level γ, to target a specific player base. Based on the selected challenge level γ the monopoly developer maximizes revenue by using the optimal unit price of the virtual goods/currency.

Proofs for all Propositions and Lemmas are presented in the Appendix.

Proposition 1 asserts that a monopoly game developer creates games that are not rich in content, with different challenge levels to target different player bases. Moreover, if there were an optimal challenge level, all mobile games would have the same challenge level and only a small portion of the players would be interested in playing those games.

We now turn our attention to finding the optimal unit price p^* for the monopoly game provider. Lemma 1 reveals the properties of the monopoly game provider's revenue function with respect to the unit price of virtual goods/currency p.

Lemma 1: When $V < \gamma p - \frac{p^2}{4c}$, a monopoly game provider's revenue will increase with the decrease of p.

The partial derivative of the revenue function with respect to p is strictly negative ($\frac{\partial R}{\partial p} < 0$) due to the upper bound $p < 2\sqrt{cV}$, and the second-order condition is strictly positive $\left(\frac{\partial^2 R}{\partial^2 p} > 0\right)$. This indicates that the revenue of the monopoly game provider is convex and increases as p decreases. But obviously, p cannot be set to zero, as we assume that the monopoly game provider collects income solely based on selling virtual goods/currency. The optimal price, p^* is thus determined by the lower-bound solution found at:

$$p^* = 2\left(c\gamma - \sqrt{c(c\gamma^2 - V)}\right). \tag{8}$$

By lowering the unit price to the optimal level as shown in Equation (8), a monopoly game provider increases the size of the targeted player base ($\theta_U - \theta_L$), and hence increases the total amount of virtual goods/currency purchased by players to its maximum, which leads to the highest possible revenue for the game provider.

Scenario 2—Fully covered market: *When* $V > \gamma p - \frac{p^2}{4c}$:

A second interesting scenario is when a mobile game offers rich content to players such that $V > \gamma p - \frac{p^2}{4c}$ and the market is fully covered, since all players derive positive utility from playing the game.

Since everyone in the market will play the game, the revenue base for the game provider consists of those players whose preference on the game challenge level is between 0 and θ_U. In this case, the game provider maximizes the revenue using both the unit price of the virtual goods/currency p and the game challenge level γ. Similar to Equation (7), the game provider's revenue maximization problem is presented in Equation (9):

$$\max_{p,\,\gamma} \; R = p\int_0^{\theta_u} G^*(\theta)d\theta = \frac{p(p-2c\gamma)^2}{8c^2}, \tag{9}$$

Subject to:

$$2\sqrt{cV} < p < 2c\gamma$$

$$0 \leq \gamma \leq 1.$$

Lemmas 2 and 3 summarize the properties of the revenue function with respect to the two decision variables p and γ, respectively.

> *Lemma 2: When $V > \gamma p - \frac{p^2}{4c}$, a monopoly game provider's revenue will first increase and then decrease with an increase of the unit price p.*

> *Lemma 3: When $V > \gamma p - \frac{p^2}{4c}$, a monopoly game provider's revenue function monotonically increases with an increase of the game challenge level γ.*

The partial derivative of the revenue function with respect to γ is strictly positive due to the upper bound of the unit price $p < 2c\gamma$, which is needed to guarantee $\theta_U > 0$. The second-order partial derivative of R with respect to γ is also strictly positive indicating the revenue function is convex in γ. Since both the first order and the second order partial derivatives of R with respect to γ are strictly positive, the revenue of the monopoly game provider increases with an increase in the game's challenge level γ. Thus, the optimal γ should be the highest value possible, which is normalized to 1 in our model. Proposition 2 summarizes the optimal solutions for the two decision variables under this scenario.

> *Proposition 2: When $V > \gamma p - \frac{p^2}{4c}$, the monopoly game provider should design the game to be as challenging as possible (i.e., $\gamma^* = 1$) and set the optimal unit price for the virtual goods/currency to $p^* = \frac{2c\gamma}{3}$.*

The optimal unit price, $p^* = \frac{2c\gamma}{3}$, is found by solving the first-order condition of the revenue function (i.e., $\frac{\partial R}{\partial p} = 0$) following Lemma 2. In a monopoly case, if the game offers rich content $\left(\text{i.e., } V > \gamma p - \frac{p^2}{4c}\right)$, it is in the game provider's best interest to always make the game as challenging as possible. This result is reasonable since monopoly game providers create games based on the expected revenue they would generate from selling virtual goods/currency and creating games to be as challenging as possible would result in more revenue.

Copycat Provider: A Duopoly Case Analysis

Cloning is as old as the video game industry itself. In the mobile game market, the problem of copycat games is even more staggering due to familiarity with the popular games and an increased chance of capturing the attention of players (e.g., Pokémon Go vs. Citymon Go, Clash of Clans vs. Game of War, Super Mario Bros. vs. Super Max, 2048 vs. Threes, etc.) [4]. With a seemingly infinite number of games on mobile platforms, it is quite common to see many games that are extremely similar to each other, particularly when you consider the features of the gameplay mechanics. Analyzing a duopoly case in our problem coincides with the copycat problem of the F2P mobile game market. In our model, there are two game providers, A and B, whose F2P games are competing for the same market. Thus, the game providers need to make their decisions not only to capture market share and generate revenue from players buying virtual goods/currency, but also to consider the strategy of the other game providers. Without loss of generality, we assume that game provider B creates a copycat game of provider A; thus, the problem is modeled as a three-stage Stackelberg game as shown in Figure 3.

