Online Customer Reviews and Product Sales:  
The Moderating Role of Signal Characteristics  

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Abstract

Although considerable research has been conducted to investigate how online reviews influence product sales, understanding of why consumers rely on online reviews and the effect of interactions between key metrics (volume, valence, and variance) on product sales is very limited. We develop a research framework by applying information economics and signaling theory to demonstrate that online reviews have an impact on product sales because reviews act as market signals that contain information about the quality of products. The characteristics of signals (intensity, valence, consistency, and clarity) help consumers in reducing search cost and improving evaluations on product quality. We propose that signal intensity and signal consistency moderates the relationship between online reviews and product sales. Regarding methodological contribution, we propose a multilevel text mining approach to analyze online reviews by considering nested structure of reviews and uniqueness of individual review. The results of a pilot study and discussions are presented as well.

Keywords

Online review, information economics, signaling theory, multilevel modeling, latent Dirichlet allocation.

Introduction

Due to the increasing maturity of electronic markets and advances in the development of analytical techniques, the study of online reviews has emerged as an important research stream. In the past 15 years (from 1999 to 2013), more than 100 studies have investigated the online review phenomenon from the perspective of social communication, by applying electronic word-of-mouth (eWOM) communications to explain contemporary consumer behavior in the e-commerce environment (Rosario et al., 2016).

Despite considerable research focusing on the effect of online reviews on product sales, our review of the prior literature suggests that there are at least three further improvements that could be made to develop a better understanding of the effectiveness of online reviews. Frist, most existing studies assess how online reviews influence consumers’ decision making and attitude formation from the perspective of social communication by applying eWOM, which originates from word-of-mouth communication research (Rosario et al., 2016). By applying the eWOM proposed by Hennig-Thurau et al. (2004), however, we cannot answer the question of why consumers rely on online reviews when making decisions. Without knowing the fundamental mechanisms by which online reviews affect consumers, studies on the effectiveness of online reviews lack solid theoretical foundations and lead to the inconclusive findings that can be observed in past research (Dellarocas et al., 2007). Second, the emerging research on online reviews has only focused on the separate effects of three key metrics of online reviews (volume, valence, and variance) on product sales (e.g. Duan et al., 2009; Bao and Chang, 2014). Only a few studies, however, have investigated the effect of the interactions among them. In the e-commerce environment, consumers do not only focus on the average rating of a product but also care about how many people
rated it and how much previous consumers differ in their enjoyment of the product (e.g. Sun 2012). Since all key metrics of online reviews are easily available in electronic markets, it is highly possible that consumers would consider them comprehensively, and thus it is necessary to investigate interactions among these, such as consistency among key metrics of online reviews influence, consumers’ purchase decisions. Third, in prior research, a widely-accepted text mining approach to analyzing textual online reviews is aggregating all reviews for one product with an underlying assumption that all textual messages are equal regarding consumer impact. In this approach, individual reviews’ uniqueness and extremity would be balanced out, implying that all reviews are treated equally and have the same impact on consumers’ perception of products. Research in many areas of psychology, however, has revealed that compared with positive information, negative information has a greater impact on human attitudes, cognition, physiological response, and behavior (Labianca et al., 1998). Therefore, the text mining approach needs to be improved to maintain the uniqueness of individual reviews in the analysis.

This study aims to address these research issues and contributes to the online review literature from both theoretical and methodological perspectives. Regarding our theoretical contribution, we develop a research framework by applying the economics of information and signaling theories to demonstrate that online reviews have impacts on product sales because online reviews act as market signals that contain information about the quality of products. The characteristics of signals (intensity, valence, consistency, and clarity) help consumers in reducing search costs and improving their evaluations of product quality, which in turn influence purchase decisions. Furthermore, we propose that signal intensity and signal consistency moderate the relationship between online reviews and product sales. From a methodological standpoint, we propose a multilevel text mining approach to analyze online reviews by considering the nested structure of reviews and the uniqueness of individual reviews.

The rest of this paper is organized as follows. First, we briefly review the economics of information literature and signaling theory and present our research framework. Next, we propose hypotheses related to the moderating role of signal consistency. We then introduce our data collection, variable description, text mining methodology, and regression analysis. We also present empirical results and related discussion. Finally, we briefly discuss the contributions of this research.

**Theoretical Foundation and Model**

In the e-commerce environment, information asymmetry exists because consumers cannot physically evaluate the quality of products (Mavlanova et al., 2012). Treating the online review environment as a “market” (Hu et al., 2008), we argue that this market provides consumers with a good solution for information asymmetry by reducing search costs (easy access to a pool of information) and improving product evaluations (useful information about product quality). We apply the economics of information and signaling theory to develop a research model that demonstrates the fundamental reason why consumers rely on online reviews when making decisions.

