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Competition Networks as a New Insight into the Determinants of Firm Technological and Market Performance

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Abstract

Based on the global patents of 109 mobile phone vendors filed from 1992 to 2016 and sales data from 2002 to 2016, this study formulates technological and market competition networks. We find that an increasingly large number of firms joined the market, leading to a competition network of increasingly larger scale and greater density. We also propose indicators to measure competitive intensity, which reflects the extent to which the firms are competing against each other. We examine the role of competitive intensity in mediating firms' performance. We employ a weighted least squares regression model for the empirical analysis. The empirical results confirm the significant role of competitive intensity in determining firm performance. However, in technological and market competition networks, competitive intensity generates essentially different mediating impacts. For technological competition, competitive intensity positively mediates the impact between the leaders' and followers' technological performances. There is an asymmetric mediating effect that enlarges the gap between the technological performances of leading vendors and their followers. Accordingly, competitive intensity may generate different impacts on the technological performance of leaders and followers. In comparison, the competitive intensity embedded in the market competition network has a symmetrical role in mediating the mutual impact between the leaders' and followers' market performances, that is, it neither enlarges nor narrows the market performance gap between leaders and followers. Therefore, when creating a development strategy, firm managers need to account for their competitors' behaviors, carefully analyze the significance of these behaviors, and adjust their strategic arrangements in a timely manner.

Keywords

competition network; competitive intensity; technological performance; market performance; mobile phone vendor

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1. Introduction

To be successful on the market, firms should not only focus on their internal business activities, but also constantly pay attention to the external environment and respond timely to the actions of their competitors. Firms always attempt to maintain a competitive advantage relative to others, which is vital to their survival and development on the market (Barney, 1991, 2001; Leiblein *et al*., 2017; Wang and Gao, 2020; Yu and Chen, 2020). This highlights the role of competitive relationships in firms' internal business activities. Many studies investigated the impact of competition using social network analysis, such as Zhang *et al*. (2020), Zhang and Guan (2019), and Wang and Gao (2020), taking the firms who target the same market as vertices and the competitive relationships between them as edges to develop competition networks.

Therefore, competition networks deserve an in-depth study. Competing firms compete for market share and the services associated with their products, and endanger their strategic positions and competitive advantage especially, when the market is highly unstable and premature. As such, competing firms' hostile relationships embedded in a competition network will produce negative effects (Ang, 2008; Cai *et al*., 2017; Coccorese and Ferri, 2019; Ljubownikow and Ang, 2020; Takata, 2016). However, a competition network can also positively affect firms that perceive their changing market positions and generate progress by avoiding being satisfied with the status quo. Firms obtain relevant information about their competitors through competition relationship such as market behavior, development failure, and successful experience (Aghion *et al*., 2001; Wang and Gao, 2020; Zhang and Guan, 2019). Firms also internalize the above information into their own development strategies through absorption and by responding or adjusting quickly (Adegbesan, 2009; Aghion *et al*., 2001; Wang and Gao, 2020; Zhang and Guan, 2019). Therefore, whether firms attempt to avoid negative effects or expand the positive ones, a competition network is of great importance for them in establishing their own unique competitive advantages.

The literature shows that, as social network analysis is rapidly becoming a standard diagnostic and guiding tool in the field of management (Baker, 2000; Borgatti and Halgin, 2011; Lai, 2009), collaborative networks have attracted more research attention than competition networks. As such, there are some studies that focused on competition networks, such as Zhang and Guan (2019), who analyzed the structure of competition networks in depth, as well as their evolution over time. The roles of a competition network in determining a firm's competitive advantage and performance were also investigated by Skilton and Bernardes (2015), Zhang and Guan (2019), Wang and Gao (2020), and Zhang and Xiong (2020) among others. However, these studies mostly focused on the direct impact of competition networks, for example, the effect of the number of competitors (Capron and Chatain, 2008; Ryvkin and Drugov, 2020; Skilton and Bernardes, 2015; Wang and Gao, 2020), competition intensity (Zhang and Guan, 2019; Zhang and Xiong, 2020), and network density (Skilton and Bernardes, 2015; Zhang and Guan, 2019) on firms' performance, thus ignoring the characteristics of competitors and discussing only the direct effect of the competition network. Therefore, the role of competitors' characteristics, such as competency, scale, and innovation capability, in determining firms' performance remains unknown. It is also evident that competitors affect each other through their competing relationships, which leads to a mediating role of competitive intensity. However, we still lack knowledge about this mediating effect. Therefore, unveiling the impact of competition networks from more perspectives would help us better understand competition theory.

