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The Impact of User-generated Content on Product Innovation

David A. Schweidel, Aric Rindfleisch, Matthew S. O'Hern, and Kersi D. Antia

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David A. Schweidel*

Aric Rindfleisch

Matthew S. O'Hern

Kersi D. Antia

*David A. Schweidel (dschweidel@bus.wisc.edu) is assistant professor of marketing, School of Business, University of Wisconsin-Madison, Aric Rindfleisch (aric@bus.wisc.edu) is professor of marketing, School of Business, University of Wisconsin-Madison and research professor, Korea University Business School, Matthew S. O'Hern (mohern@lcbmail.uoregon.edu) is assistant professor of marketing, Lundquist College of Business, University of Oregon, Kersi D. Antia (kantia@bus.wisc.edu) is assistant professor of marketing, School of Business, University of Wisconsin-Madison. The authors contributed equally and are listed in reverse-alphabetical order. This research benefited from helpful feedback from participants at the Emergence and Impact of User-Generated Content Conference at the University of Pennsylvania and from financial support from the Marketing Science Institute.

THE IMPACT OF USER-GENERATED CONTENT ON PRODUCT INNOVATION

ABSTRACT

Our research investigates the impact of user-generated content (UGC) on product innovation. Prior research has focused on the role of UGC as a form of consumer-to-consumer communication that enhances product promotion. In contrast, we examine UGC as a form of consumer-to-business communication that facilitates product innovation. Specifically, we examine the impact of three types of UGC (reports, requests, and revisions) on two innovation outcomes (product development and market response). We apply this categorization to a longitudinal sample of 4,450 open source software projects and jointly model the monthly incidence of new product releases, product downloads, and UGC activity. In contrast to commonly held thought, our results suggest that the impact of UGC is not strictly positive, but varies according to both the type of UGC as well as the metric of product innovation. Collectively, our research provides a broadened conceptualization of UGC and suggests that user contributions may both help and hinder product innovation.

The recent rise in user-generated content (UGC) is dramatically reshaping the marketing landscape (Marketing Science Institute 2008). An increasing number of knowledgeable and connected consumers are no longer content with merely choosing and using a company's offerings; they also want to contribute to the development, distribution, and promotion of these offerings (O'Hern and Rindfleisch 2009; von Hippel 2005). These contributions have fueled the rise of new ventures such as Jones Soda, Threadless, and YouTube, and are being creatively leveraged by a growing collection of established firms such as Dell, Intuit, and Procter & Gamble (Chafkin 2008; Cook 2008; Huston and Sakkab 2006; Seybold 2006). These changes in marketing practice also challenge marketing thought, as the rise of user contributions disrupts established paradigms regarding the roles of firms and consumers (Vargo and Lusch 2004). Thus, UGC is a timely and important research topic.

In recent years, a growing number of scholars have begun to investigate the impact of UGC on various marketing outcomes (Chevalier and Mayzlin 2006; Godes and Mayzlin 2004; Li and Hitt 2008; Mayzlin 2006; Moe 2009). Although this emerging research provides important contributions to our understanding of UGC, it focuses on consumer-to-consumer (C2C) communications and largely views UGC as a form of product promotion via positive word-of-mouth. Moreover, the extant research has concentrated on the effects of a single type of UGC: product reviews. Although product reviews (e.g., Amazon.com, Yelp.com) represent a substantial portion of UGC activity, users can contribute in a variety of other ways, ranging from requests and responses for product assistance (e.g., Dell consumer forums) to actual product revisions and enhancements (e.g., Linux and Firefox). These latter forms of UGC serve as a means of consumer-to-business (C2B) communication, as they provide a mechanism for consumers to contribute ideas and insights that may influence product innovation.

Our research seeks to extend the emerging UGC literature by assessing the impact of this broader array of UGC activity on product innovation. Our conceptualization builds upon the extant UGC literature by incorporating insights from related research in the domain of open innovation (e.g., Chesbrough 2003; Thomke and von Hippel 2002; von Hippel 2005). This conceptualization serves as a point of distinction from prior research, which broadly views UGC as a promotional tool rather than a means of product innovation. Specifically, our conceptualization suggests that users contribute to product innovation in a variety of ways and these contributions may vary in their impact.

Using open source software (OSS) as our empirical context, we test this claim by jointly examining the impact of three different types of contributions (reports, requests, and revisions) on two different types of marketing outcomes (product development and market response) using a longitudinal sample of 4,450 OSS projects. Our analysis reveals both positive and negative effects of UGC on product innovation. Furthermore, the type of UGC that enhances product development is different from the type of UGC that cultivates market response. Thus, our results suggest that the impact of UGC is more nuanced than previously detailed.

Our research contributes to both marketing theory and practice. First, in contrast to prior UGC research, we offer an expanded conceptualization by considering the role of UGC as a means of product innovation. Second, our results offer managerially relevant insights regarding the types of UGC that are most likely to lead to success (or failure) in terms of both internal (i.e., product development) and external (i.e., market response) marketing metrics.

THE IMPACT OF UGC ON PRODUCT INNOVATION

This section begins with a review of marketing's emerging UGC literature and summarizes its key assumptions and major findings. We then contrast this literature to research in the related domain of open innovation research and offer testable propositions regarding the impact of various types of C2B user contributions on both market response and product development.

User-Generated Content Research

The impact of UGC on marketing outcomes has recently captured the attention of a small but expanding cadre of marketing scholars. An overview of several of the key studies in this emerging literature is provided in Table 1.

[Insert Table 1]

As shown in Table 1, the extant literature concentrates on UGC in the form of user reviews of various products and services such as books (Chevalier and Mayzlin 2006), movies (Liu 2006), music albums (Dhar and Chang 2009), and television shows (Godes and Mayzlin 2004). For example, Godes and Mayzlin (2004) relate the volume and dispersion of product reviews to television show ratings. Likewise, Chevalier and Mayzlin (2006) study the impact of book reviews posted on Amazon.com and Barnesandnoble.com on online book sales. Conceptually, these studies view UGC as a means of word-of-mouth (WOM) by enthusiastic users (Godes and Mayzlin 2004; Li and Hitt 2008; Mayzlin 2006). Thus, this literature typically considers UGC as a form of C2C communication.