In Stage 1, the original game provider A announces the game challenge level γ_A and the unit price for the virtual goods/currency p_A for its game. In Stage 2, the copycat announces game challenge level γ_B and the unit price for the virtual goods/currency p_B for its game, observing the strategies adopted by provider A. In Stage 3, players decide which game to play and choose the amount of virtual goods/currency G_A and G_B to purchase. As in the monopoly case, the duopoly case is solved by backward induction.

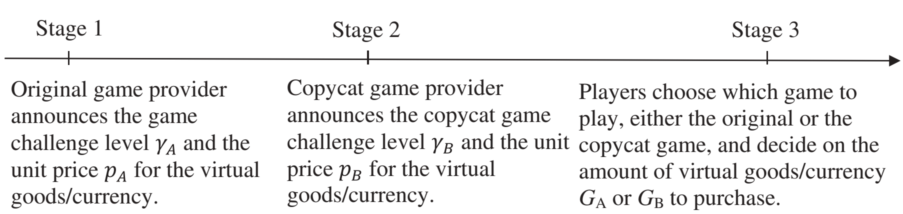

Figure 3. Timing of the Three-stage Stackelberg Game

Player's Decision Problem in Stage 3

Through backward induction, first we solve the player's decision problem in Stage 3, assuming that the game challenge levels (both original and copycat games) and the unit prices for the virtual goods/currency are already observed by players. A player's utility function has the following forms depending on the choice of the F2P game:

$$U_A = V - c(\gamma_A - \theta - G_A)^2 - p_A G_A \tag{10}$$

$$U_B = V - s - c(\gamma_B - \theta - G_B)^2 - p_B G_B. \tag{11}$$

As shown in Equation (11), we assume a penalty $s > 0$ for the gross utility of the copycat game. This is because the original game often offers a larger player base and is deemed by players as more valuable due to positive network effects. Furthermore, most F2P mobile games are multiplayer, so there are already more players playing the original game when the copycat game is introduced. Hence, the copycat game provider will suffer for not being first to market. In our analysis, we also choose to focus on the duopoly competition between the original game and the copycat when the market is fully covered, i.e. $V > \gamma p_A - \frac{{p_A}^2}{4c}$. An original game with large gross utility (V) often enjoys an initial release success, which not only attracts a lot of players but also draws copycat competitors due to its popularity. In fact, in F2P games if an original game is indeed very popular then a copycat game is almost guaranteed to show up, hence a duopoly competitor. For example, within days of the release of Pokémon Go, CityMon Go was released and became one of the most downloaded iOS games in China [17]. We also assume that both game providers bring similar game content (V is the same for both game providers) to the market. This assumption is reasonable since the copycats would most likely clone original games when competing against them [10, 17].

Regardless of the different game challenge levels and the prices set by the two game providers in duopoly, a player always chooses the game that brings the most utility to play. In Stage 3, a player select which game to play, either the original or the copycat game, and decides on the amount of virtual goods/currency G_A or G_B to purchase. The maximization problems for an individual player are therefore given by Equations (12) and (13):

$$\max_{G_A} U_A = V - c(\gamma_A - \theta - G_A)^2 - p_A G_A, \tag{12}$$

Subject to: $G_A \geq 0$

$$\max_{G_B} U_B = V - s - c(\gamma_B - \theta - G_B)^2 - p_B G_B \tag{13}$$

Subject to: $G_B \geq 0$.

Since U_A and U_B are concave in G_A and G_B, respectively, the optimal amount of virtual goods/currency purchased by the player is found by solving the first-order conditions $\frac{\partial U_A}{\partial G_A}$ $\frac{\partial U_B}{\partial G_B}$ and the optimal solutions are presented in Equations (14) and (15):

$$G_A^* = \gamma_A - \theta - \frac{p_A}{2c}, \tag{14}$$

$$G_B^* = \gamma_B - \theta - \frac{p_B}{2c}. \tag{15}$$

Setting $G_A^* = 0$ and $G_B^* = 0$, we find the indifference points for the players purchasing virtual goods/currency or not as shown in Equations (16) and (17):

$$\theta_{UA} = \gamma_A - \frac{p_A}{2c}, \tag{16}$$

$$\theta_{UB} = \gamma_B - \frac{p_B}{2c}. \tag{17}$$

To find out which game an individual player would choose to play, we substitute G_A^* and G_B^* back into the player's utility functions and obtain the maximized utility functions as shown in Equations (18) and (19):

$$U_A^* = \frac{p_A^2}{4c} + V - p_A(\gamma_A - \theta), \tag{18}$$

$$U_B^* = \frac{p_B^2}{4c} + V - p_B(\gamma_B - \theta) - s. \tag{19}$$

Depending on the value of θ, a player would choose to play the original game if $U_A^* > U_B^*$ or the copycat game if $U_A^* < U_B^*$. When $U_A^* = U_B^*$, a player with game challenge level preference θ_i, is indifferent between choosing games A or B.

$$\theta_i = \frac{p_A^2 - p_B^2 + 4c(p_B\gamma_B + s - p_A\gamma_A)}{4c(p_B - p_A)}. \tag{20}$$

Depending on the value of θ_i as shown in Equation (20), the market is segmented between the original and the copycat game providers.

