

Do structural holes matter? An empirical study of negative eWOM on exploitative and exploratory innovation

Summary

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This study investigates how negative electronic word-of-mouth (NWOM) affects firms' product innovation, with particular emphasis on the moderating role of structural holes in online consumer networks. Drawing on social network and organizational learning theory, this study uses a panel dataset of 198 firm-year observations from Taiwan's biotechnology industry and applies Tobit regression analyses to examine the effects of NWOM on exploratory and exploitative innovation. Results indicate that NWOM has a marginally significant positive effect on exploitative innovation but no significant effect on exploratory innovation. In addition, the effects of NWOM on exploratory and exploitative innovation are significantly moderated by structural holes. Specifically, NWOM becomes more influential when generated by consumers who occupy structural hole positions. The moderating effect is stronger for exploratory innovation, suggesting that the structural position of NWOM sources enhances the informational value of such feedback. These findings extend current understanding of digital consumer input and offer actionable insights for companies seeking to leverage eWOM in innovation management.

Keyword: negative word-of-mouth; structural hole; exploitative innovation; exploratory innovation; ambidexterity; big data

Introduction

With the enormous popularity of social media and online social networks, consumers can easily share their experiences, opinions, and recommendations by electronic word-of-mouth (eWOM) on social media platforms (Gong et al., 2020; Klostermann et al., 2018). EWOM derived from social media data enables companies to better understand market insights and customer needs (Timoshenko & Hauser, 2019). EWOM tends to be spontaneous and has access to massive audiences (Nisar et al., 2020) that is the large amount of data on authentic customer behavior (Roulet & Laker, 2020). Hence, analysis of eWOM could be regarded as an important information source for innovation (Zhou et al., 2018).

While the WOM literature has provided a thorough understanding on the antecedents and consequences of eWOM in consumer behavior perspective (e.g., Berger & Schwartz, 2011; Dalman et al., 2020; Hennig-Thurau et al., 2004; Mariani & Borghi, 2021; Pescher & Spann, 2014), there is a dearth of research exploring the influence of eWOM on product innovation in business organization perspective. Recent work has found that eWOM sentiment helps companies to assess consumers' reactions (Homburg et al., 2015) to improve new product success (Nguyen & Chaudhuri, 2019). More specifically, extant research has consistently shown that consumers pay more attention to negative eWOM (hereafter NWOM) than positive WOM (Yang & Mai, 2010) because NWOM is more impactful (Lee & Suh, 2020) and tends to be credited to the performance of the product itself (Mizerski, 1982). NWOM plays a critical role in product innovation; however, few studies have utilized large-scale data derived from social media feedback (Liu, 2020), and its specific impact remains insufficiently understood.

New product innovation is a critical corporate strategy for companies to maintain their competitive advantage and sustain long-term growth but has a high failure rate of new products (Nguyen & Chaudhuri, 2019). In organizational learning theory, organizational innovation competency includes exploitative and exploratory innovation that are indispensable for companies but each entail distinct and conflicting skills and processes (March, 1991). The distinction between exploratory and exploitative innovation is their contradictory knowledge processes (Floyd & Lane, 2000) that tap different organizational routines and managerial behaviors (Lubatkin et al., 2006; March, 1991). A predominant theme in the literature is that exploratory and exploitative innovation have been treated as balance or combine approach, which has been conceptualized as ambidexterity (Tushman & O'Reilly III, 1996). Companies can balance of the two through sequential pursuit of exploration and exploitation or, they can engage in the simultaneous pursuit of both exploration and exploitation (Levinthal & March, 1993) based on the ambidexterity perspective.

Recent work proposed that information and communication technologies help companies to

explore and exploit the opportunities in the external environment (Roberts & Grover, 2012) in order to achieve ambidexterity (Lee et al., 2015). While some studies have demonstrated that companies can simultaneously enhance their exploitative and exploratory innovation by creation of insights stemming from big data (Dezi et al., 2018; Ghasemaghaei & Calic, 2019), the role of NWOM stemming from social medial platforms on exploitative and exploratory innovation has been quite neglected. NWOM related to concerns about product functionalities (Nguyen & Chaudhuri, 2019) and attributes (Bickart & Schindler, 2001) which is used by customers that the more NWOM of a new product, the greater its valuable insights residing information (Ghasemaghaei & Calic, 2019). Both exploitative and exploratory innovation entail diverse insights (Gupta et al., 2006), leading to the first research question: does NWOM have effect on the exploitative and exploratory innovation?

Recent research has increasingly recognized the complexity of consumer behavior across different contexts, particularly in how individuals engage with and influence others in digital environments. Understanding the variability in consumers' social roles across domains is essential for accurately capturing their behavior in online interactions. One substantive group of studies has initiated to explore the moderating role of characteristics of reviewers (Lai et al., 2021) or opinion leaders (Dalman et al., 2020); however, consumers may strongly desire to be opinion leaders in some product categories but weakly so in others (Ruvio & Shoham, 2007). Opinion leadership varies by product domain (Dalman et al., 2020); thus, other factors may better explain moderating effects in online social networks.