In this study, global patent counts and sales data for 109 mobile phone vendors were used to address these research gaps by examining how the competitive intensity embedded in technological and market competition networks determines vendor performance. We found that these technological and market competition networks have asymmetric and symmetric mediating effects, suggesting different functioning mechanisms for each network. Our work fills the existing gap in the following ways: first, we focus on the mediating effects of competition networks. Specifically, we investigate how the strengths and weakness of a competitive relationship, through which firms could carry out perception, information transmission, mutual learning, and imitation (Bengtsson *et al*., 2016; Downing *et al*., 2019; Grahovac and Miller, 2009), play indirect roles in determining firm performance. Second, we tested the asymmetric effect, which has been ignored in the literature, as most extant studies investigated the holistic effects on a focal firm. Since firms may take either leading or following positions, a competitive relationship may impact leaders and followers differently based on their different business strategies (Guizzardi *et al*., 2019; Lieberman and Asaba, 2006; Roy and Raju, 2011). Ongoing technological breakthroughs (Chakrabarty and Wang, 2012; Fleming, 2001; Yan *et al*., 2020) and market achievements (Podolny, 2001; Sinkula, 1994; Zaheer and Zaheer, 1997) are two critical determinants for firms to overcome their limitations and acquire new resources. This study thus focused on both technological and market competition within the mobile phone industry. Industry competitors can exhibit either congruent or divergent behaviors when engaged in both market and technological competition (Bonanno and Haworth, 1998; Chih-Yi and Bou-Wen, 2021; Li *et al*., 2017; Tang and Zhang, 2020). This study provides a way to uncover these different behaviors and addresses the gap in the literature through comprehensive analyses of both market and technological competition networks.

The rest of this paper is organized as follows. Section 2 presents the theory and hypothesis, Section 3 describes the data and variables, Section 4 presents the empirical results, Section 5 verifies the robustness of the results, Section 6 discusses the significance of the research findings, and Section 7 concludes the paper.

2. Theoretical Background and Hypotheses Development

The need for resources can make firms reliant upon acquiring external resources and the related distribution channels of these resources. Social relationships with other firms can reduce channel limitations and overcome various development bottlenecks (Carnovale *et al*., 2019; Chen and Miller, 2015; Kaprielyan, 2016). The competition network arises from a mutual competitive relationship between firms and their direct competitors who run the same or similar businesses and target the same market (Skilton and Bernardes, 2015; Wang and Gao, 2020). Competition brings not only challenges that threaten the survival of firms, but also benefits the increase in their competitiveness. Firms' business behaviors are closely related to the number of their competitors, competitive intensity, and field where they compete. However, the impact of competitive relationships is usually indirect, obscure, and imperceptible. For example, when a firm changes its business strategy, we are less likely to attribute it to its competitors. The competitive relationship embedded in a competition network will help firms perceive opportunities and challenges better. Accordingly, they will adjust their business strategies and re-allocate their resources to enhance their competitive advantages and adopt a leading role in market competition (Bengtsson and Kock, 2000; Costa *et al*., 2013; Duysters *et al*., 2020; Galvin *et al*., 2020; Wang and Gao, 2020).

Competitors usually have relevant knowledge and adopt similar technologies (Chen and Miller, 2015; Powell *et al*., 1996). The more firms' resources and markets overlap, the greater the competitive intensity is (McPherson, 1983). Competitive intensity affects the extent to which a firm responds to the market behaviors of competitors (Chih-Yi and Bou-Wen, 2021; Guo *et al*., 2020; Zhang and Guan, 2019). Firms usually pay more attention to competitors with higher competitive intensity (Baum and Korn, 1999; Chen, 1996; Gimeno, 2004; Smith *et al*., 1991), because they more intensively compete for market share. Thus, they must try their best to collect information about these competitors and react accordingly, which may lead to a faster transmission of useful information through the competition network. The competition network provides a key channel for firms to anticipate technological changes in their industries and update their technological skills accordingly. Competitors also provide key information about other market participants, along with information suggesting more opportunities from the external environment (Hung *et al*., 2008; Podolny, 2001; Skilton and Bernardes, 2015; Zaheer and Zaheer, 1997). A competition network provides a variety of ways for firms to constantly monitor technological evolution. Based on the competition network, firms can verify the credibility of information through different competitors (Jolink and Niesten, 2021). The greater the competitive intensity is, the more valuable the verified information will be. By contrast, a firm facing weaker competition is less motivated to collect information from others and may become insensitive to the changes in the external environment. The firm's business activity may thus be slow and defective. Therefore, firms' performance is related to the availability of information about their competitors' behaviors, which indicates the key mediating role of competitive intensity. Accordingly, we propose the following hypothesis:

H1. Competitive intensity has a significant role in mediating the impact on firms' performances.

When attempting to capture a highly overlapping market, competitors will produce isomorphic and comparative pressure on firms. Greater competitive intensity increases firms' pressure and reduces their discretion (Anand *et al*., 2009; Wang and Gao, 2020), which may lead to a negative impact on their performance.

The competition network may also have other negative effects that lead to knowledge leakage and opportunistic risk. Firms tend to avoid tacit information disclosure, reduce knowledge sharing, and strengthen self-defense when facing increased competition (Das and Teng, 2003; Dyer and Singh, 1998; Wu and Wu, 2020). In the absence of the necessary exchanges of information, firms cannot accurately predict market demand, meaning their behavior will inevitably be limited. Therefore, it is impossible to improve the internalization and absorption of outside knowledge comprehensively and systematically (Estrada *et al*., 2016). The relationship between firms is highly dynamic, where firms both cooperate in terms of their common interests and compete when there are conflicts of interest (Bengtsson and Kock, 1999, 2000; Maria Bengtsson *et al*., 2016; Duysters *et al*., 2020; Fernandez *et al*., 2014). Competition compresses the technological space for firms acquiring the necessary inspiration from cooperative firms and leads to a decline in business ability (Aghion *et al*., 2001; Lane and Lubatkin, 1998).

Competition also leads to opportunistic behaviors that damage common interests and hinder innovation capability (Carnovale and Yeniyurt, 2015; Estrada *et al*., 2016; Walter *et al*., 2015). Therefore, a greater competitive intensity hinders the flow of key knowledge, impedes R&D cooperation, and reduces the trust between firms. When the competitive intensity changes, firms will further compete for resources such as technology, capital, talent and market, and become more sensitive to performance and benefits (Chatain, 2014; Zhou *et al*., 2017). Additionally, due to the ecological contagion mechanism (Dobrev, 2007), firms facing greater competitive intensity tend to focus on competitors, while ignoring other potential factors that may influence the external environment. Therefore, they may have limited visions, leading them to only take measures in attempt to impede their competitors. In the face of a highly uncertain and rapidly changing market environment, firms may have to further rely on symbiotic relationships of interdependence (Ang, 2008; Beckman *et al*., 2004). However, a greater competitive intensity increases the unpredictability of competition outcomes (Crick, 2019; Harris and Vickers, 1987) and, thus, reduces the possibility of reaching a consensus among firms. Consequently, we propose the following hypothesis:

H2. Competitive intensity has a negative role in mediating the impact between competitors' performances.

As the competitive relationship is composed of firms in leading positions and those that follow them (Viglia *et al*., 2016), it is necessary to investigate the effects that a competition network has on both leaders and followers, as they usually adopt different competition strategies (Guizzardi *et al*., 2019; Shankar and Bayus, 2003). Followers tend to learn from leaders and adjust their business strategies accordingly (Casadesus-Masanell and Zhu, 2013; Posen and Martignoni, 2018; Rhee and Stephens, 2020; Roy and Raju, 2011), which would prevent followers from updating their reactions according to the latest market trend (Lieberman and Asaba, 2006; Roy and Raju, 2011). Therefore, although competition makes firms more aggressive and active, it has different consequences for leaders and followers. The increase in competitive intensity burdens firms, particularly the followers that are more vulnerable to costs and risks (Bonanno and Haworth, 1998; Schilling, 2002; Singh and Mitchell, 2005). It also makes it difficult for the followers to allocate resources to new technologies (Baum *et al*., 2000; Lieberman and Asaba, 2006; Semadeni and Anderson, 2010). By contrast, the leaders tend to have more advantages in terms of financing, attracting talent, and exploring the market, making it difficult for followers to catch up. Therefore, although leaders motivate their followers to some extent, the latter must handle the pressure brought by resource constraints, which are proportional to the competitive intensity (Barney, 1991). Even if followers want to catch up with the leaders, resource constraints will prevent the improvement of their innovation capabilities, as well as impair the motivation brought by leaders (Barney, 1991).