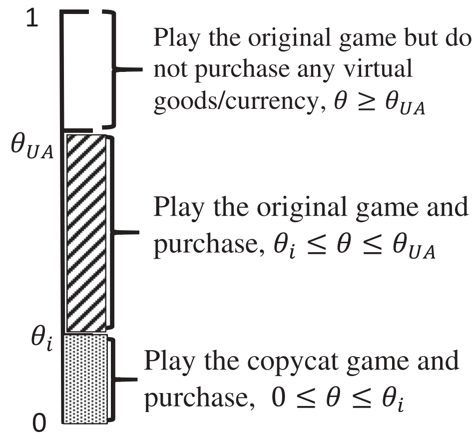

Figure 4. The Distribution of Players in a Duopoly When $p_B < p_A$

Copycat's Decision Problem in Stage 2

The copycat game provider's objective is to optimize its revenue using both its game's challenge level and the pricing of the game's virtual goods/currency. Note that if the copycat provider sets the unit price for its virtual goods higher than the original game provider (i.e., $p_B > p_A$), the duopoly game is expected to be dominated by the original game provider. This is because players already perceive the copycat game as the less valuable product (due to the discount factor s), if the virtual goods in the copycat game are more expensive, consumers will have no incentive to play the copycat game. Hence, we choose to focus on the case in which $p_B \leq p_A$. This leads to the market segment as shown in Figure 4. The shaded area of Figure 4 corresponds to those players who would play the game and purchase the virtual goods/currency. Since we assume that selling virtual goods/currency is the only source of revenue for both game providers, the shaded area also represents the targeted market for both providers.

The shaded area between $\theta_i$andθ_{UA} is the targeted market for the original game provider, A , while the shaded area between 0 and θ_i is the targeted market for the copycat provider, B . The revenue function for the copycat game provider is given by Equation (21):

$$R_B = p_B \int_0^{\theta_i} G_B d\theta. \tag{21}$$

To maximize R_B, the copycat provider finds optimal p_B^* and γ_B^* by observing p_A^*, γ_A^* set by the original game provider in Stage 1. The revenue maximization problem for the copycat provider is presented in Equation (22):

$$\max_{p_B,\, \gamma_B} R_B = \frac{p_B\left(p_B^2 - 4cs - p_A^2 + 4p_A\gamma_A - 4cp_B\gamma_B\right)\left(4cs + p_A^2 + 3p_B^2 - 4p_A(p_B + c(\gamma_A - 2\gamma_B)) - 4cp_B\gamma_B\right)}{32c^2(p_A - p_B)^2}, \tag{22}$$

Subject to: $0 < p_B < 2c\gamma_B - \sqrt{p_A^2 - 4cp_A\gamma_A + 4c(s + c\gamma_B^2)}$

$$0 \le \gamma_B \le 1.$$

To ensure that the copycat game provider's revenue is positive, that is, $R_B > 0$, there is an upper bound such that $p_B < 2c\gamma_B - \sqrt{p_A^2 - 4cp_A\gamma_A + 4c(s + c\gamma_B^2)}$. Note that this upper bound on p_B is smaller than the lower bound on p_A (derived based on $\theta_{UA} > \theta_i$). Thus, the price set on the virtual goods/currency sold by the original game provider is always going to be greater than that of the copycat game provider, that is, $p_A > p_B$, which is consistent with our previous assumption. The copycat game must offer virtual goods/currency at a cheaper price than the original game to have positive revenue. The failure to provide cheaper virtual goods/currency will have the result that players choose to participate only in the original game. Lemma 4 provides key characteristics of the copycat provider's revenue function with respect to the two decision variables γ_B and p_B.

Lemma 4: The copycat provider's revenue function will first increase and then decrease with the raising of the game challenge level γ_B and the unit price p_B for the virtual goods/currency.

Lemma 4 also confirms the existence of a pair of interior optimal solutions for the copycat provider. The optimal price and the challenge level for the copycat game are solved by using the first-order conditions $\frac{\partial R_B}{\partial \gamma_B} = 0$, $\frac{\partial R_B}{\partial p_B} = 0$ and are derived by solving the two equations simultaneously. Proposition 3 summarizes the optimal solutions for the copycat game provider in Stage 2.

Proposition 3: Copycat game provider should set its game challenge level at $\gamma_B^* = \frac{10p_A - \sqrt{12cs + 19p_A^2 - 12cp_A\gamma_A}}{6c}$ *and the unit price for the virtual goods/currency at* $p_B^* = \frac{1}{3}\left(4p_A - \sqrt{12cs + 19p_A^2 - 12cp_A\gamma_A}\right)$ *to maximize its revenue.*

The optimal price and challenge level for the copycat provider depends on the original game provider's challenge level and price. The copycat provider's optimal price will be lower than the original game provider's price, and will thus allow the copycat to attract players. There exists an optimal game challenge level for the copycat provider in response to the original game providers' strategies set in Stage 1.

Original Game Provider's Decision Problem in Stage 1

In Stage 1, the original game provider A sets its price and challenge level with the expectation that a copycat game will show up in Stage 2. The revenue function of the original game provider is derived based on the targeted market between $[\theta_i, \theta_{UA}]$ as shown in Figure 4. The original game provider's optimal p_A and γ_A can be found by substituting the optimal p_B^* and γ_B^* (found in Stage 2) into R_A and then solving the revenue maximization problem for the original game provider as shown in Equation (23):

$$\begin{aligned}\max_{p_A,\,\gamma_A} R_A &= p_A \int_{\theta_i}^{\theta_{UA}} G_A d\theta \\ &= \frac{p_A\left(p_A^2 + p_B^2 - 2p_A p_B - 4c(p_B\gamma_B + s - p_A\gamma_A)\right)^2}{32c^2(p_A - p_B)^2},\end{aligned} \tag{23}$$