Another significant body of studies has highlighted the growing importance of network position within online social networks (Pescher & Spann, 2014), particularly due to the dissemination of new product information and adoption behaviors through these networks (Centola & Macy, 2007). Although extant literature has examined the moderating role of consumers' network position in information diffusion (Zhang & Gong, 2021a, b), there is scant research on considering the moderating role of consumers' network position in innovation, especially in the context of consumers occupying structural hole positions.

This study focuses on structural holes because the function of bridges in the individual diffusion of product-related information is critical for companies to adopt relevant actions (Pescher & Spann, 2014). Consumers bridging more structural holes are typically better positioned within social networks to expand the scope of information diffusion in comparison with traditional opinion leaders (Gong et al., 2020). Most notably, Burt (1992) argues that social networks rich in structural holes provide unique opportunities by offering access to non-redundant information and enabling brokerage positions that network members can exploit. These brokerage positions provide significant informational and control advantages (Burt, 1992), which are particularly beneficial for

innovation by facilitating access to diverse, non-redundant information and enhancing the ability to coordinate and integrate disparate information flows. Such advantages enable consumers occupying structural hole positions to act as effective conduits for novel ideas and insights, thereby supporting the development and diffusion of innovation. Given their strategic importance in social networks, the limited focus on structural holes in eWOM literature is particularly surprising (Pescher & Spann, 2014).

At the same time, NWOM can be easily manipulated, often stemming from unfair or vindictive complaints (He et al., 2019; Huang & Philp, 2021) or anti-branding behaviors by consumers affiliated with rival companies (Rauschnabel et al., 2016). Compared to exploitative innovation, it is more challenging for firms to recognize authentic NWOM from misinformation or rumors for exploratory innovation. This challenge leads to the second research question: does the effect of NWOM on exploratory and exploitative innovation depend on whether consumers occupy structural hole positions within social networks?

This study aims to investigate the impact of NWOM on two types of product innovation—exploitative and exploratory—and examines the moderating role of structural holes in online social networks. Drawing on organizational learning theory and social network theory, the findings reveal a significant moderating effect of structural holes: consumers bridging more structural holes amplify the positive relationship between NWOM and two types of product innovation.

The remainder of this study is structured as follows: Section 2 reviews the relevant literature and develops the hypotheses. Section 3 details the research methodology, including data collection and measurement. Section 4 presents the empirical results, followed by Section 5, which discusses the findings and their theoretical and practical implications.

Literature review and hypothesis development

Word-of-mouth (WOM)

Word-of-Mouth (WOM) is regarded as an informal flow of communication between consumers regarding their product experiences (Anderson, 1998; East, Hammond, & Wright, 2007) and has been one of the central topics of marketing research and practice (Chu & Kim, 2011; Swaminathan et al., 2020). With the rise of social media platforms, WOM is transformed into a new form of online communication, which is termed as electronic Word-of-Mouth (eWOM). EWOM is an action taken by consumers, to share their attitudes, information and knowledge concerning brands or products (Verma & Yadav, 2021), including blog posts, videos, online product reviews, opinions posted on review sites, online conversations in virtual communities and social networks

(Chu & Kim, 2011; Cheung & Thadani, 2012). On the one hand, researchers have increasingly recognized the critical role of eWOM in shaping consumer attitudes and behaviors (Todri et al., 2022). All customers can access social media platforms to share their opinions or review the online comments of information concerning products or services (Nieto et al., 2014). Therefore, more consumers rely on eWOM to gain knowledge or make decisions than ever before (Bloem, 2017; Murphy, 2018).

On the other hand, marketing literature treats social media as a monitoring and information source (Li et al., 2022). Traditionally, companies had to depend on research methods such as surveys and focus groups to obtain information from their target groups. Social media review data can be considered as big data due to its high volume, velocity, and variety (Zhou et al., 2018), which is particularly suited for collecting information and obtaining feedback from customers (Nisar et al., 2020). EWOM provides companies a cost-effective way to identify customers' perceptions by eWOM from diverse social media platforms (Nieto et al., 2014), which implies a great amount of commercial information for brands or companies in NPD. Many companies are struggling with acquirement of the right marketing insights in order to marketing activities (Talwar et al., 2020) and new product development strategy (Nguyen & Chaudhuri, 2019). EWOM tends to be spontaneous and is the large amount of data on authentic customer behavior (Roulet & Laker, 2020). Accordingly, analysis of eWOM could be important in connection with product development (Zhou et al., 2018).

EWOM can be negative, positive, or neutral (Lovett et al., 2013) and all new products failing in the market generate eWOM (Dalman et al., 2020) which provides brands or companies to gather NPD information. More specifically, extant research has consistently shown that consumers pay more attention to NWOM than positive WOM (Yang & Mai, 2010). Furthermore, negative eWOM (hereafter NWOM) is more impactful than positive eWOM (Lee & Suh, 2020) because consumers perceive negative product information as more credible (Kusumasondjaja et al., 2012) and diagnostic (Allard et al., 2020) than positive product information. Hence, managing NWOM is a crucial task for focal companies in product innovation.