Given this C2C orientation, UGC researchers focus on the impact of UGC on various forms of market response such as consumer perceptions (Godes and Mayzlin 2004; Mayzlin 2006) and product sales (Chevalier and Mayzlin 2006; Godes and Mayzlin 2009; Li and Hitt 2008). Interestingly, the UGC literature has found, with a few exceptions (i.e., Moe 2009), that the impact of product reviews upon market response is generally positive. For example, Chevalier and Mayzlin (2006) find that user reviews posted on Amazon.com and Barnesandnoble.com positively influences online book sales. In a related project, Mayzlin (2006) shows that online user reviews play an important role in shaping perceptions of product quality and combating the promotional activity of competing offerings. In sum, the extant UGC literature adopts a C2C orientation, examines how user contributions in the form of reviews impact market response, and finds that this impact is generally positive.

Open Innovation Research

While the extant UGC literature provides important insights regarding the impact of user contributions on other users (C2C), it does not directly address UGC's impact on product developers (i.e., C2B). To understand the role of user contributions on product innovation and inform our conceptualization, we draw on research in the related domain of open innovation (Bendapudi and Leone 2003; Raymond 1999; von Hippel 2005). In congruity with the UGC literature, open innovation research recognizes the active role that users play in shaping marketing outcomes. However, while UGC research focuses on users as agents of promotion, the open innovation research focuses on users as agents of innovation. A defining characteristic of this literature is the recognition that users can contribute to innovation in a variety of ways (Cook 2008; Seybold 2006). For example, Raymond's (1999) historical account of user contributions to the early development of Linux recognizes the contributions of both technically savvy users who revised Linux's source code, as well as the contributions of less technically equipped users who reported technical flaws or requested changes that led to important product improvements.

The multifaceted nature of user contributions is also evident in a variety of other OSS ventures. For example, approximately 30% of the source code for the popular OSS web browser, Firefox, is directly developed by users (Vogelstein 2008). In addition, users can indirectly contribute to the development of Firefox by identifying bugs in its current software, beta-testing new releases, or simply contributing ideas for potential product improvements (www.mozilla.org/contribute/). Other examples of multifaceted user contributions to OSS include the webserver Apache (www.apache.org), the database MySQL (www.mysql.org), and the development tool NetBeans (www.netbeans.com).

Although OSS is the best known setting in which users contribute significantly to product innovation, users have begun to actively contribute to the development of products and services in a variety of other domains, including architecture (www.architectureforhumanity.org), medical devices (www.designthatmatters.org), and automobiles (www.edag-light-car.com). Across all of these contexts, users mainly contribute by communicating product-related ideas to developers (i.e., C2B) rather than by trying to persuade or inform other users (i.e., C2C). Thus, the nature and type of UGC in an innovation context is qualitatively different than the nature and type of UGC that marketing scholars have typically studied to date. We provide a summary overview of the key differences between these two forms of UGC (C2C vs. C2B) in Table 2. These distinctions are emphasized in both our own conceptualization and empirical analysis, as we focus on three types of C2B UGC (reports, requests, and revisions) that are distinct from the type of user contribution (reviews) examined in the extant C2C UGC literature.

[Insert Table 2]

The Impact of UGC on Market Response. One important distinction between C2B UGC and C2C UGC is their impact on marketing outcomes. As noted earlier, the extant UGC literature largely focuses on the impact of user contributions on some indicant of market response, such as product sales or perceived quality. These are important external metrics for assessing the impact of marketing efforts in general and have also been identified as useful indicants for evaluating the success of a firm's innovation efforts (Hauser et al. 2006). For example, Bendapudi and Leone (2003) link user co-production to consumer satisfaction. More recently, Rajagopalan and Bayus (2008) examine the impact of user revisions on market response (i.e., number of downloads) to OSS projects. In addition to these external metrics, a number of studies in the open innovation domain have focused on internal metrics (which are more directly linked to product development activity) such as the number of product enhancements, the number of new product releases, and the speed of product development (Grewal, Lilien, and Mallapragada 2006; Mallapragada, Grewal, and Lilien 2008; Rajagopalan and Bayus 2008; von Krogh, Spaeth, and Lakhani 2003). Thus, our research builds on and extends this stream of research by examining the impact of multiple types of user contributions (reports, requests, and revisions) on both external (market response) and internal (product development) indicants of innovation success.

As noted earlier, marketing's extant UGC literature has generally found that UGC has a positive impact on market response (see Godes and Mayzlin 2004 for a notable exception). This positive impact is at least partly due to the fact that this literature largely focuses on UGC in the form of product reviews, such as those displayed on Amazon.com, which are overwhelmingly positive in nature (Chevalier and Mayzlin 2006). We expect that the impact of UGC in a C2B context is unlikely to be strictly beneficial. In contrast to the generally positive tone of product reviews, some types of C2B UGC display a more mixed disposition and are often weighted toward criticism rather than praise. For example, many OSS projects have one or more online forums geared toward reporting bugs and identifying flaws (von Krogh et al. 2003). These reports may send a negative signal about a program's quality and consequently dissuade potential users from downloading the software. Similarly, an abundance of user requests for new features may signal that an offering is lacking in terms of functionality. On the other hand, other forms of C2B

UGC may positively impact market response. For example, Rajagopalan and Bayus' (2008) recent study of OSS development shows that adoption of an OSS program is positively related to the number of users who revise it by contributing source code. In sum, we expect that the impact of C2B UGC on market response will vary according to the type of UGC. Specifically, we expect that revisions will exhibit a more positive impact on market response than reports or requests.

The Impact of UGC on Product Development. In addition to influencing market response, C2B UGC may also impact internal metrics of innovation success, such as the quality and speed of product development (Grewal et al. 2006; Rajagopalan and Bayus 2008; von Krogh et al. 2003). Although the linkage between user contributions and product development has not been considered by the extant UGC literature, it is widely recognized by open innovation researchers.