Subject to:

$$p_B + 2\sqrt{cs - cp_B\gamma_A + cp_B\gamma_B} < p_A < \frac{1}{2}\left(\sqrt{(4c - 4c\gamma_A)^2 - 4(4cs - 4cp_B - p_B{}^2 + 4cp_B\gamma_B)} - 4c(1 - \gamma_A)\right)$$

$$0 \leq \gamma_A \leq 1.$$

The upper bound of p_A is derived based on the constraint that $0<\theta_i<1$ and the lower bound of p_A is derived based on the constraint that $\theta_{UA} > \theta_i$. Solving the above maximization problem, we obtain the optimal unit price for the original game provider such that:

$$p_A{}^* = \frac{2}{15}\left(7c - 2\sqrt{c^2 + 15cs}\right). \tag{24}$$

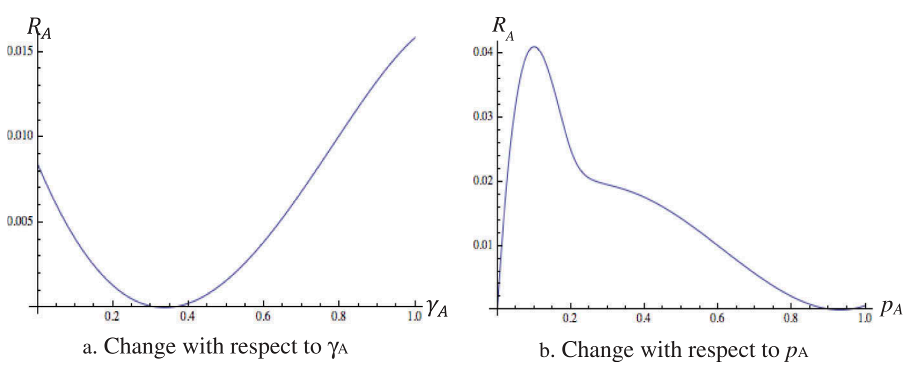

Figure 5. Change of the Original Game Providers' Revenue Function

Since the revenue function R_A is convex in γ_A, the interior optimal solution of $\gamma_A{}^*$ does not exist. As a result, we plot the revenue function R_A with respect to γ_A in Figure 5a and analyze the optimal $\gamma_A{}^*$ as well as the optimal unit price $p_A{}^*$ numerically.

Figure 5 illustrates the change of the original game provider's revenue function with respect to γ_A and p_A. We set $c = 0.35$, $p_A = 0.11$ $s = 0.1$ in Figure 5a and $c = 0.35$, $\gamma_A = 1$, $s = 0.1$ in Figure 5b. The revenue function R_A as shown in Figure 5a is convex in γ_A. Starting at approximately $\gamma_A = 0.33$, the original game provider may choose to raise the game challenge level to increase its overall revenue. Furthermore, raising the game challenge level to the highest value leads to the maximum revenue possible. This indicates that the optimal solution for the game challenge level is found at $\gamma_A{}^* = 1$. In other words, it is in the original game provider's best interest to offer the most challenging game in the duopoly setting. Moreover, if the original game provider does not set γ_A to the upper bound value, the copycat provider will steal market share by cutting the price of its virtual goods/currency. That is not a desirable situation for the original game provider; hence, the challenge level γ_A should be the maximum feasible value based on previously set parameters. As is also illustrated in Figure 5b, although the revenue function R_A is not strictly concave in p_A, the optimal value for the unit price p_A that maximizes the original game provider's revenue does exist (at approximately p_A = 0.11) in the example shown, which is consistent with the closed-form solution presented in Equation (24).

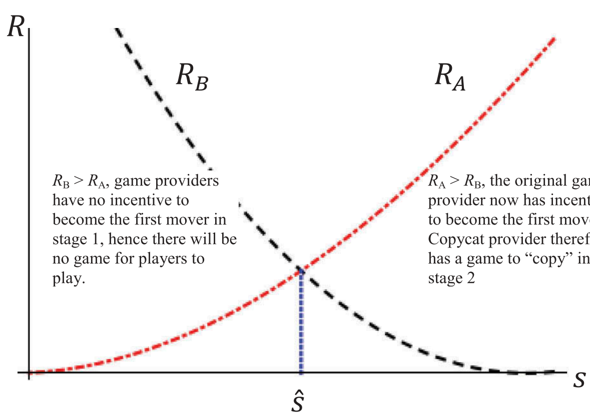

Figure 6. The Critical Threshold Value of the Discount factor *s* that Provide First Mover Advantage

The Impact of the Discount Factor s

Figure 6 illustrates the impact of the discount factor s on the revenues of the two game providers. In Figure 6, we set $c = 0.35$, $p_A = 0.11$ and $\gamma_A = 1$, to represent revenue functions for two game providers.

As shown in Figure 6, when $s < \hat{s}$ the revenue of the copycat game provider's revenue is higher than the original game provider, which is a somewhat surprising result. If the discount factor value $s < \hat{s}$ is known to the original game provider beforehand, then the original game provider is better off as a copycat. Thus, no original game would be introduced to the market at all. The discount factor or penalty s reflects a first-mover advantage for the original game provider. To ensure that there is a healthy market in which original games will continue to be produced, the industry can examine the use of regulations. For example, by regulating the release time of games, the industry can potentially ensure that $s > \hat{s}$ and prevent market failure. While this study does not recommend regulation, it is potentially in the industries' best interest to examine the possible use of regulations to sustain a healthy mobile game market. The larger the first-mover advantage the more incentive for the original game provider to develop brand new games. The original game provider may pursue legal methods through copyright or patent protection to secure a penalty from the copycat provider so that the discount factor is big enough to provide the necessary incentives. But often, the copycat game only clones the game play and mechanics of the original game, which is not copyrightable or enforceable. Thus, the original game provider should consider investing more in the content of the game so that it will take longer and make it harder for the copycat provider to clone. By releasing the game first into the market, the original game provider also enjoys the first-mover advantage in building up its play base. In choosing F2P mobile games, players often favor the game with the larger player base. From the copycat game providers' perspective, it is in their best interest to reduce the first-mover advantage received by the original game provider. The copycat game provider may achieve this by releasing the cloned version of the game soon after the release of the original game before the original game builds up a dominant player base. This practice is often observed in the real world. When a popular mobile game is released a copycat game tends to follow quickly. For example, Clash of Clans was released in August 2012 and less than a year later Game of War was released in July 2013. When comparing the revenue of the two games in 2015, Clash of Clans came out ahead with $1.345 billion while Game of War made $799 million [10].