Within the eWOM literature, abundant research has accumulated on the antecedents and consequences of eWOM, including characteristics of the product (Berger & Schwartz, 2011), as the content of eWOM (Hennig-Thurau et al., 2004), the identification of eWOM helpfulness (Mariani & Borghi, 2021), the determinants and motivation factors for spreading eWOM (Dalman et al., 2020; Hennig-Thurau et al., 2004), the impacts of eWOM on consumers' brand attitudes (Ray et al., 2021), innovation diffusion and adoption (Pescher & Spann, 2014)

Previous literature emphasizes that NWOM messages are more influential than positive and

has paid considerable attention to study the negative (Allard et al., 2020) or positive (Anagnostopoulou et al., 2020; Wang & Kim, 2021) consequences of NWOM. Recent work investigated the drivers of NWOM generation and transmission (He et al., 2019; Liao et al., 2023). For instance, Liao et al. (2023) found that consumers who identify with rival brands tend to feel *schadenfreude* and transmit NWOM of the focal brand. They demonstrated the influence of empathic response in alleviating the *schadenfreude* of consumers of rival brands.

Prior studies have also examined eWOM in connection with product innovation (Ghasemaghaei & Calic, 2019; Kawakami et al., 2013; Nguyen & Chaudhuri, 2019). For example, Nguyen & Chaudhuri (2019) investigated how a failed product innovation generates the eWOM and found that a high level of product innovativeness creates a larger amount of NWOM. Dalman et al. (2020) also argued that higher-equity brands suffering new products failure attract more NWOM from consumers and showed how companies manage and mitigate NWOM through opinion leadership and consumer testimonials. As argued by previous mention, NWOM is regard as an important source of product innovation and extant literature focuses on the effect of new product failure on NWOM. Yet little research examines the impact of NWOM on product innovation, except for the recent work by Ghasemaghaei & Calic (2019) who examined the effect of social media data characteristic (i.e., volume, velocity, variety, and veracity) on exploitation and exploration innovation. Despite the significance of NWOM in product innovation, less is known about how NWOM affects product innovation.

In a methodological perspective, most of studies examined the issue of NWOM using survey data in eWOM literature (Allard et al., 2020; Dalman et al., 2020; Ghasemaghaei & Calic, 2019; Kawakami et al., 2013; Liao et al., 2023; Nguyen & Chaudhuri, 2019) due to their greater availability and easier accessibility (Li et al., 2022). Although researcher has called for more usage of automated eWOM analysis, there are few studies using social media data from eWOM (Liu, 2020). Li et al. (2022) also proposed that future research should make greater use of data mining techniques with the help of new technologies to gain more accurate data.

Exploitative and exploratory innovation in the era of online social networks

March's (1991) work of exploration and exploitation has triggered numerous interest from researchers studying phenomena such as organizational learning, innovation and strategic management. Organizational learning theory suggests that exploration and exploitation are parts of organizational learning process through which companies create new knowledge and expertise to develop innovations (Argote, 1999; March, 1991). While exploitative innovation is related to use explicit knowledge bases to develop existing technological or marketing trajectories by

internalizing and combining them, exploratory innovation refers to use tacit knowledge bases to create new technological or marketing trajectories by externalizing and combining them (Nonaka, 1994).

Both exploitative and exploratory innovation is crucial to innovate successfully in companies (Tushman & O'Reilly III, 1996). March (1991) stated that the trade-off between exploration and exploitation makes the simultaneous pursuit of both all but impossible due to scarce organizational resources. While previous research accepted the trade-offs between exploration and exploitation due to competency or learning traps, inertia, and short-term resource allocation dominance (Levinthal & March, 1993; March, 1991), recent work has paid more efforts to understand the strategies that companies might use to achieve a balance between exploration and exploitation (Lampert & Kim, 2019). The need to have an appropriate balance between exploitation and exploration has been conceptualized as ambidexterity (Tushman & O'Reilly III, 1996). Referring to the ambidexterity perspective, companies can balance of the two through sequential pursuit of exploration and exploitation or, they can engage in the simultaneous pursuit of both exploration and exploitation by means of loosely coupled (Levinthal & March, 1993). Theory development concerning the ease or difficulty with which an organization can pursue both exploration and exploitation depend on whether the two tasks are regarded as competing or complementary sides of organizational actions (Gupta et al., 2006).

Researchers have suggested that information and communication technologies and other new technologies can lead companies to achieve ambidexterity (Lee et al., 2015) because these technologies simultaneously help them to explore and exploit the opportunities that exist in the external environment (Roberts & Grover, 2012). Further, the two types of innovation entail combining insights. While exploratory innovation exerts dispersed and varied insights in new ways, exploitative innovation employs current knowledge in well-understood ways (Gupta, Smith, & Shalley, 2006). Extant research argued that companies can enhance their learning capabilities by creation of insights stemming from big data in terms of how to extend their current knowledge to improve products and how to renew their product innovation knowledge and skills to generate unique and novel products simultaneously (Dezi et al., 2018; Ghasemaghahi & Calic, 2019; Raisch, Birkinshaw, Probst, & Tushman, 2009).