Indeed, the open innovation literature generally views the developmental aspect of user contributions (i.e., access to free and high quality intellectual talent) to be one of its most attractive qualities (Cook 2008; Prahalad and Ramaswamy 2004; von Hippel 2005). Von Hippel (2005) suggests that users who provide detailed reports about a product's problems or shortcomings help developers improve the quality of their offerings and generate novel solutions. For example, Intuit executives rely heavily on user reports as a means of not only identifying the most important enhancements that their consumers desire but also speeding up the development of these solutions (Cook 2008). The value of user reports is succinctly captured by Raymond (1999, p. 30), who famously quipped, "Given enough eyeballs, all bugs are shallow."

Although user reports may provide a useful tool for enhancing product development, other types of C2B UGC may be less effective or even detrimental. For example, developers that try to accommodate user requests are likely to find that this effort may be quite difficult and time consuming, as users are likely to express considerable heterogeneity in their desires. In addition, only a handful of users offer contributions to developers (Weber 2004). Thus, these requests may represent a weak and inaccurate form of market sensing, resulting in an orientation that is overly niche-focused and too market-driven (Jaworski, Kohli, and Sahay 2000). Moreover, as suggested by Simonson (2005), user requests may reflect needs that are weakly articulated and constantly evolving. Thus, developers that alter their offerings based upon user requests may be chasing the wind.

As previously noted, user revisions are often touted as an effective and low-cost mechanism for continuous product improvement (Grewal et al. 2006; von Hippel 2005; von Krogh et al. 2003). This type of UGC may also reduce cycle time by providing product developers with ready-made solutions that can be quickly integrated into a given product (Huston and Sakkab 2006). Although obtaining user assistance in revising a product offering may lead to substantial product improvements, many of the revisions submitted by users are either low quality in nature or are difficult to integrate (Raymond 1999). As noted by Moorman and Miner (1997), the ability of a group of individuals to collaboratively develop new products is highly dependent upon shared mental models, a common base of knowledge, and a high degree of tacit knowledge. These characteristics are unlikely to be possessed by most users, who typically work in isolation from other users and seldom meet face-to-face. Thus, an essential feature of successful open innovation is the degree to which developers are able to select high quality revisions and dismiss lower quality ones (O'Hern and Rindfleisch 2009).

A popular example of this principle is Wikipedia, which rejects many of the revisions submitted by its users (Lih 2009). Without a careful selection process, user revisions are likely to lead to incoherence and hamper product quality. For example, Penguin Publishing's recent attempt to develop a wiki novel ("A Million Penguins") by incorporating 100% of the revisions submitted by its users resulted in a novel marred by rambling prose, under-developed characters, and no discernable plot (Mason and Thomas 2008). Thus, the impact of user revisions on product development is somewhat uncertain. In sum, we expect that the role of C2B UGC on product development will vary according to the type of UGC, with reports exhibiting a more positive impact on product development than requests or revisions.

EMPIRICAL CONTEXT

We investigate the impact of UGC on product innovation within the context of OSS projects. In contrast to commercially available software programs, OSS is freely distributed and encourages users to not only use the program but also to suggest and/or makes changes to it. Thus, compared to UGC in traditional C2C domains (e.g., Amazon.com), OSS is considerably more reliant upon users for the development of new products and offers a rich context for observing multiple types of UGC activity (Cook 2008; Raymond 1999; von Hippel 2005). Examples of OSS projects are plentiful and include several well-known and successful programs such as MySQL (database management system), Mozilla (web browser) and Linux (operating system), as well as many failed offerings such as Xara (graphics program) and Darwin (operating system). Although OSS has a long history of scholarly investigation in the computer science domain, it has only recently garnered the attention of marketing scholars (e.g., Grewal et al. 2006; Mallapragada et al. 2008; Rajagopalan and Bayus 2008).

Data

We obtained our data from Sourceforge.net, the world's largest repository of OSS projects. This repository has been employed in recent studies in the open innovation domain (e.g., Grewal et al. 2006; Mallapragada et al. 2008; Rajagopalan and Bayus 2008). Maintained by Geeknet, a publicly traded US-based company, this repository includes more than 230,000 software projects and has more than two million users. In addition to providing a means for users to download various types of software projects, Sourceforge also allows them to contribute to these projects by reporting problems, requesting edits, or even revising the project's source code. This data is available for download via Sourceforge's data archive service (Van Antwerp and Madey 2008). For each project, this archive provides information about the kind of software application being developed, the date the project was registered on Sourceforge, the date of both the initial product launch and subsequent releases (if any), the number of cumulative downloads per release, and the content and timing of various types of user contributions.

From this repository, we selected a subset of approximately 40,000 software projects initiated between February 2006 and July 2007 and tracked each selected project until January 2008. This time frame allowed us to observe each project for a minimum of seven months to a maximum of 23 months. From this subset, we randomly selected a sample of 6,000 projects that had at least one release. After the removal of 1,550 projects that had insufficient details about release activity, 4,450 projects remained for which we had complete data on release, download, and UGC activity. Of these 4,450 projects, 55% had just one and 90% of the projects had five or fewer releases. In terms of average monthly downloads, these projects had a minimum of .84, a maximum of 145, and a median of 4 downloads. Across projects, the cumulative UGC contributions of each type were sparse with a median number of 2 reports (range: 0-1,088) , 0 requests (range: 0-111), and 0 revisions (range: 0-37).

Measures

Release Activity. For each OSS project contained in its repository, Sourceforge records the date when a release is made available for download. The timestamp for initial and subsequent releases (if any) serves as our measure of product development. An initial release is akin to a new product rollout (Raymond 1999). Following prior research, we assume that the release of a new version of an OSS project represents a substantial improvement over a previously released version (e.g., Mallapagrada et al. 2008; Rajagopalan and Bayus 2008). Thus, release activity appears to be a reasonable indicant of product development activity.

Download Activity. For each generation of a project release, Sourceforge provides a cumulative count of its number of downloads each month. Monthly download activity, which can be derived by taking the difference in cumulative downloads between contiguous months, serves as our indicant of market response. In essence, download activity can be viewed as a form of product acquisition, which is a commonly used measure of market response in the UGC literature (e.g., Chevalier and Mayzlin 2006; Godes and Mayzlin 2009; Li and Hitt 2008).