Conclusion and Discussion

Revenue generation in F2P games is a challenging task for game providers due to heterogeneous consumers and strong competition from copycat games. In this study, we characterize optimal strategies for a monopoly game provider and for both the original and copycat game providers in a duopoly case. To our knowledge, ours is the first study that attempts to integrate mobile game design with pricing and competition in a duopoly setting.

In the monopoly case, the game provider's revenue is heavily dependent on the game design features. These design features include the game challenge level and the unit price for the virtual goods/currency sold through in-game microtransactions, which are often utilized by casual players either to lower the game challenge level or to speed up the game progress. If the F2P mobile game is not expected to be very rich in content, the optimal game challenge level does not exist. A monopoly game provider may choose to develop a small F2P mobile game at any challenge level to target a specific type of player base (e.g., casual, moderate, or hardcore gamers). Once a player base is selected, the game provider's problem is to maximize its revenue by finding the optimal unit price for the virtual goods/currency sold in the game. We provide a closed-form solution for the game provider's optimal price, which reveals that the optimal price is dependent on the game challenge level selected by the monopoly game provider. Conversely, if the game is expected to be very rich in content, the market is then fully covered because every player in the market receives positive utility from playing the game. The game provider maximizes its revenue by determining both the optimal unit price of the virtual goods/currency and the optimal game challenge level. We show that the optimal game challenge level does exist and should be set to the highest value possible. Furthermore, there is an optimal unit price for the virtual goods/currency such that the monopoly provider's revenue is maximized. Thus, in a monopoly case, it is in the game provider's best interest to always make the game as challenging as possible if the game is very rich in content.

In the duopoly case, we focused on popular F2P games with rich content. We show that there exists a pair of optimal solutions for the copycat provider's decision problem. To maximize revenue, both the optimal game challenge level and the optimal unit price for the virtual goods/currency should be set by the copycat provider in observation of the original game provider's strategy. Our analysis shows that there is an upper bound on the price of virtual goods/currency in the copycat game and this price should be lower than that of the original game. Regarding the original game provider's strategy, we show that an optimal unit price for the virtual goods/currency does exist for the original game and the original game provider should set the challenge level of the game to the highest value possible to maximize its expected revenue, anticipating that the copycat provider will cut its price in the duopoly setting. Moreover, through numerical analysis, we show that there should be a reasonable first-mover advantage—in the form of discounted value to copycat games—for the original providers in order for them to create original games.

This study is not without limitations. Although it integrates pricing decisions with F2P game design and heterogeneous players, our model does not take players' adaptive behaviors into consideration. Players may improve their playing skills and thus modify their preferred game challenge levels as they become more skilled with game-play mechanics, which in turn could affect game providers' strategies. In addition, our model assumes that the discount factor is the same for all players, but in actuality it might be different. Besides this assumption, the duopoly case analysis is limited to popular F2P games with rich content (i.e., the gross utility of the game is sufficiently large). For future research, we are working on extending our model to address these limitations, incorporate the network externality effect of the F2P mobile games, and explore endogenous gross utility/game content in the player's utility function. It will also be interesting to expand the model to include players with multiple accounts for the same game and players playing both games in the duopoly case.

REFERENCES

1. Agarwal, R., and Karahanna, E. Time flies when you're having fun: Cognitive absorption and beliefs about information technology usage. *MIS Quarterly*, *24*, 4 (2000), 665–694.
2. Anderson, C. *Free: The Future of a Radical Price*. New York: Hachette Book Group, 2009.
3. Animesh, A.; Pinsonneault, A.; Yang, S. B.; and Oh, W. An odyssey into virtual worlds: Exploring the impacts of technological and spatial environments on intention to purchase virtual products. *MIS Quarterly*, *35*, 3 (2011), 789–810.
4. "App Annie & IDC Portable Gaming Report 2014 Review." http://go.appannie.com/app-annie-idc-portable-gaming-report-2014-review/ (accessed on February 2, 2017).
5. "AppLift and NewZoo latest report finds global mobile games market to double by 2016." http://venturebeat.com/2013/10/29/the-mobile-opportunity-global-mobile-games-market-to-double-by-2016/(accessed on May 18, 2016).
6. Bakos, Y., and Brynjolfsson, E. Bundling information goods: Pricing, profits, and efficiency. *Management Science*, *45*, 12 (1999), 1613–1630.
7. Benjamin, E. *Freemium Economics: Leveraging Analytics and User Segmentation to Drive Revenue*. Burlington, MA: Morgan Kaufmann, 2014.
8. Campbell, C. "Worldwide video games market will grow 9.4 percent this year, says report." http://www.polygon.com/2015/4/22/8471789/worldwide-video-games-market-value-2015, (accessed on May 18, 2016).
9. Cheng, H.K., and Liu, Y. Optimal software free trial strategy: The impact of network externalities and consumer uncertainty. *Information Systems Research*, *23*, 2, (2012), 488–504.