In the empirical evidence, Dezi et al., (2018) has investigated the role of big data in shaping ambidextrous business process management in terms of exploitation and exploration using three case studies in the service industry. They also proposed some advantages and managerial challenges of big data deployment in exploitative and explorative processes. Ghasemaghahi & Calic (2019) further conducted a survey to examine the influence of social media data characteristics on

innovation (i.e., competency exploitation and exploration innovation). Nevertheless, empirical research regarding the role of NWOM stemming from social media platforms on exploitative and exploratory innovation has been neglected.

The impact of NWOM on exploitative and exploratory innovation

Social media platforms provide consumers to express their opinions and sentiments regarding companies' products or services, which leads companies to utilize social media data analytics to better understand market insights and customer needs (Timoshenko & Hauser, 2019), and thereby identifying innovation opportunities (Carlson et al., 2018). Listening to social media comments is a good way to collect customer sentiments (Li et al., 2022). Previous studies have found that eWOM sentiment is a strong predictor of new product success (Nguyen & Chaudhuri, 2019) and companies can employ sentiment measures as a way to assess consumers' reactions (Homburg et al., 2015). Positive eWOM is prone to be credited to social norm dynamics but NWOM tends to be credited to the performance of the product itself (Mizerski, 1982).

Researchers argued that new product failures are likely to generate NWOM concerning the focal brand (Dalman et al., 2020; Zhang et al., 2014). Not only does such information of product evaluations share concerns about product functionalities (Nguyen & Chaudhuri, 2019), it also presents product attributes in terms of usage situations and depicts product performance from a user's point of view (Bickart & Schindler, 2001). NWOM involves in product related information which is used by customers that the more NWOM of a new product, the greater its valuable insights residing information (Ghasemaghaei & Calic, 2019). These insights could be an important driver of innovation (Tan et al., 2015; Xu, Frankwick, & Ramirez, 2016). Hence, both exploitative and exploratory innovation entail combining insights (Ghasemaghaei & Calic, 2019).

There are several factors to explain companies' exploitative innovation is helpful through NWOM. First, NWOM involves in customers' demand-side knowledge which is useful for product development (Zhou et al., 2018). Companies extract new ideas, better understand customers and products, and help companies to improve their capabilities in refining revisions of existing products (Tan et al., 2015; Zhou et al., 2018) through employing current knowledge in well-understood ways which can achieve exploitative innovation (Gupta et al., 2006). Second, exploitative innovation emphasizes efficiency and execution (Rosing & Zacher, 2017). Analysis of customers' demands from NWOM leads companies to prioritize unresolved problems and consider new functions in a sequential product to maximize the product's performance (Sambamurthy et al., 2003). Third, exploitative innovation is to respond to current environmental conditions by adapting existing technologies and further meeting the needs of existing customers (Benner & Tushman,

2002; Harry & Schroeder, 2000), making companies more likely to detect unfair or unauthentic NWOM. Therefore, companies can utilize NWOM derived from social media data to generate insights regarding how to extend their existing product innovation knowledge in order to achieve exploitative innovation (Raisch et al., 2009) based on customers' need (Ghasemaghaei & Calic, 2019). This leads to the following hypothesis:

H1a: The impact of NWOM on exploratory is nonsignificant.

For exploratory innovation, companies can process NWOM from social media data to hence their exploratory innovation due to generation of insights concerning how to renew their product innovation knowledge and skills (Raisch et al., 2009) for three factors. First, exploratory innovation requires to experimentation and search (Rosing & Zacher, 2017) and considerable efforts to generate unique and novel products through the new insights they generate (Ghasemaghaei & Calic, 2019). NWOM from social media data can provide companies to utilize large sizes of heterogeneous data in almost real time (Ghasemaghaei, Ebrahimi, & Hassanein, 2017) for developing new products. Second, exploratory innovation leverages dispersed and varied insights in new ways (Gupta et al., 2006). NWOM tends to come from a variety of sources online such as review platforms, blogs, and discussion forums, which provides companies with great prospects for understanding consumer demands in different contexts (Moe & Schweidel, 2017). Even though NWOM derived from the same platform can also be considered as coming from a variety of sources because customers who are from different backgrounds, expertise, and experience, post different comments on the same product feature (Zhou et al., 2018). Lastly, customers' demand-side knowledge is critical for developing newly products because customers can sometimes create more novel ideas than professional developers (Poetz & Schreier, 2012). Not all consumers are equal in their desire to spread NWOM (Dalman et al., 2020). Rather, experts are relatively more likely to be familiar with multiple uses of an innovation to share their opinions (Kawakami et al., 2013).