UGC Activity. Sourceforge actively encourages UGC by providing several forums whereby registered users may provide various types of project-specific input. For example, users may post *reports* pointing out specific questions or problems (i.e., bugs) encountered when using the software. Registered users may also post *requests* for additional refinements that would enhance the project’s functionality. In contrast to reports, requests are considerably more forward-looking in nature and entail suggestions for further project improvements. Lastly, users may make their own *revisions* (i.e., patches) to the project and immediately offer these revisions either for other users to download or for the software developers to incorporate in subsequent releases. Collectively, user-generated reports, requests, and revisions comprise three distinct (though potentially inter-related) means by which users may provide feedback for use by both consumers and project developers. Examples (from Sourceforge) of each of these types of UGC are provided in Table 3.

[Insert Table 3]

MODEL SPECIFICATION

Three aspects of our empirical context must be accommodated in our analysis. First, user contributions to OSS occur at the project level, and thus, are not directly tied to a specific release. Second, over the course of the observation period, a number of releases receive little or no download activity in a given month. Third, some projects may generate more interest than others across all fronts (i.e., download activity, release activity and UGC activity), resulting in a high correlation among these activities. Accordingly, we estimate a joint model that accounts for each of these characteristics. This model is comprised of three distinct components: (1) download activity, (2) release activity, and (3) contribution activity according to each type of UGC. We provide a stylized depiction of these three components in Figure 1.

[Insert Figure1]

We next describe each of the model components.

Download Activity

To assess the impact of UGC contributions on download activity, we model both the incidence and amount of downloads for release g of project i in month t, denoted Y_{igt}. We relate both incidence and volume to the same set of potential drivers. First, we expect that the incidence and volume of downloads to be related to a generational trend, as later project releases may build upon the success of earlier releases. This expectation is based on the logic that users should be more prone to download later releases of a project because they ostensibly offer improvements over prior releases. To account for differences in download activity across releases of the same project, we allow for a generational trend that includes a corresponding quadratic term to accommodate potential nonlinear effects. Second, users should also prefer to download the latest available release of a particular project. For example, if a third version of a project is released, users should be less likely to download the two earlier releases. Thus, the download incidence and volume for a particular release will likely display a precipitous decline due to obsolescence attributable to subsequent releases. Third, diffusion research suggests that most products follow a life cycle (Golder and Tellis 2004). Thus, download activity is likely to diminish over time following a particular release. Accordingly, we allow for an age trend with a corresponding quadratic term.

We also allow each type of UGC to have a varying impact on download activity. While some types of UGC may spur download activity, consistent with what has been observed in the extant UGC literature (Godes and Mayzlin 2009; Li and Hitt 2008), others types may stifle download activity. For example, because revisions are essentially patches that address a project's flaws and shortcomings, this form of UGC should make a project more attractive, and thus, increase download activity. In contrast, because reports draw attention to a project's flaws and problems, this form of UGC may cause potential users to delay or even re-think their download decision.

Formally, we assume that the monthly download incidence of the g^{th} generation of project i in month t ($Y_{igt} > 0$) follows a Bernoulli distribution with probability q_{igt}, such that:

$$\begin{aligned}\text{logit}(q_{igt}) = \alpha_{i1} &+ \overbrace{(\kappa_1 \cdot g) + (\kappa_2 \cdot g^2)}^{\text{Generational Trend}} + \overbrace{(\kappa_3 \cdot Age_{igt}) + (\kappa_4 \cdot Age_{igt}^2)}^{\text{Age Trend}} + \overbrace{\left(\kappa_5 \cdot \log\left(1 + \sum_{t'=1}^{t-1} \sum_{g'=1}^{Gen_{it}} Y_{ig't'}\right)\right)}^{\text{Installed Base Effect}} \\ &+ \underbrace{\sum_{z=1}^{3} \kappa_{(5+z)} \cdot \log\left(1 + \sum_{t'=1}^{t-1} UGC_{izt'}\right)}_{\text{UGC Effect}} + \underbrace{(\kappa_9 \cdot I(g < Gen_{it}))}_{\text{Obsolescence}}\end{aligned} \tag{1}$$

where Gen_{it} is the latest release of project i that is available in month t (i.e., the current generation of the project), Age_{igt} is the number of months for which the g^{th} release of project i has been available as of month t, and UGC_{izt} is the number of UGC contributions of type z that were contributed to project i in month t.

The first term in equation (1) accounts for differences in download incidence that may exist across projects. The next two terms (κ_1 and κ_2) capture the generational trend described previously using a quadratic function. Variation attributable to the number of months for which a particular release of the project has been available is also captured using a quadratic trend (κ_3 and κ_4). The installed base effect (κ_5) accounts for the growth or decline in users' interest in the project over time. To account for the effect of UGC contributions until time t, we allow each contribution type to differentially impact download incidence. Lastly, we include an indicator variable to reflect the availability of a newer release, and hence, the obsolescence of prior releases.

Using the same explanatory variables, we model the amount of download activity for those generations of projects downloaded in month t. Conditional on $Y_{igt} > 0$, we assume that $\log(Y_{igt}/1000) \sim N(\mu_{igt}, \sigma^2)$, such that:

$$\mu_{igt} = \alpha_{i2} + (\kappa_{10} \cdot g) + (\kappa_{11} \cdot g^2) + (\kappa_{12} \cdot Age_{igt}) + (\kappa_{13} \cdot Age_{igt}^2) + \left(\kappa_{14} \cdot \log\left(1 + \sum_{t'=1}^{t-1} \sum_{g'=1}^{Gen_{it}} Y_{ig't'}\right)\right) + \sum_{z=1}^{3} \kappa_{(14+z)} \cdot \log\left(1 + \sum_{t'=1}^{t-1} UGC_{izt'}\right) + (\kappa_{18} \cdot I(g < Gen_{it})) \quad (2)$$