10. Crawley, D. “Rise of the clones: Why it pays (sometimes) to be a copycat mobile game.” https://www.chartboost.com/blog/2016/01/why-it-pays-to-be-copycat-mobile-game/(accessed on May 26, 2016).
11. de la Iglesia, J.L.M., and Gayo, J.E.L. Doing business by selling free services. In M.D. Lytras, E. Damiani, and P.O. dePablos (eds.), *Web 2.0: The Business Model*. New York: Springer Science+Business Media, LLC, 2009, pp. 89–102.
12. Dey, D.; Lahiri, A.; and Liu, D. Consumer learning and time-locked trials of software products. *Journal of Management Information Systems*, *30*, 2 (2013), 239–267.
13. Draganov, D. *Freemium Mobile Games: Design and Monetization*. CreateSpace Independent Publishing Platform, 2014.
14. Fabricatore, C.; Nussbaum, M.; and Rosas, R. Playability in action videogames: A qualitative design model. *Human Computer Interaction*, *17*, 4 (2002), 311–368.
15. Finneran, C.M., and Zhang, P. Flow in computer-mediated environments: Promises and challenges. *Communications of the Association for Information Systems*, *15*, 1 (2005), 82–101.
16. Fishburn, P.C.; Odlyzko, A.M.; and Siders, R.C. Fixed fee versus unit pricing for information goods: Competition, equilibria, and price wars. In D. Hurley, B. Kahin, and H. Varian (eds.), *Internet Publishing and Beyond: The Economics of Digital Information and Intellectual Property*. Cambridge, MA: MIT Press, 1997, pp. 167–189.
17. Game makers already developing copycat Pokémon Go Apps CityMon Go’s Pikachu Lookalike Rockets game to top of Chinese charts. http://adage.com/article/digital/game-makers-creating-copycat-pokemon-apps/304921/(accessed on February 2, 2017).
18. Gamers gone mobile: Half of Americans play video games on mobile devices. http://www.mintel.com/press-centre/technology-press-centre/gamers-gone-mobile-half-of-americans-play-video-games-on-mobile-devices (accessed on April 26, 2017).
19. Gartner says worldwide device shipments to grow 1.9 percent in 2016, while end-user spending to decline for the first time. http://www.gartner.com/newsroom/id/3187134 (accessed on April 26, 2017).
20. Global games market report infographics 2015. https://newzoo.com/insights/articles/global-games-market-reaches-99-6-billion-2016-mobile-generating-37/(accessed on October 20, 2016).
21. Global mobile market report: App market to gross $44.8BN this year. https://newzoo.com/insights/articles/global-mobile-market-report-app-market-to-gross-44-8bn-this-year/(accessed on February 2, 2017).
22. Guo, H.; Hao, L.; Mukhopadhyay, T.; and Sun, D. Selling virtual currency in digital games: Implications on gameplay and social welfare. *Proceedings of Theory in Economics of Information Systems*. Banff, Canada, 2015, pp. 1–28.
23. Guo, Y., and Barnes, S. Why people buy virtual items in virtual worlds with real money. *ACM SIGMIS Database*, *38*, 4 (2007), 69–76.
24. Hamari, J. Why do people buy virtual goods? Attitude toward virtual good purchases versus game enjoyment. *International Journal of Information Management*, *35*, 3 (2015), 299–308.

25. Hamari, J., and Lehdonvirta, V. Game design as marketing: How game mechanics create demand for virtual goods. *International Journal of Business Science and Applied Management*, *5*, 1 (2010), 14–29.
26. Hanner, N., and Zarnekow, R. Purchasing behavior in free to play games: Concepts and empirical validation. *Proceedings of the Forty-Eighth Hawaii International Conference on System Sciences (HICSS2015)*. Hawaii: IEEE, 2015, pp. 3326–3335.
27. Hardly pocket change: Mobile gamers spend an average of $87 on in-app purchases. https://intelligence.slice.com/hardly-pocket-change-mobile-gamers-spend-an-average-of-87-dollars-on-in-app-purchases/(accessed on October 26, 2016).
28. Ke, D.; Ba, S.; Stallaert, J.; and Zhang, Z. An empirical analysis of virtual goods permission rights and pricing strategies. *Decision Sciences*, *43*, 6 (2012), 1039–1061.
29. Kearl, M. 30 essential stats on in-app purchases and monetization. https://www.appboy.com/blog/in-app-purchase-stats/(accessed on February 2, 2017).
30. Keating, L. Gaming on-the-go: The future of mobile gaming vs. consoles. http://www.techtimes.com/articles/57048/20150604/gaming-go-future-mobile-vs-consoles.htm (accessed on May 26, 2016).
31. Kim, K.; Yoo, B.; and Kaufmann, R. J. Valuation of participation in social gaming. *International Journal of Electronic Commerce*, *18*, 2 (2014), 11–49.
32. Kourouthanassis, P.E., and Giaglis, G.M. Introduction to the special issue on mobile commerce: The past, present, and future. *International Journal of Electronic Commerce*, *16*, 4 (2012), 5–17.
33. Liang, T.P.; Li, X.; Yang, C.; and Wang, M. What in consumer reviews affects the sales of mobile apps: A multifacet sentiment analysis. *International Journal of Electronic Commerce*, *20*, 2 (2016), 236–260.
34. Lin, H., and Sun, C. 2011. Cash trade in free-to-play online games. *Games and Culture*, *6*, 270–287.
35. Liu, C.; Au, Y.; and Choi, H. Effects of freemium strategy in the mobile app market: An empirical study of Google Play. *Journal of Management Information Systems*, *31*, 3 (2014), 326–354.
36. Liu, D.; Li, X.; and Santhanam, R. Digital games and beyond: What happens when players compete? *MIS Quarterly*, *37*, 1 (2013), 111–124.
37. Luton, W. *Free-to-Play: Making Money from Games You Give Away*. San Francisco: New Riders, 2003.
38. Malone, T.W., and Lepper, M.R. Making learning fun: A taxonomy of intrinsic motivations for learning. In R.E. Snow and M.J. Farr (eds.), *Aptitude, Learning, and Instruction Volume 3: Conative and Affective Process Analyses*, Hillsdale, NJ: Lawrence Erlbaum, 1987, pp. 223–253.
39. Mobile games hit $34.8B in 2015, taking 85% of all app revenues. http://venturebeat.com/2016/02/10/mobile-games-hit-34-8b-in-2015-taking-85-of-all-app-revenues/(accessed on October 26, 2016).
40. Moon, J.; Hossain, Md. D.; Sanders, G.L.; Garrity, E.J.; and Jo, S. Player commitment to massively multiplayer online role-playing games (MMORPGs): An integrated model. *International Journal of Electronic Commerce*, *17*, 4 (2013), 7–38.