However, NWOM may be generated by unfair or vindictive complaining opinions (He et al., 2019), especially for anti-branding behavior which is from consumers of rival companies (Rauschnabel et al., 2016). There is an increasing number of fans of rival companies who engage in conveying NWOM of a competing company in recent years (Liao et al., 2023). Consumers with a higher identification with a brand tend to have a negative attitude toward competitor brands (Itani, 2020), especially when they encounter unsatisfied. Liao et al. (2023) demonstrated that consumers of rival brands are more likely to transmit NWOM of the focal brand because of *schadenfreude*. Opposition to competing brands by fans of one brand present as transmission of NWOM. As a

result, NWOM may be easily manipulated and reduce its authentic.

Considering that exploratory innovation is essentially intended to drive and respond to latent environmental trends by creating innovative technologies and new markets (Lubatkin et al. 2006). More specifically, exploratory innovation refers to a shift to a different knowledge domain with the aim to develop new products and emphasizes the creation of knowledge that differs from that used by companies in previous innovations (Benner & Tushman, 2002). Thus, exploratory innovation involves the integration of diverse and novel insights, which introduces complexity and ambiguity in evaluating the authenticity of NWOM. As a result, the relationship between NWOM and exploratory innovation remains uncertain, given the presence of both potentially valuable insights and misleading information. This leads to the following hypothesis:

H_{1b}: The impact of NWOM on exploitative innovation is positively significant.

The moderating role of structural holes

In social network theory, network position has been developed for a long time and is well established. Online social networks have been shown to make such an exploration process more effective by directing the consumers toward products they tend to enjoy (Goldenberg et al., 2012). While extant literature has examined the moderating role of consumers' network position in information diffusion (Zhang & Gong, 2021a, b), there is scant research on considering the moderating role of consumers' network position in innovation.

More specifically, structural holes are more important than others (Pescher & Spann, 2014) and highlight as the divergent mechanisms underlying such advantageous locations in pursuit of innovation. An individual's structural hole positions are its brokerage locations between two otherwise disconnected members in a social network (Burt, 1992). An individual bridging structural holes of network can act as a broker in a network when connecting at least two otherwise disconnected members in its social network (Burt, 2000). Network scholars argued that the main advantages of the structural holes are access to more diverse information, more timely access to that information and control over information flow (Adler & Kwon, 2002; Burt, 1992).

Due to this promising network position, this study argues that consumers occupying higher structural holes may be helpful to achieve exploitative and exploratory innovation from NWOM in several factors. In online social networks, for exploitative innovation, numerous communities of social media are isolated and even opposed to each other (Gong et al., 2020). Consumers bridging more structural holes are tied to disconnected groups of network members and tend to have early access to a broader range of new product information or advice (Burt, 1992; Burt, 1999) that benefit

to broaden their new knowledge in the given product category or across product categories. Such that they can criticize more useful product-related information (NWOM) to build their expert reputation and controlling over the information flows across the network to expand the scope of information diffusion (Gong et al., 2020). The above helps companies to generate valuable insights for search and experiment in pursuit of exploratory innovation. Conversely, consumers bridging less structural holes acquire redundantly product-related information because the homogeneity of information and behaviors is generally higher within any group of members compared to that between two groups of members (Burt, 1992). Thus, they do not acquire novel information to improve their knowledge.

For exploratory innovation, consumers bridging more structural holes not only receive as much relevant information or knowledge as possible in social networks (Burt, 2000), but also obtain timely, diverse, and state-of-art product information because of their strategic positions spanning structural holes (Burt, 1999). In online social networks, consumers bridging more structural holes are likely to be exposed earlier to product information. The consumers tend to search, compare, filter and experiment the heterogeneous information among otherwise disconnected groups, such that they can recognize whether authentic NWOM, rumors, retaliatory or anti-branding behaviors and possess more accurate product information or alternative opinions regarding NWOM (Kawakami et al., 2013; Van Eck et al., 2011).

In addition, bridging structural holes allows the consumers an opportunity to broker the flow of valuable information from one group to another (Burt, 2000; Gong et al., 2020) to present their abilities to monitor and manipulate the flow of information (Burt, 1992). Therefore, when consumers bridge structural hole, they can clarify unauthentic NWOM and decide to deliver accurate product information across the network in order to elicit more information sharing among consumer, and thereby reduce unfair or unauthentic NWOM. On this basis, customers bridging structural holes strengthen the impact of NWOM on exploitative and exploratory innovation, which leads to the following hypotheses:

H2a: The effect of NWOM on exploratory innovation is positively moderated by bridging structural holes, such that consumers bridging more (versus lower) structural holes benefit the impact of NWOM on exploratory innovation.

H2b: The effect of NWOM on exploratory innovation is positively moderated by bridging structural holes, such that consumers bridging more (versus lower) structural holes benefit the impact of NWOM on exploitative innovation.

Research methods

Research setting

The sample consists of companies in the biotechnology industry which is listed on the Taiwan Stock Exchange, which covers pharmaceutical manufacture, medical devices, applied biotechnology and healthcare services. There are several reasons why biotechnology and medical care industry is pertinent to the study. First, biotechnology is a technology-intensive industry that have been applied in various fields to contribute advance technologies with high patenting rate. Second, Taiwan has designated the biotechnology industry as a key industry for development and has already achieved important accomplishments in each area. Third, although the COVID-19 pandemic caused economic damage, coronavirus vaccine development and medical devices created investment opportunities for bio-tech and pharmaceutical companies to achieve innovation. Four, the COVID-19 pandemic significantly drives consumer eWOM expressed on various social media platforms. The sample data for this research was obtained from the Taiwan Economic Journal (TEJ) database, comprising 84 companies within the biotechnology industry.