As competitive intensity increases, firms' R&D motivation will show a trend of polarization. Since the R&D motivation depends on the differences in expected profit between R&D success and failure (Chen, 1996; Zhou *et al*., 2017), rational firm managers will not invest in R&D if a firm has no technological advantages. Therefore, in a highly competitive market, followers are more likely to suppress their R&D motivation and learn from leaders, making the former unable to catch up with and surpass the latter. Their business activities may thus be highly consistent. Leaders have advantages in product development, reputation, and market share, making it easier for them to apply for new patents and release new products. Although the intellectual property policies dedicated to leaders also benefit followers, the trickle-down effect will award more benefits to the former (Acemoglu and Akcigit, 2012; Aghion *et al*., 2001; Amir and Lazzati, 2011) and put more pressure on the latter (Acemoglu and Akcigit, 2012; Ishikawa and Shibata, 2020). Therefore, we hypothesize:

H3. Competitive intensity enlarges the performance gap between leaders and followers by generating asymmetric mediating effects on their performances.

3. Data and Method

We investigate how a competition network functions in the mobile phone industry, which is one of the most innovative segments that has substantially changed the lifestyle of human beings (Zhang *et al*., 2021). The innovations developed by competing firms have been continuous over time, with many new models winning a large market share from existing markets every year.

3.1. The measurement of firms' technological and market performance

We introduce two dependent variables to measure firms' technological and market performance, respectively.

In$pat_{i,k}$ is the logarithm of the number of mobile phone patents that firm *f* filed in country *k*, which is used to measure technological performance. The mobile phone patents are collected from the Derwent Innovation Index (DII). Following Aronoff *et al*. (2009), we set the query condition as "TS (Theme) = (Cell Phone or Cellular Phone or Mobile Phone or Smartphone or Smart Phone or Handset)" to filter mobile phone patents. Finally, we obtain 521,113 mobile phone patents, from which we select the 109 firms with the highest patent counts. Since a firm usually runs its business in many countries, it may adapt its technological strategy to the particularities of each country, such as institution specificity, cultural heterogeneity, and geographical proximity. Therefore, we classify the patents into different country cohorts according to the first two digits of the patent numbers, which contain information about the patent family, that is, in which country the patent was filed. As a result, we have 31 countries.

Market performance should be measured by firms' product sales data. However, it is impossible for us to acquire mobile phone sales data for each vendor. We instead investigate a mobile phone model's popularity, which is believed to be proportional to its sales. We also account for the price of the mobile phone model and introduce alternative variables by multiplying the popularity and launch price of each mobile phone model and summing up these values for all mobile phone models launched by a vendor. The popularity data and launch price of each mobile phone model is acquired from the website GSMArena (Global System for Mobile Communications Arena)[1], which records phone pricing information from stores worldwide for over 20 years. The visitors of this website can contribute to the popularity of each mobile phone model by clicking the corresponding links. The number of clicks for each mobile phone model will be recorded by GSMArena. We also classify each mobile phone model into 21 country cohorts according to the market coverage information recorded by GSMArena. Then, we get the variable In$Poprice_{i,k}$, which is the logarithm of the sum of popularity×price,

$$\ln Poprice_{i,k} = \ln\left[\sum_{m=1}^{M_{i,k}} Popularity_{i,k,m} \times Price_{i,k,m}\right] \tag{1}$$

where $Popularity_{i,k,m}$ and $Price_{i,k,m}$ are the popularity and launch price of mobile phone model *m* that sells in country *k*'s market, respectively. $M_{i,k}$ is the total number of mobile phone models launched by *i* in country *k*'s market. It is reasonable to use In$Poprice_{i,k}$ as the alternative variable of a mobile phone vendor's market performance, because both the popularity and price of a mobile phone model are believed to be positively correlated with its sales.

Besides popularity, GSMArena also records the hits for each mobile phone model. Since people are more likely to visit a web page that describes a mobile phone model with higher sales, we introduce variable In$Hitprice_{i,k}$ as the logarithm of the sum of each mobile phone model's hit×price, to measure *i*'s market performance in country *k*.