41. Murtagh, R. Mobile now exceeds PC: The biggest shift since the Internet began. http://searchenginewatch.com/sew/opinion/2353616/mobile-now-exceeds-pc-the-biggest-shift-since-the-internet-began (accessed on May 18, 2016).
42. Okazaki, S.; Skapa, R.; and Grande, I. Capturing global youth: Mobile gaming in the US, Spain, and the Czech Republic. *Journal of Computer Mediated Communication*, *13*, 4 (2008), 827–855.
43. "Pokemon Go" latest news & updates: Niantic offering sponsored location spawn points to businesses for Pokestops. http://www.gamenguide.com/articles/56530/20161018/pokemon-go-latest-news-updates-niantic-offering-sponsored-location-spawn-points-to-businesses-more-money-for-developer.htm (accessed on October 26, 2016).
44. Ryan, R.M.; Rigby, C.S.; and Przybylski, A. The motivational pull of video games: A self-determination theory approach. *Motivation and Emotion*, *30*, 4 (2006), 344–360.
45. Shapiro, C. Optimal pricing of experience goods. *Bell Journal of Economics*, *14*, 2 (1983), 497–507.
46. Shi, S.W.; Xia, M.; and Huang, Y. From minnows to whales: An empirical study of purchase behavior in freemium social games. *International Journal of Electronic Commerce*, *20*, 2 (2016), 177–207.
47. Strauss, K. The $2.4 million-per-day company: Supercell. http://www.forbes.com/sites/karstenstrauss/2013/04/18/the-2-4-million-per-day-company-supercell/(accessed on May 18, 2016).
48. Sundararajan, A. Nonlinear pricing of information goods. *Management Science*, *50*, 12 (2004), 1660–1673.
49. Theatrical Market Statistics. http://www.mpaa.org/wp-content/uploads/2017/03/MPAA-Theatrical-Market-Statistics-2016_Final.pdf (accessed on April 26, 2017).
50. Varian, Hal R. Pricing information goods. *Proceedings of Scholarship in the New Information Environment Symposium*. Cambridge, MA: Harvard Law School, 1995. http://people.ischool.berkeley.edu/~hal/Papers/price-info-goods.pdf
51. Yee, N. Motivations for play in online games. *CyberPsychology & Behavior*. 9, 6 2006, 772–775.
52. Wagner, T.; Benlian, A.; and Hess, T. Converting freemium customers from free to premium: The role of the perceived premium fit in the case of music as a service. *Electronic Markets*, *24*, 4 (2014), 259–268.
53. Wei, P.S., and Lu, H.P. Why do people play mobile social games? An examination of network externalities and of uses and gratifications. *Internet Research*, *24*, 3 (2014), 313–331.
54. Wu, J.; Li, P.; and Rao, S. Why they enjoy virtual game worlds? An empirical investigation. *Journal of Electronic Commerce Research*, *9*, 3 (2008), 219–230.
55. Zhang, Z.; Nan, G.F.; Li, M.Q.; and Tan, Y. Duopoly pricing strategy for information products with premium service: Free product or bundling? *Journal of Management Information Systems*, *33*, 1 (2016), 260–295.

ISMAIL CIVELEK (ismail.civelek@wku.edu) is an associate professor and Hays Watkins Research Fellow in the Department of Management at Gordon Ford College of Business at Western Kentucky University. He received his Ph.D. in operations management and manufacturing from Tepper School of Business at Carnegie Mellon University. His areas of expertise are manufacturing and service operations management, queuing theory, simulation, and revenue management. His research work has been published in a number of journals, including *European Journal of Operational Research*, *International Journal of Manufacturing Technology and Management*, and *Annals of Management Science.*

YIPENG LIU (yliu@niu.edu; corresponding author) is an assistant professor in the Department of Operations Management and Information Systems at Northern Illinois University. He received his Ph.D. in information systems at the University of Florida. His areas of expertise include economic modeling of information systems, design of mobile apps, public safety networks, online two-sided market, software free trial strategies, cloud computing security, and quantum computing algorithms in global optimization. His research has appeared in a number of journals, including *Information Systems Research*, *Journal of Management Information Systems*, *International Journal of Electronic Commerce*, and *European Journal of Operational Research.*

SEAN R. MARSTON (sean.marston@wku.edu) is an associate professor in the Department of Information Systems at the Gordon Ford College of Business at Western Kentucky University. He received his Ph.D. in information systems and operations management at the Warrington College of Business at the University of Florida. His research includes the analysis of digital distribution of information, the economic analysis of information systems policies, and cloud computing security policy. His work has been published in *Journal of Management Information Systems*, *International Journal of Electronic Commerce*, *Decision Support Systems*, and *Decision Science Journal.*

Note: All authors contributed equally and are listed in alphabetical order.