**Economics of Information**

Economics of information theory, proposed by Stigler (1961), focuses on discussing search costs as a means of generating price dispersion and was later applied by Nelson (1970) to study consumer behavior. This theory provides a relevant foundation to address the role of online customer reviews in the consumer decision process (Mudambi and Schuff, 2010). The online review environment is a rich source of product information and recommendations from the consumer perspective. In online sales websites like Amazon.com, potential customers can easily find useful information related to the products in online reviews. With a wide range of choices, consumers face a tradeoff between search cost and benefit. The decision-making process is time-consuming and involves cognitive efforts. Poston and Speier (2005) argue that online reviews (numerical content ratings) could be used to conserve cognitive resources and reduce energy expenditure. Therefore, consumers rely on online reviews because online reviews help them in reducing search costs in the decision-making process.

**Signaling Theory**

Signaling theory is fundamentally concerned with “reducing information asymmetry between two parties by having one party send a signal that would reveal some piece of relevant information to the other party” (Spence 2002). It was first proposed and applied by Spence (1973) in his economics research
to illustrate how education signals worker productivity, which triggered an enormous volume of studies applying signaling theory in a range of business areas from financial investment to organizational behavior. For example, individual investors consider friendship-tie a signal of credit quality and incorporate it into lending decisions (Lin et al. 2013). An organization’s attractiveness could be enhanced by its diversity management policy since it signals proactive working conditions related to management of diversity (Rynes, 1991). In online auction business, e-image provides consumers with signals indicating the quality of products and abilities of transaction companies before purchasing (Rao et al. 1999).

**Hypotheses Development**

In e-commerce studies, Hu et al. (2008) use a “market reaction” lens to assess the effectiveness of online reviews and argue that online reviews are like market signals containing information about the quality of products. Mavlanova et al. (2012) show that product information could be communicated through market signals. The signaling theory literature has identified several key characteristics of signals (Connelly et al., 2011). In this study, we focus on four of them that are applicable to online review research: signal intensity, signal valence, signal consistency, and signal clarity, which can be mapped to the key metrics of eWOM in online review literature.

Prior literature has identified three key metrics of online reviews in the marketplace: volume, valence, and variance (Clemons et al., 2006). The most widely recognized one is volume, which refers to the number of reviews on a product (Dellarocas et al., 2007) and could be identified as signal intensity (Gao et al., 2008). When more customers discuss a product, there is higher chance that other customers will become aware of it (Forman et al. 2008). Herding theory supports this argument by arguing that a high volume of reviews generates more conversations and increases others’ curiosity about the product, which may lead to higher sales (Lu et al. 2013). Moreover, the signal theory argues that if a signal is hard to fake or costly to mimic by its information source, it is more reliable for assessing information quality and can be trusted (Donath 2007). Thus, online reviews in high volume serve as an important warrant or signal that information is valid and reliable, which enhances the impact of reviews on product sales. Therefore, the volume of reviews positively moderates the relationship between review valence and product sales. We propose that:

**H1. Signal intensity positively moderates the relationship between signal valence and purchase decisions.**

Signal consistency refers to the degree to which a mix of components reflects the intended whole (Erdem & Swait, 1998), which could be interpreted in three ways in the context of online review environment. First, one product is usually rated by multiple people who might have different opinions towards the product. Regardless of the valence of online reviews, it is not difficult for consumers to interpret them if they have a low variance, which means the consistency of opinions among individuals is high. This consistency might enhance the effect of signal valence on product sales. This perspective is supported by informational social influence theory, which argues that convergence among multiple opinions signals enhanced subjective reality (Asch 1955; Mullen 1983). Therefore, we propose that:

**H2. Signal consistency positively moderates the relationship between signal valence and purchase decisions.**

The second interpretation of signal consistency is the similarity between product description and customer reviews. Pavlou et al. (2007) define the diagnosticity of the text product description as “the degree to which a buyer believes that the seller offers useful textual information to describe a product.” For sellers, the product description may be a liability since any deviation from the true characteristics may give a legal basis for product misrepresentation. For consumers, the textual product description is an effective signal that helps them reduce product uncertainty (Dimoka et al., 2012). If the content mentioned in online reviews is similar with that in the product description, the information in online reviews would be considered more useful since multiple signals showing little contradiction across dimensions are more credible (Gao et al., 2008). Therefore, we propose that:

**H3. The consistency among signals from different sources has a positive effect on purchase decisions.**

The third way to interpret signal consistency is by examining whether numerical information and textual information delivers the same message about the products. For example, a high number of raters indicates the popularity of products, which has a positive influence on the purchase decision. If the
comments for a popular product are long, there is a high chance that it provides clear explanations about why the product is popular, which enhances the positive effect; the converse is true for the opposite situation. Therefore, this consistency between a number of raters and length of textual comments enhances the effect of the valence of reviews on product sales. However, it is common that some products have many short comments, while other products have a few long comments. In this situation, several long comments are more influential than a large number of short comments since detailed explanations reduce the level of ambiguity, leading to higher signal clarity. The signal clarity refers to the absence of ambiguity in signals (Erdem & Swait, 1998).

H4a. The consistency between numerical and textual signal intensity positively moderates the relationship between signal valence and purchase decisions.