The above dependent variables are all calculated based on yearly data in *t*+1.

[1] https://www.gsmarena.com/

3.2. The competition network

The competition network is composed of competitors and their competitive relationships. We take the firms as vertices and the competitive relationships between each pair of firms as the edges.

3.2.1. The technological competition network and competitive intensity

As per Markman *et al*. (2004) suggested, we employ patent data to measure the volume of a firm's technology resources and investigate the extent to which the distributions of two firms' technology resources overlap. This is indicative of the competitive intensity between them, because firms with highly overlapping technology resources are more likely to intensely compete against each other, particularly when we restrict the competition within a country.

We employ the distribution of all patents' International Patent Classifications (IPCs) that a firm filed to represent its technology resources distribution. The IPCs of the all patents held by a firm are classified into the 35 technological fields originally proposed by Schmoch (2008), that is, $\boldsymbol{IPC\_ratio_{i,k}}=(IPC\_ratio_{i,k,1}, IPC\_ratio_{i,k,2}...IPC\_ratio_{i,k,35})$, where $IPC\_ratio_{i,k,f}$ is the ratio of firm i's IPC count in technological field f to all IPC counts in f.

For a pair of firms i and j, the extent of the overlap between $\boldsymbol{IPC\_ratio_{i,k}}$ and $\boldsymbol{IPC\_ratio_{j,k}}$ reflects their competitive intensity, because competing firms targeting the same technology are more likely to file more patents in the same technological fields. Accordingly, we measure the intensity of technological competition using the following arccosine function:

$$Tech\_cint_{ij,k}=\pi/2\text{-}arccos\left(\frac{IPC\_ratio_{i,k}\times IPC\_ratio_{j,k}}{||IPC\_ratio_{i,k}||\times||IPC\_ratio_{j,k}||}\right)$$

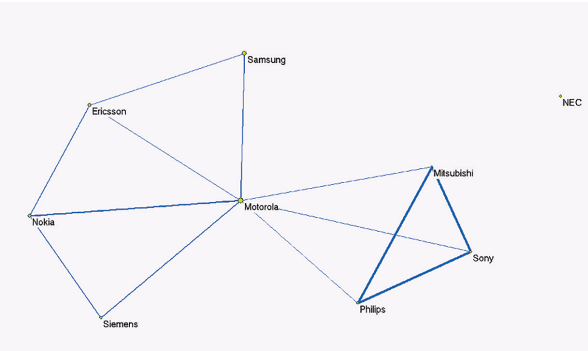
The value of $Tech\_cint_{ij,k}$ depends on the extent to which $\boldsymbol{IPC\_ratio_{i,k}}$ and $\boldsymbol{IPC\_ratio_{j,k}}$ coincide. Similar measurements of competitive intensity are employed by Zhang and Guan (2019) and Zhang and Xiong (2020), who focused on the technological dimension of a competition network. To smooth the data, we take the logarithm (In $Tech\_cint_{ij,k}$) in the following empirical analysis.

To investigate how the competition network evolves, we carry out a dynamic analysis by employing five-year moving windows, that is, patents filed within five consecutive years are pooled together. Since our patent data cover the period between 1992 and 2016, we have 21 technological competition networks. This data processing method would also smooth the variables by creating a moving average. Figure 1 presents the technological competition networks in China and the U.S., where each vertex corresponds to a firm and the thickness of an edge represents the competitive intensity between the firms it connects. We also account for a firm's technological performance by making the size of the vertex proportional to the patent count the firm filed. To illustrate the network, Figure 1 shows only the edges corresponding to the highest 15% competitive intensity.

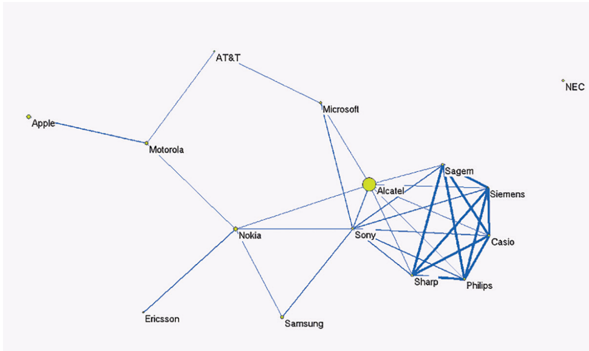
From Figure 1, an increasingly large number of firms joined the competition network over time, leading to a network with increasingly larger scale and greater density. The sizes of the vertices also increased over time, suggesting ever improving technological performance. This may be attributed to the competition network, which is believed to serve as an important source of competitive advantage (Wang and Gao, 2020). However, technological performance increased unevenly, resulting in some vertices with larger sizes in the later stages, such as ZTE, Samsung, Huawei and Oppo in China and Amazon in the U.S., while most others have much smaller sizes. This suggests that technological competition is becoming increasingly monopolistic.