Data collection

The study utilized secondary data for patents and primary data for eWOM, collected annually between January 1, 2020, and December 31, 2022. Patent data was collected from two primary sources to ensure comprehensive coverage and analytical accuracy. The Taiwan Patent Search System (TPSS), administered by the Intellectual Property Office of the Ministry of Economic Affairs, served as the primary database for retrieving patent information specific to Taiwan. In addition, the Global Patent Search System (GPSS), developed by Taiwan's Intellectual Property Office (TIPO), was utilized to extend the scope of data collection beyond Taiwan. GPSS is a comprehensive patent retrieval platform that integrates data from over 100 countries, encompassing more than 150 million patent documents, including information from major patent offices such as the United States, Europe, Japan, Korea, and China, as well as the World Intellectual Property Organization (WIPO). To ensure data accuracy, this study employed a cross-verification process using both TPSS and GPSS, identifying and eliminating duplicate patents across systems. This approach allowed for the precise determination of patent counts in each year, thereby enhancing the reliability of the dataset for comparative analysis of innovation trends.

This study collected NWOM data from social media, online forums, blogs, news platforms, Q&A sites, and other review sources via OpView¹ community database. A senior biotech manager and a professor validated product selection, resulting in 321 keywords for data collection. OpView's DeepNLP classified reviews as positive, negative, or neutral eWOM. Due to missing data, 15 firms in 2020, 18 in 2021, and 21 in 2022 were excluded, yielding 198 firm-year observations

¹ OpView community word-of-mouth database is the only social analysis tool approved by the Chinese Applied Statistics Association, which covers more than 90% of community volume of listed in Taiwan.

(2020–2022). Following Wang (2022), a reviewer–brand network was constructed using an adjacency matrix to map relationships between consumers and biotech firms.

Measure

Product innovation *Exploitative innovation* is measured by *number of utility model patents applied*, whereas *exploratory innovation* is measured by *number of invention patents applied*. Patent count is one of the most direct measures of innovative output available (Hitt et al., 1991) and is a useful measure of companies' technological competitiveness and a good indicator of their progresses in technical knowledge (Pegels & Thirumurthy, 1996). The year when a company filed for a patent was used, rather than the year when it was granted, as the innovation in a company is realized once it files for a patent rather than when the patent is granted (Vanhaverbeke et al., 2009, 2011). Thus, the research uses patent counts as measure of product innovation. Profiles of all companies in the sample are calculated to derive the dependent variables, by logging the invention and utility model patents that each company filed (applied) for each year of observation.

NWOM *NWOM* is measured as the natural logarithm of number of negative sentiment review scores derived from OpView community word-of-mouth database.

Structural holes The moderating variables in this study are network-based. Measures of network structure are calculated from the full structural network adjacency matrix based on the primary data providing from OpView community word-of-mouth database. The study measures *network constraints* as the extent to which a network member's contacts are redundant (Burt, 1992). This accounts for companies' scope to negotiate or exploit potential structural holes in their network. The constraint (C_{ij}) is computed by the squares of the sum of the direct link strength and the indirect link strength from node i . to node j . ct j of actor i :

$$C_{ij} = (P_{ij} + \sum P'_{ij})^2 = (P_{ij} + \sum_q P_{iq}P_{qj})^2 \quad (q \neq i, q \neq j) \quad (1)$$

Specifically, companies with low structural constraint (C_{ij}) have networks in which their contacts are not themselves connected i.e., networks with many structural holes (Kleinbaum & Stuart, 2014). The matrix is input into UCINET to calculate network measure (Borgatti et al., 2002). The measure values define the levels of structural holes of consumers based on average values. More specifically, the research uses the measure values of consumers ranging from below average to above average to define consumers bridging lower structural holes and consumers with bridging more structural holes.

Control variables There is a variety of control variables including in this study that may influence innovation. *Firm size* is defined as the logarithmic transformation of total assets, which indicates the firm's physical and financial resources and is widely used as to assess the competitive positioning within an industry (Qian et al., 2008). Small firms are more innovative due to their simpler task structure and dissimilar attitude to risk (Holmstrom, 1989). Moreover, the study controls for *firm age* measured as the number of years since the firm's inception because Francis & Smith (1995) argued that younger firms are more active in innovation activities than older firms. *R&D intensity* is also included that may affect product innovation. R&D expenditures reflect firms' innovation efforts and have been widely used in studies of innovation (Hoskisson & Hitt, 1988; Baysinger & Hoskisson, 1989). Hence, R&D intensity is calculated as the ratio of research and development expenditures over total assets.