H4b. The textual signal intensity has a greater effect on purchase decisions than numerical intensity when the consistency between them are low.

Methodology

Data

In this study, we conducted web scrapping in Python to collect data from Amazon.com, which dominates the e-commerce market regarding total sales and market capitalization (Jopson, 2011). We chose to analyze the smart watch category, and we collected the in-platform information from the top 309 products from the top sales list. For each product, the collected data includes price, average rating, the total number of raters, the number of raters for each star, product description, and the top 30 online customer reviews ranked by their usefulness. Since Amazon does not provide actual sales, we estimated product sales based on product rank.

Sentiment Analysis and Text Sematic Similarity

Sentiment analysis is performed to identify the positive and negative language in online reviews. We used a general approach that is scalable for the size of data in which the strength of an opinion is estimated based on the occurrences of sentiment words within the content (Das and Chen, 2007; Archak et al., 2007). The sentiment score for individual review was used in the multilevel modeling for regression analysis.

To measure the content similarity between product description and online reviews, we applied a text-mining technique called Latent Dirichlet Allocation (LDA), which is a statistical method used to discover abstract “topics” from textual documents (Blei et al., 2003). The underlying assumption in LDA is that each document is composed of topics and each topic is composed of vocabularies. To discover vocabularies in documents, the vocabularies of topics and the topics of the documents are jointly estimated. Based on LDA, Shi et al. (2016) proposed a data-analytic approach to measuring firms’ business proximity by calculating the normalized Euclidean distance between firms’ business description. We applied the same approach to measure the content similarity between product description and online reviews.

Multilevel Modeling

In this study, we investigated the relationship between online reviews and product sales. For a product, some information is at product-level, such as product sales, price, average rating, etc.; some information is at review-level, such as individual reviews. To investigate the product-level and review-level information synchronously, we applied a latent variable multilevel model proposed by Croon and Van Veldhoven (2007), which keeps the uniqueness of online reviews in the aggregation process and integrates the relationship between a review-level variable and product-level variable in regression analysis. The individual reviews are the first level (lower-level) variables and other variables like price, rating, number of raters are the second level (upper-level) variables.

\[ y_i = \beta_0 + \beta_1 z_i + \beta_2 \delta_i + \epsilon \]

Where \( y_i \) is the product sales in Amazon.com for product \( i \); \( z_i \) refers to observed product-level variables for product \( i \), which includes both simple variables like price and component variables like average rating * No. of raters; \( \delta_i \) refers to latent product variable for product \( i \) (e.g. sentiment scores).
Results

As seen in the results presented in Table 1, both numerical and textual reviews influence consumers' purchase decisions. First, average rating and number of raters have a positive effect on product sales, which is consistent with findings in prior research. We expanded the discussion about volume and valence into textual information, demonstrating that the length and tone of comments also have positive influence on sales. Additionally, when the number of raters is high, the effect of the average rating is enhanced since it indicates the popularity of products. When the comments are long, the effect of review valence is also increased. H1 is supported. Second, variance refers to the degree to which individuals have the same opinions, which represents signal consistency in an opposite way. The higher variance, the lower level of signal consistency. Different with signal intensity, the moderating effect of signal consistency only works for numerical information. The reason could be the variance of the rating is easily observed, but it is very hard to calculate the variance of textual comments in mind when people read them. Therefore, H2 is partially supported. The same reason could be applied to explain why H3 is not supported. For a human being, comparing product description and online reviews could be really challenging. By applying business analytic techniques, we can extract topics from two textual documents. Unfortunately, the topics are not available for consumers when they make purchase decisions. Therefore, the similarity between product description and online reviews is not significant. Finally, regarding the moderating effect of signal consistency, the results show that when the numerical and textual intensity is consistent, the effect of review valence is enhanced. When they are inconsistent, the moderating effect of textual information is higher. H4a and H4b are supported.

<table>
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<tr>
<th>Construct</th>
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<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
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<td>Variance of Comments</td>
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<td>-.065*</td>
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*p<0.05, **p<0.01, ***p<0.001, N=309 Table 1. Results of Regression Analysis

Conclusion

This study analyzes the effectiveness of online reviews from the perspective of information economics. Instead of investigating how online reviews influence consumers’ purchase decisions, we focused on answering the fundamental question of why it occurs and developed a research framework by applying signaling theory. The characteristics of signals (intensity, valence, consistency, and clarity) help consumers in reducing search costs and improving their evaluations of product quality, which in turn influence purchase decisions. This research is related to, but distinct from, prior literature since we discussed the interactions between key metrics rather than single metrics. To be more specific, we demonstrated the moderating role of signal intensity and signal consistency. Furthermore, we applied LDA text mining in an innovative way to investigate the relationship between online reviews and product sales. Additionally, we proposed a multilevel text mining approach to analyzing online reviews by considering the nested structure of reviews and the uniqueness of individual review. This paper makes contributions to online review literature from both theoretical and methodological aspects.

Due to the limitation on length, references are available upon request.