Release Activity

To model developers' decision to release a new generation of project i in month t, (denoted $Release_{it}$), we employ a set of explanatory variables similar to those of our download activity-related model. We first allow for variation across projects in the propensity of developers to release a newer version of the software each month. We also consider variation in release activity that may be explained by the number of releases that have been made available to date, given by Gen_{it}. As developers may be more (or less) likely to release a new generation of a project as time passes since the latest release was made available, we incorporate the number of months since the last release as a regressor (denoted $SinceLast_{it}$ and given by $\min(Age_{igt})$ over all releases g) for the decision to release a new version of the project in month t. We also account for the size of the installed base and the volume of the three types of UGC contributions. We assume that $Release_{it}$ follows a Bernoulli distribution with the probability of releasing a new generation of project i in month t given by p_{it}, such that:

$$\text{logit}(p_{it}) = \alpha_{i3} + (\gamma_1 \cdot Gen_{it}) + (\gamma_2 \cdot Gen_{it}^{\ 2}) + (\gamma_3 \cdot SinceLast_{it}) + (\gamma_4 \cdot SinceLast_{it}^2)$$
$$+ \left(\gamma_5 \cdot \log\left(1 + \sum_{t'=1}^{t-1}\sum_{g'=1}^{Gen_{it}} Y_{ig't'}\right)\right) + \sum_{z=1}^{3} \gamma_{(5+z)} \cdot \log\left(1 + \sum_{t'=1}^{t-1} UGC_{izt'}\right) \quad (3)$$

While prior research largely focuses on the effect of UGC contributions on market response, these contributions may also affect developers' decisions to release new generations of a project. As such, there are two ways in which UGC may contribute to market response. First, UGC may have a direct effect, reflected by the parameters κ_6, κ_7, and κ_8 in equation (1) and κ_{15}, κ_{16}, and κ_{17} in equation (2). It may also have an indirect effect on market response by affecting the likelihood with which a new release is made available. If there is a positive generational trend in download activity (i.e., $\kappa_{10} > 0$), with later releases being downloaded more frequently than earlier releases, hastening the release of a new generation may increase overall download activity. Our modeling approach allows for both possibilities.

UGC Contributions

While our research is focused on understanding the effects of different types of C2B UGC contributions on both download and release activity, we must also consider how these activities may affect UGC contributions. As the contributions of UGC may not be exogenous, we model number of UGC contributions of type *z* in month *t* to project *i* as a function of the number of releases and the time elapsed (in months) since the latest release. It also seems reasonable to assume that a larger installed base may be associated with a higher volume of UGC contributions, thanks to a larger pool of potential contributors. Accordingly, we model the number of UGC contributions of type *z* to project *i* in month *t* according to a Poisson distribution with rate λ_{izt}, where:

$$\log(\lambda_{izt}) = \alpha_{i(3+z)} + (\beta_{1z} \cdot Gen_{it}) + (\beta_{2z} \cdot Gen_{it}^{\ 2}) + (\beta_{3z} \cdot SinceLast_{it}) + (\beta_{4z} \cdot SinceLast_{it}^2) + \left(\beta_{5z} \cdot \log\left(1 + \sum_{t'=1}^{t-1}\sum_{g'=1}^{Gen_{it}} Y_{ig't'}\right)\right) \quad (4)$$

for z = 1, 2, 3.

As in the case of downloads and release activity, some projects may be more likely to attract UGC contributions than others. To allow for these differences across projects, as well as to account for the potential correlation that may exist among the project-level intercepts of model components, we assume that:

$$\alpha_{i\cdot} \sim MVN\left(\overline{\alpha}, \Sigma\right) \tag{5}$$

While the volume of each type of UGC contributed varies both over time and across projects, the vector of intercepts ($\alpha_{i\cdot}$) is assumed constant over time. We thus are able to distinguish between differences in the baseline levels of activities and the effects of UGC.

We assume diffuse normal priors for the parameters β, κ, and γ, and an Inverse-Wishart prior for Σ. To make inferences from our model, two chains of an MCMC sampler were run for 10,000 iterations, which were discarded as a burn-in period. We then draw inferences from posterior samples of the next 20,000 iterations.

RESULTS

The estimated correlations among the random effects α_i, derived from the covariance matrix Σ, are displayed in Table 4.

[Insert Table 4]

These results indicate that download activity, release activity, and UGC contributions are positively correlated with the project-level intercepts for our three types of C2B UGC. Thus, projects that tend to be popular (i.e., are downloaded more frequently) also exhibit higher release activity and experience more UGC contributions. Whereas previous research has focused primarily on the impact of UGC on marketing outcomes, our results point to the need to also consider the UGC contribution process. Simply because a project receives more UGC, has more releases, and is downloaded more in comparison to other projects does not necessarily imply that releases and downloads are the result of UGC activity. Ignoring these relationships may lead to spurious conclusions regarding the impact of UGC contributions on market response and release activity.

We next examine the effect of the predictors of download activity, release activity, and UGC activity. We begin with the results for download activity. The posterior means and 95% highest probability density (HPD) intervals for the download incidence and amount models are displayed in Table 5.

[Insert Table 5]

For both model components, we observe a negative trend in release age ($\kappa_3 = -.25$, $\kappa_{12} = -.19$). Thus, as more time passes since a release is made available, fewer downloads occur. The quadratic terms ($\kappa_4 = .01$, $\kappa_{13} = .01$) indicate that the magnitude of this negative trend diminishes over time. Our results also reveal a positive generational trend ($\kappa_1 = .18$, $\kappa_{10} = .16$) that diminishes over time ($\kappa_2 = -.00$, $\kappa_{11} = -.00$), indicating that later project releases are likely to experience higher download activity compared to earlier releases. The size of the installed base, reflected by cumulative downloads to date, is positively related to the volume of downloads in a given month ($\kappa_{14} = .02$). Also, as expected, the availability of a new release reduces interest in earlier versions, as indicated by the negative effects for the obsolescence variable ($\kappa_9 = -3.21$, $\kappa_{18} = -1.57$).