Appendix

Proof of Proposition 1

When V is small, the targeted market for the monopoly game provider is determined by the difference of the two threshold values $\theta_U - \theta_L = \frac{V}{p} - \frac{p}{4c}$, which are dependent on the unit price p of the virtual goods/currency sold through the microtransactions of the game. As we show in Equation (8), the optimal unit price p is determined by the boundary solution found at:

$$p^* = 2\left(c\gamma - \sqrt{c(c\gamma^2 - V)}\right).$$

This in turn shows that the game challenge level γ has an impact on the targeted market size hence the revenue of the monopoly game provider through the optimal unit price p for the virtual goods/currency set by the monopoly game provider.∎

Proof of Lemma 1

$$R = p\int_{\theta_L}^{\theta_u} G^*(\theta)d\theta = \frac{\left(p^2 - 4cV\right)^2}{32c^2 p}$$

$$\frac{\partial R}{\partial p} = \frac{\left(p^2 - 4cV\right)\left(3p^2 + 4cV\right)}{32c^2 p^2} < 0$$

$$\frac{\partial^2 R}{\partial^2 p} = \frac{3p}{16c^2} + \frac{V^2}{p^3} > 0 \blacksquare .$$

Proof of Lemma 2

$$R = p\int_{0}^{\theta_u} G d\theta.$$

By substituting $G^*(\theta) = \gamma - \theta - \frac{p}{2c}$ and $\theta_U = \gamma - \frac{p}{2c}$ into R, we obtain:

$$R = \frac{p(p - 2c\gamma)^2}{8c^2},$$

$$\frac{\partial^2 R}{\partial^2 p} = \frac{3p - 4c\gamma}{4c^2}.$$

Proof of Lemma 3

$$R = p\int_{0}^{\theta_u} G d\theta = \frac{p(p - 2c\gamma)^2}{8c^2}.$$

$$\frac{\partial R}{\partial \gamma} = \frac{2cp\gamma - p^2}{2c} > 0.$$

$$\frac{\partial^2 R}{\partial^2 \gamma} = p > 0 \blacksquare .$$

Proof of Proposition 2

By Lemma 4, R is convex in γ and monotonically increasing as γ increases; thus the monopoly provider selects the highest possible γ (i.e., $\gamma = 1$) when V is large. As for p, R is concave in p; hence, the first-order condition provides the optimal p :

$$R = \frac{p(p - 2c\gamma)^2}{8c^2},$$

$$\frac{\partial R}{\partial p} = \frac{(p - 2c\gamma)(3p - 2c\gamma)}{8c^2} = 0,$$

Since $p<2c\gamma$, $p = \frac{2c\gamma}{3}$, ∎.

Proof of Lemma 4

To guarantee $R_B > 0$, one must have $\left(-p_B^2 + p_A^2 + 4c(p_B\gamma_B + s - p_A\gamma_A)\right) < 0$. This condition is also a necessary condition to guarantee $\theta_i > 0$. Solving $\left(-p_B^2 + p_A^2 + 4c(p_B\gamma_B + s - p_A\gamma_A)\right)<0$ gives the upper bound on p_B, such that:

$$p_B < 2c\gamma_B - \sqrt{p_A^2 - 4cp_A\gamma_A + 4c\left(s + c\gamma_B^2\right)}.$$

The revenue of the copycat game provider is given by:

$$R_B = p_B \int_0^{\theta_i} G_B d\theta = -\frac{p_B\left(-p_B^2 + p_A^2 + 4c(p_B\gamma_B + s - p_A\gamma_A)\right)\left(4cs + p_A^2 + 3p_B^2 - 4p_A(p_B + c(\gamma_A - 2\gamma_B)) - 4cp_B\gamma_B\right)}{32c^2(p_A - p_B)^2},$$

$\frac{\partial^2 R_B}{\partial^2 \gamma_B} = \frac{p_B^2(p_B - 2p_A)}{(p_A - p_B)^2} < 0$ due to $p_B<p_A$,

$$\frac{\partial^2 R_B}{\partial^2 p_B} = \frac{\begin{array}{c} 2p_A^5 - 16c^2s^2p_B + 9p_B^5 - 16cp_B^4\gamma_B + p_A^4(p_B - 16c\gamma_B) \\ -8p_A^3\left(3p_B^2 + 4c^2(\gamma_A - \gamma_B)^2 - 8cp_B\gamma_B\right) \\ +2p_A^2\left(23p_B^2 + 32c^2s(\gamma_A - \gamma_B) - 8c^2p_B(\gamma_A - \gamma_B)^2 - 48cp_B^2\gamma_B\right) \\ +p_A\left(-32c^2s^2 - 34p_B^4 + 32c^2sp_B(\gamma_A - \gamma_B) + 64cp_B^3\gamma_B\right) \end{array}}{16c^2(p_A - p_B)^4} < 0.$$

Note that the above equation $\frac{\partial^2 R_B}{\partial^2 p_B}$ is less than 0 due to $p_B\ 2c\gamma_B - \sqrt{p_A^2 - 4cp_A\gamma_A + 4c(s + c\gamma_B^2)}$∎.

Proof of Proposition 3

By Lemma 6, R_B is concave in γ_B and p_B; hence, solving the first–order conditions with respect to γ_B and p_B simultaneously provides γ_B^* and p_B^*.

$$\frac{\partial R_B}{\partial \gamma_B} = 0,$$

$$\frac{\partial R_B}{\partial p_B} = 0.$$

Since $0 \leq \gamma_B \leq 1$, $p_B > 0$, $p_A > p_B$ and $p_B < 2c\gamma_B - \sqrt{p_A^2 - 4cp_A\gamma_A + 4c(s + c\gamma_B^2)}$ (Lemma 5), only a pair of optimal solution satisfies these conditions:

$$\gamma_B^* = \frac{10p_A - \sqrt{12cs + 19p_A^2 - 12cp_A\gamma_A}}{6c},$$

$$p_B^* = \frac{1}{3}\left(4p_A - \sqrt{12cs + 19p_A^2 - 12cp_A\gamma_A}\right) \blacksquare.$$