Results

Table 1 presented the descriptive statistics and the correlation matrix of the variables used in this study. Tobit regression analysis was employed to test the proposed predictions. For hypotheses testing, H_{1a} posits that the impact of NWOM on exploratory is not significant. Table 2 reported the Tobit regression results, where Model 1 examined the main effect of NWOM on exploratory innovation. The results indicated that NWOM had a positive but nonsignificant effect on exploratory innovation ($\beta = 0.0002$, $p > 0.10$), thus not supporting H_{1a}.

Conversely, H_{1b} posits that the impact of NWOM on exploitative innovation is positively significant. Table 4 presented the regression model analyzing the main effect of NWOM on exploitative innovation. The finding exhibited that NWOM had a positive and significant effect on exploitative innovation ($\beta = 0.0044$, $p < 0.05$). Therefore, the results provided empirical support for H_{1b}, suggesting that NWOM had a positive effect on exploitative innovation.

H_{2a} predicts that bridging structural holes strengthens the impact of NWOM on exploratory innovation. In Model 3, the structural holes variable was centralized to mitigate potential multicollinearity. The analysis results indicated that the moderating effect of bridging structural holes on exploratory innovation was positive and significant ($\beta = 0.1095$, $p < 0.01$), providing support for H_{2a}. This finding suggested that bridging structural holes enhances the relationship between NWOM and exploratory innovation.

H_{2b} predicts that bridging structural holes strengthens the impact of NWOM on exploitative innovation. The results reveal a positive and significant effect ($\beta = 0.0666$, $p < 0.05$), thus supporting for H_{2b} and suggesting that bridging structural holes can strengthen the relationship between NWOM and exploitative innovation.

Discussion and conclusions

Discussion

This study employs big data analysis to examine the impact of NWOM on two types of product innovation—exploitative and exploratory innovation. Furthermore, it develops a contingency framework to assess the moderating effect of structural holes on the relationship between NWOM and product innovation based on organizational learning theory and social network theory. The findings offer novel insights into the distinct influences of NWOM on these two types of innovation.

First, empirical results indicate that NWOM has a significantly greater positive effect on exploitative innovation than on exploratory innovation. This supports the argument that exploitative innovation, which emphasizes refinement and efficiency (Gupta et al., 2006), is more reliant on known customer demands and performance feedback. NWOM provides demand-side knowledge and actionable product criticisms (Zhou et al., 2018), allowing firms to address issues in existing offerings, align product modifications with market expectations, and reduce uncertainty.

In contrast, the impact of NWOM on exploratory innovation is less pronounced. Exploratory innovation demands novel, often ambiguous insights, and is more susceptible to the challenges of information veracity and manipulation in online environments (He et al., 2019). As noted by Liao et al. (2023), NWOM is susceptible to manipulation, making it more challenging for firms to distinguish between authentic NWOM and misinformation in the context of exploratory innovation compared to exploitative innovation. The difficulty in verifying the authenticity of NWOM—especially when stemming from consumers of rival brands or from orchestrated anti-branding behaviors—makes it harder for firms to leverage such information for exploratory innovation. This reinforces the view that balancing exploration and exploitation requires different informational filters and cognitive frames.

Second, the findings reveal a significant moderating effect of structural holes: consumers bridging more structural holes amplify the positive relationship between NWOM and two types of innovation. Specifically, consumers bridging structural holes provide access to non-redundant, diverse product-related information. This structural position allows firms to overcome information redundancy and interpret fragmented NWOM into meaningful insights (Burt, 1992; Gong et al., 2020), particularly for exploratory innovation, which relies on novel and dispersed knowledge. Our analysis reveals that the effect of NWOM is contingent upon the network positions of the consumers who generate such information.

Additionally, consumers bridging structural holes can help distinguish between authentic and unauthentic NWOM and choose to disseminate accurate product information across the network.

This process encourages greater information sharing among consumers and reduces the prevalence of misleading or unfair NWOM. The findings underscore the strategic significance of structural holes in mitigating the negative effects of NWOM by enhancing access to diverse external knowledge, ultimately facilitating exploratory innovation.

Third, the results indicate that NWOM originating from social media platforms can simultaneously enhance both exploitative and exploratory innovation under the condition of structural holes, enabling firms to achieve ambidexterity. This finding aligns with prior research suggesting that information and communication technologies facilitate ambidexterity in organizations. While previous studies have demonstrated that firms can enhance both types of innovation by generating insights from big data (Dezi et al., 2018; Ghasemaghaei & Calic, 2019), this study further highlights the contingent conditions under which ambidexterity can be effectively pursued.

Contributions

The findings demonstrate that the impact of NWOM on innovation is not direct but contingent upon the network positions of consumers. While NWOM shows a marginal positive influence on exploitative innovation, it lacks direct influence on exploratory innovation. However, consumers bridging more structural holes significantly strengthen the effect of NWOM on both types of innovation, with a notably stronger impact on exploratory innovation. These insights highlight the importance of considering network structure when leveraging eWOM for innovation. Firms seeking to enhance innovation should not only analyze content but also evaluate the structural positions of information sources.