With respect to UGC contributions, we observe varying effects across the three contribution types. Revisions appear to have the strongest effect, with more revisions contributing to increased download activity ($\kappa_6 = 2.01$, $\kappa_{15} = .98$). This result is in accord with our expectations, as revisions seek to resolve identified problems, and should thus contribute positively to download activity. Interestingly, the remaining two types of UGC contributions (requests and reports) largely exhibit an *adverse* effect on download activity (requests: $\kappa_7 = .02$; $\kappa_{16} = -.27$; reports: $\kappa_8 = -.33$, $\kappa_{17} = -.10$). At first glance, these negative effects may seem surprising, as prior research focusing on C2C UGC has generally found positive effects on market response (Chevalier and Mayzlin 2006; Li and Hitt 2008; Mayzlin 2006). However, requests and reports are examples of C2B UGC activity that typically focus on the identification of problems rather than spreading positive WOM. Thus, firms that seek (and openly post) feedback from users may ultimately hinder product adoption by cultivating adverse quality perceptions among potential users. Consequently, it may be in a developer's best interest to employ "walled gardens" in the project development phase by identifying and resolving problems among a core group of users and thus avoid revealing these issues to the broader public.

The results of our analysis of the predictors of release activity are presented in Table 6.

[Insert Table 6]

Again, we observe a positive generational trend that diminishes with subsequent releases ($\gamma_1 = .07$, $\gamma_2 = -.00$). In essence, developers appear more likely to release a subsequent generation of a project for which they have already released a number of prior generations. We also observe that the time since the latest release was made available is related to the likelihood of the release of a subsequent generation. As the time since the release latest generation increases, developers appear less prone to release a newer version ($\gamma_3 = -.44$, $\gamma_4 = .01$). In contrast to our findings relating to download activity, we do not observe any significant association between cumulative downloads and release activity.

We do, however, observe several interesting effects of UGC activity on release activity. First, reports are positively related to the release of a new generation ($\gamma_8 = .38$). This association may be due to the fact that these reports contain "low hanging fruit" that can be easily remedied by developers, which consequently facilitates the release of a new generation. On the other hand, developers appear less likely to release a new generation as the number of requests increases ($\gamma_7 = -.27$). Software requests are often difficult for developers to implement (Raymond 1999). Thus, implementing these requests may lengthen the time required to release a new generation. Finally, in contrast with our findings for download activity, user contributions in the form of revisions appear unrelated to release activity. This finding may be due to the nature of revisions, which can be implemented by users without intervention by developers.

The results of our analysis of the predictors of UGC activity are presented in Table 7.

[Insert Table 7]

As reflected by the intercepts reported in this table, reports are the most frequently contributed type of UGC, followed by requests, and then revisions. For the contributions of both reports and requests, we observe a negative trend in number of months since the latest generation was released (requests: $\beta_{32} = -.30$; reports: $\beta_{33} = -.42$). Thus, although contributions of these types appear to diminish as time passes, user contributions seem to be spurred by a new release. In addition, our results indicate that the incidence of reports increases as subsequent releases are introduced ($\beta_{13} = .12$). This finding is similar to our results for download activity and suggests that subsequent releases may serve as a signal of product quality (Dutta, Narasimhanm, and Rajiv 1999), and hence, stimulate further user contributions. Finally, our results indicate that as adoption increases, the frequency of reports diminishes (β_{53} = -.08), while the frequency of requests increases (β_{52} = .04). The decline in reports may be attributable to the fact that most of the easily addressable issues have already been resolved in earlier releases, while the uptick in request activity may be driven by the diverse desires of a larger user base.

DISCUSSION

Our research goal was to investigate the impact of UGC on product innovation. Drawing from prior research in both the UGC and open innovation domains, we conceptualized user contributions as a form of C2B communication and considered three distinct types of UGC (reports, requests, and revisions) and two types of innovation outcomes (market response and product development). Our joint analysis of 4,450 OSS projects revealed two key findings: (1) the impact of these three types of UGC is both positive and negative and (2) the predictors of market response are different from the predictors of product development. Specifically, our results indicate that market response (downloads) is positively related to revisions but negatively related to both requests and reports, while product development (release activity) is positively related to reports but negatively related to requests and unrelated to revisions. This final section details the theoretical and managerial implications of our findings.

Theoretical Implications

Our research enriches marketing's extant UGC literature by considering user contributions as a form of C2B communication. Specifically, we argue that, in addition to serving as a source of WOM, users may also contribute to marketing efforts by providing insights and ideas that may enhance product innovation. This shift in focus from UGC as a form of promotion to UGC as a form of innovation offers a broadened conceptualization of user contributions.

The three types of UGC examined in our research provide an important conceptual distinction from the user reviews studied in the extant UGC literature (e.g., Chevalier and Mayzlin 2006; Godes and

Mayzlin 2004; Li and Hitt 2008). While reviews are a means by which users communicate their *consumption* experience to other consumers, reports, requests, and revisions are a means by which users communicate their *production* ideas to developers. Thus, the C2B UGC examined in our inquiry is conceptually and empirically distinct from the C2C UGC that has captured the attention of marketing scholars to date.

Indeed, rather than just reflecting upon usage experience, users who engage in C2B UGC participate as co-developers to enhance and improve product offerings. This participation largely involves identifying product flaws and fixing operational shortcomings (Raymond 1999). According to open innovation proponents, this type of user co-development is an especially valuable tool for product innovation (Chesbrough 2003; Prahalad and Ramaswamy 2004; von Hippel 2005). However, while the benefits of C2B UGC have received some recent empirical support (Grewal et al. 2006; Mallapragada et al. 2008; Rajagopalan and Bayus 2008), little attention has been paid to its potential costs.

Our research contributes to this effort by suggesting that, in some cases, user contributions may actually be a detriment to innovation activity. Among the three types of UGC that we examine, reports hamper market response (i.e., download activity), revisions hinder product development (i.e., release activity), and requests harm both of these metrics. These mixed results provide a valuable contrast to the more favorable portrait of user contributions provided by both open innovation research as well as the extant UGC literature (Chevalier and Mayzlin 2006; Franke and Shah 2003; Li and Hitt 2008; Ogawa and Piller 2006). According to open innovation scholars, user contributions provide a high fidelity means of sensing user needs, which should, in turn, allow developers to provide high quality solutions to these needs (von Hippel 2005). Our findings suggest that this sensing process may contain more noise than commonly believed.

Although our data do not allow us to delve deeply into the underlying causal agents, user reports may provide noise in the form of sending an unintended signal (to potential users) that a product is potentially flawed. Requests may be noisy in the sense that it is difficult for developers to determine if these suggestions are important indicants of broader market sentiments or just the ramblings of a lunatic fringe. Finally, revisions may create noise if users lack a tacit understanding of how their revisions fit into the broader product offering. These mixed results provide needed balance to the literature and indicate that future studies of the impact of UGC should consider both the risks and rewards of user contributions.

In addition to offering a broader typology of UGC and revealing the mixed effects of user contributions, our research expands the purview of UGC research by examining an important, yet under-examined, context (i.e., OSS). As detailed by O'Hern and Rindfleisch (2009), user contributions come in a variety of forms and may vary considerably based on context. Indeed, OSS projects such as Linux are contextually distinct from online user review sites such as Amazon.com. For example, while Linux actively encourages users to revise its program source code, Amazon merely allows users to review the work of others. While user review sites and OSS represent two important UGC contexts, there are a wide variety of emerging contexts that may allow users to contribute in ways other than reviewing, reporting, requesting, or revising. For example, the highly successful online T-shirt manufacturer, Threadless.com depends upon its users for not only reviewing T-shirt designs but also for creating these designs (Chafkin 2008). Designing is akin to revising but ratchets user contributions up to an even higher level, as Threadless has no in-house designers and depends completely on its users for its creative outputs. Another interesting UGC context is the communal manufacturer, Quirky.com. Like Threadless, Quirky depends upon its users for all of its product designs. However, it goes a step further by co-opting users as part of its salesforce and actually shares product revenues with these user-salespeople (Schleis 2010). These and other emerging UGC contexts provide intriguing territory for future exploration.

Managerial Implications

From a managerial perspective, our results may appear to paint a rather dismal picture of the value of UGC as a tool for enhancing product innovation. Indeed, two of the three types of user contributions exhibit a negative impact on market response and/or product development. As noted by Cook (2008), many managers express doubt about the wisdom of allowing users to actively contribute to product innovation activity. Thus, our results may serve to reinforce this managerial skepticism. Clearly, our findings suggest that managers who wish to utilize UGC as a tool for product innovation should exercise due caution. However, our findings also indicate, that if employed judiciously, user contributions can enhance both internal and external metrics of innovation success.

Our results suggest that the impact of UGC varies across different innovation outcomes. Specifically, managers interested in bolstering internal innovation metrics such as the rate of product development should heavily rely upon user reports. On the other hand, managers seeking to improve external innovation metrics such as market response should place considerable emphasis on user revisions. While these suggestions are in accord with our findings, managers should remember that these results emerge from an OSS context and may be not generalize to all other contextual settings. Thus, future research that examines the impact of requests, reports, and revisions across other UGC contexts would be quite valuable.

Nevertheless, these mixed results suggest that a single type of UGC is unlikely to be able to positively impact a wide range of innovation metrics. Specifically, internal innovation metrics appear to be driven by involving users as problem identifiers, while external innovation metrics appear to be driven by involving users as problem solvers. Since both types of metrics are important to most managers, employing multiple types of UGC is likely to be an effective strategy. The shortcoming of this strategy, however, is that a particular type of UGC (i.e., revisions) may have an offsetting impact by bolstering one outcome metric while detracting from another.

Thus, we recommend that managers not only employ multiple types of UGC but also engage in practices that minimize their deleterious impact. For example, our results suggest that user requests appear to stifle both market response and release activity, perhaps because these requests may lead developers down an idiosyncratic path that is unlikely to resonate with their broader market. Allowing other users to provide input about these requests may mitigate this risk. For instance, Dell's popular user forum, IdeaStorm (www.ideastorm.com) invites its user community to both comment and vote on user requests as a means of sensing which requests reflect the needs of its broader market.

While the value of user requests may be enhanced by broadcasting them to others, our results suggest that managers should take exactly the opposite approach for user reports. As noted earlier, these reports are inherently critical in nature and focus on identifying a product's shortcomings. This may send a negative signal to potential users, who, as our results for market response suggest, may be less prone to acquire such a product. Ironically, as suggested by our results for product development, these reports are quite helpful in terms of furthering release activity. Thus, we suggest that managers harness the internal value of user reports while minimizing their external costs by shielding them from other users, akin to soliciting (but not broadcasting) customer feedback. In essence, these reports should be limited to C2B communication channels and avoid C2C transfer, if possible.

Finally, our results suggest that managers need to carefully balance the risks and rewards of allowing users to directly revise their product offerings. The ability to engage in active product revision is a hallmark of OSS and is rapidly gaining ground in a number of other domains (O'Hern and Rindfleisch 2009). However, allowing users to revise their product offerings requires managers to give up considerable control and is highly dependent upon their ability to mobilize and motivate a large, active, and knowledgeable base of contributors. Moreover, our results suggest that while user revisions may enhance market response, they do not appear to contribute to release activity. Thus, managers seeking to leverage this type of UGC need to employ stringent screening and selection mechanisms to carefully filter high quality revisions from low quality ones. Indeed, this type of selection process is a hallmark of most successful open innovation initiatives (Raymond 1999). A good example is Wikipedia, which in contrast to its open contribution image, carefully screens user revisions via a multi-layered hierarchy of volunteer gatekeepers (Lih 2009).

In conclusion, our research offers a broadened conceptualization and assessment of the impact of UGC. Due to its growing popularity, an increasing number of firms have begun to tap user contributions as a resource for innovation. As our results indicate, these contributions entail both risks and rewards and thus need to be cultivated carefully. Our research provides initial insights regarding the effective cultivation of UGC as a tool for product innovation. We hope that our work will serve as a springboard for future research that leads to a better understanding of the nature and impact of UGC.