Theoretical contributions

This research makes four theoretical contributions. First, by distinguishing between exploitative and exploratory innovation, this study contributes to organizational learning theory and the ambidexterity literature, offering empirical evidence that external information such as NWOM does not affect both types of innovation equally. Second, while eWOM has been extensively documented, there remains a lack of understanding regarding the effect of NWOM on product innovation in the eWOM literature. This study extends the eWOM and innovation literature by demonstrating that the influence of NWOM is moderated by social network structures—specifically structural holes—thereby refining our understanding of digital consumer input. Third, the research contributes to the ambidexterity literature by proposing that firms can better support both exploratory and exploitative innovation when it is generated by consumers who bridge more

structural holes. This adds a network-informed perspective to organizational learning and digital ambidexterity research. The results not only illustrate how companies achieve ambidexterity through NWOM and how its effects vary across structural holes, but also support the notion that consumers who bridge more structural holes occupy more advantageous positions in social networks for expanding the scope of information diffusion compared to opinion leaders.

Forth, eWOM, which represents a vast amount of data on authentic customer behavior (Roulet & Laker, 2020), has the potential to reach massive audiences (Nisar et al., 2020). This study contributes to the eWOM literature by employing a big data analytics approach and social network analysis, offering an alternative to the survey-based eWOM research that is currently underrepresented in the existing literature.

Practical contributions

This study provides valuable insights for managers implementing digital innovation strategies. Firms should move beyond sentiment-level analysis and incorporate social network analysis to identify NWOM originating from consumers who bridge structural holes. These consumers are likely to provide richer, cross-boundary information that enhances exploitative and exploratory innovation. Moreover, for exploitative innovation, even marginal NWOM may be useful for refining existing offerings, but attention should still be paid to the credibility and origin of the feedback. Integrating network position analytics into social listening tools can improve the accuracy and relevance of innovation-related decision-making.

Limitations and future directions

This study has several limitations. First, the study focuses on the biotechnology industry in Taiwan, which may limit the generalizability of the findings. Future research could examine other high-tech or consumer-focused industries to validate the findings across different contexts. Second, NWOM measurement was based on automated sentiment tools, which may misclassify complex sentiments such as irony or contextual cues. Future research could incorporate manual coding or advanced NLP models. Third, this study focuses on structural holes as the moderating variable. Future research could explore other network properties such as betweenness centrality or network density.

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Table 1 Means, standard deviations, and correlations

Construct	Mean	S.D.	1	2	3	4	5	6
1 EXPLOR	0.05	0.10						
2 EXPLOI	0.01	0.05	-0.015					
3 NWOM	1.69	1.96	-0.045	-0.004				
4 SHS	0.65	0.08	0.044	-0.003	0.192**			
5 SIZE	14.46	1.22	-0.369***	-0.066	0.259***	0.047		
6 AGE	24.06	17.57	-0.307***	0.011	0.242***	0.051	0.533***	
7 RDINTEN	0.11	0.16	0.671***	-0.084	-0.120 [†]	-0.009	-0.411***	-0.374***

Note:

¹ EXPLOR: Exploratory innovation. EXPLOI: Exploitative innovation. NWOM: Negative eWOM. SHS: Structural holes.
 SIZE: Firm size. AGE: Firm age. RDINTEN: R&D intensity.

² Number of firm years = 198; ***p< 0.001; ** p<0.01; * p<0.05; [†] p<0.10.

Table 2 Results of Tobit regression analyses for NWOM

	Exploratory innovation					
	Model 1		Model 2		Model 3	
	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value
NWOM	0.0002	0.09	0.0000	0.00	-0.0010	-0.37
Structural holes			0.0224	0.36	0.0552	0.83
NWOM×Structural holes					0.1095**	3.23
Firm size	-0.0109**	-2.75	-0.0109**	-2.75	-0.0108**	-2.75
Firm age	-0.0002	-0.72	-0.0002	-0.71	-0.0003	-0.96
R&D intensity	0.2643***	5.95	0.2644***	5.91	0.2607***	5.95
Constant	0.1441*	2.49	0.1304 [†]	1.92	0.1090	1.57
F-value	17.96 ***		15.48 ***		15.42 ***	

Note:

NWOM: Negative eWOM; ***p< 0.001; ** p<0.01; * p<0.05; [†] p < 0.1.

Table 3 Results of Tobit regression analyses for NWOM

	Exploitative innovation					
	Model 4		Model 5		Model 6	
	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value
NWOM	0.0044*	2.09	0.0040†	1.85	0.0032	1.34
Structural holes			0.0405	0.68	0.0390	0.68
NWOM×Structural holes					0.0666*	2.09
Firm size	-0.0097**	-2.64	-0.0098**	-2.65	-0.0094**	-2.70
Firm age	0.0006*	2.45	0.0006*	2.41	0.0005*	2.31
R&D intensity	-0.0456	-1.15	-0.0463	-1.17	-0.0437	-1.15
Constant	0.0741	1.42	0.0510	0.75	0.0491	0.76
F-value	2.83*		2.43*		3.00**	

Note:

NWOM: Negative eWOM; ***p< 0.001; ** p<0.01; * p<0.05; † p < 0.1.