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TABLE 1
SUMMARY OF SELECTED UGC STUDIES

Empirical Study	Research Context	Type of UGC	Outcome Variable(s)	Key Findings
Godes and Mayzlin (2004)	Usenet.com	User reviews of TV shows	TV ratings	The volume of online postings is not related to TV ratings but the dispersion of UGC across communities is positively related to TV ratings.
Chevalier and Mayzlin (2006)	Amazon.com, Barnesandnoble.com	User reviews of books	Online book sales	Consumer reviews on both websites are overwhelmingly positive. Both the volume and valence of reviews are positively related to sales.
Liu (2006)	Yahoo Movies	User reviews of motion pictures	Box office revenue	Consumer-generated reactions tend to be more positive prior to a movie's release and become more critical in the opening week. Despite this trend, the volume of customer reactions (but not the valence of those reactions) is a significantly predictor of box office revenue.
Mayzlin (2006)	Game theoretic model (analytic)	Online WOM	WOM credibility, purchase decision	Online WOM has a persuasive and positive impact on consumers' purchase decisions.
Li and Hitt (2008)	Amazon.com	User reviews of books	Online book sales	Consumer reviews posted in early periods exhibit a systematic positive bias. Early product reviews have a disproportionate influence on potential buyers' purchase decisions and positively impact demand.
Dhar and Chang (2009)	Amazon.com	WOM via user blogs	Online album sales	Volume of blog postings about a new album is positively related to album sales.
Godes and Mayzlin (2009)	Marketing agency, Restaurant chain, news and entertainment websites	Word-of-mouth between users and non-users	Sales	Firms can create WOM among non-consumers, and this WOM has a positive impact on sales. The positive impact of non-consumer WOM is higher than that of consumer WOM. WOM by acquaintances has a greater impact on sales than WOM by friends and relatives.

TABLE 2
COMPARISON OF C2C UGC VERSUS C2B UGC

	C2C UGC	**C2B UGC**
Focus	Promotion	Innovation
Contribution	Reviews	Requests Reports Revisions
Mechanism	Communication to other users	Communication to developers
Metrics	Market Response	Market Response Product Development
Impact	Positive	Positive & Negative

TABLE 3
EXAMPLES OF VARIOUS TYPES OF C2B UGC

Type	Action	Example
Reports	Identifying problems	"This is annoying. Skins are being listed properly, but are not being applied when you select them. There seems to be a Nullpointer Exception going on during the repaint…Shouldn't be too difficult to figure out."
Requests	Suggesting enhancements	"It would be nice to have a more global tool to have a view over all my favorite servers and connect on right mouseclick via putty, filezilla, winscp, rdp or just create a customized entry on the context menu...just an idea."
Revisions	Providing solutions	"The attached file within the zip archive is to replace the user settings page (by default 2bUser Settings.php). This fixes the user activation bug for normal users."

TABLE 4
POSTERIOR MEAN CORRELATIONS

	Download Incidence	Download Amount	Release Activity	Revisions	Requests	Reports
Download incidence (α_1)	1					
Download amount (α_2)	.89 (.88, .90)	1				
Release activity (α_3)	.08 (-.01, .16)	.26 (.18, .34)	1			
Revisions (α_4)	.12 (-.09, .33)	.35 (.16, .52)	.51 (.08, .81)	1		
Requests (α_5)	.22 (.14, .29)	.41 (.36, .47)	.68 (.56, .78)	.76 (.54, .93)	1	
Reports (α_6)	.37 (.33, .41)	.40 (.37, .44)	-.03 (-.12, .05)	.49 (.31, .68)	.46 (.40, .51)	1

Note: 95% HPD intervals are listed in parentheses. Shaded cells indicate correlations in which the 95% HPD interval is greater than 0.

TABLE 5
PARAMETER ESTIMATES FOR DOWNLOAD ACTIVITY

	Incidence Model	**Amount Model**
Intercept	4.71 (4.61, 4.82)	-3.57 (-3.62, -3.52)
Release age (linear)	-.25 (-.27, -.24)	-.19 (-.20, -.19)
Release age (quadratic)	.01 (.01, .01)	.01 (.01, .01)
Generational trend (linear)	.18 (.17,.19)	.16 (.15, .17)
Generational trend (quadratic)	-.00 (-.00, -.00)	-.00 (-.00, -.00)
Cumulative downloads	.02 (-.09, .14)	.02 (.02, .03)
Revisions	2.01 (.98, 3.10)	.98 (.65, 1.29)
Requests	.02 (-.09, .14)	-.27 (-.32,- .22)
Reports	-.33 (-.39, -.28)	-.10 (-.12, -.07)
Release obsolescence	-3.21 (-3.27, -3.15)	-1.57 (-1.60, -1.55)

Note: Shaded cells indicate those coefficients for which the 95% HPD interval does not contain 0.

TABLE 6
PARAMETER ESTIMATES FOR RELEASE ACTIVITY

Intercept	-2.00 (-2.20, -1.80)
Generational trend (linear)	.07 (.02, .11)
Generational trend (quadratic)	-.00 (-.00, -.00)
Time since last release (linear)	-.44 (-.47, -.39)
Time since last release (quadratic)	.01 (.01, .02)
Cumulative downloads	-.03 (-.08, .02)
Revisions	-.14 (-.93, .63)
Requests	-.27 (-.42, -.12)
Reports	.38 (.27, .50)

Note: Shaded cells indicate those coefficients for which the 95% HPD interval does not contain 0.

TABLE 7
PARAMETER ESTIMATES FOR UGC CONTRIBUTION

	Revisions	Requests	Reports
Intercept	-11.65 (-13.19, -10.13)	-7.11 (-7.56, -6.67)	-.90 (-.96, -.84)
Time since last release (linear)	-.02 (-.33, .31)	-.30 (-.38,-.22)	-.42 (-.43, -.40)
Time since last release (quadratic)	-.00 (-.02, .02)	.01 (-.00, .01)	.01 (.01, .01)
Generational trend (linear)	-.52 (-1.07, .04)	-.00 (-.04, .03)	.12 (.10, .13)
Generational trend (quadratic)	-.01 (-.06, .02)	-.00 (-.00, .00)	-.00 (-.00, -.00)
Cumulative downloads	.19 (-.05, .44)	.04 (.00, .08)	-.08 (-.09, -.08)

Note: Shaded cells indicate those coefficients for which the 95% HPD interval does not contain 0.

FIGURE 1
MODEL COMPONENTS