Figure 1 also suggests the heterogeneity of competition networks between countries. As shown in a1, a2, b1, and b2 of Figures 1, there were fewer such firms in China than in the U.S. in the 1990s. The firms' technological performances in China also lagged behind those in the U.S. However, these differences were reversed in the 2010s (see d1, d2, e1, and e2 in Figures 1), suggesting a more rapid progress in China driven by strong economic growth. Therefore, country heterogeneity should be controlled for in the following empirical analysis.

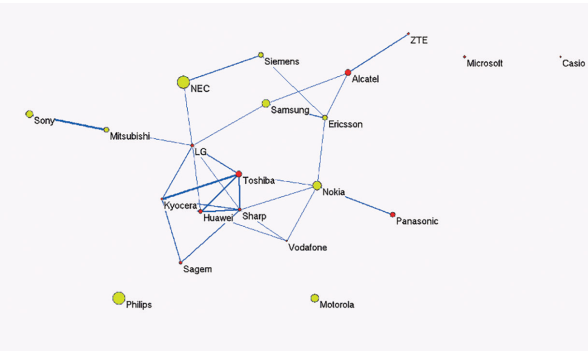
Since, a firm usually faces several competitors, which together formulate the ego-network of that firm, we additionally investigate the overall effect of that ego-network by summing up all the competitive intensity it generates, that is, In*Sum_tech_cint*$_{i,k}$, the logarithm of the sum of the technological competitive intensity that *i* encounters.



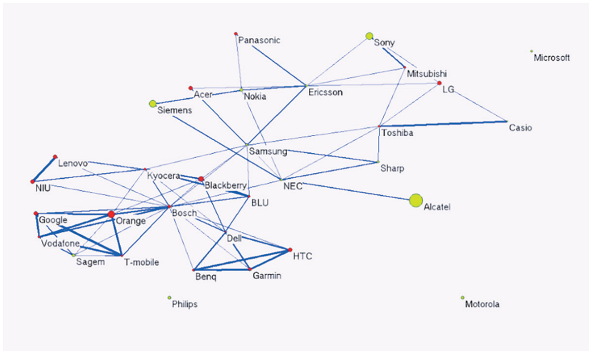
(a1) China (1992–1996)



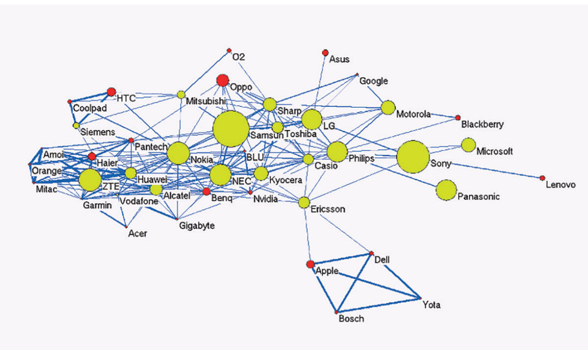
(a2) U.S. (1992–1996)



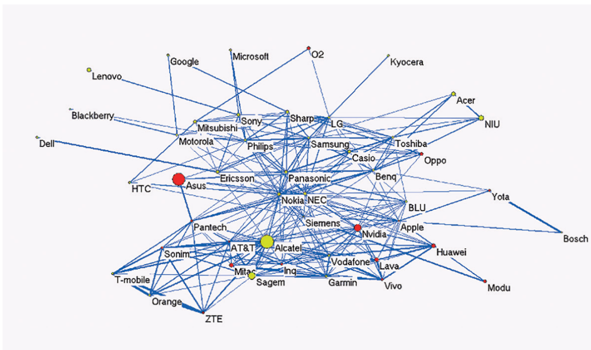
(b1) China (1997–2001)



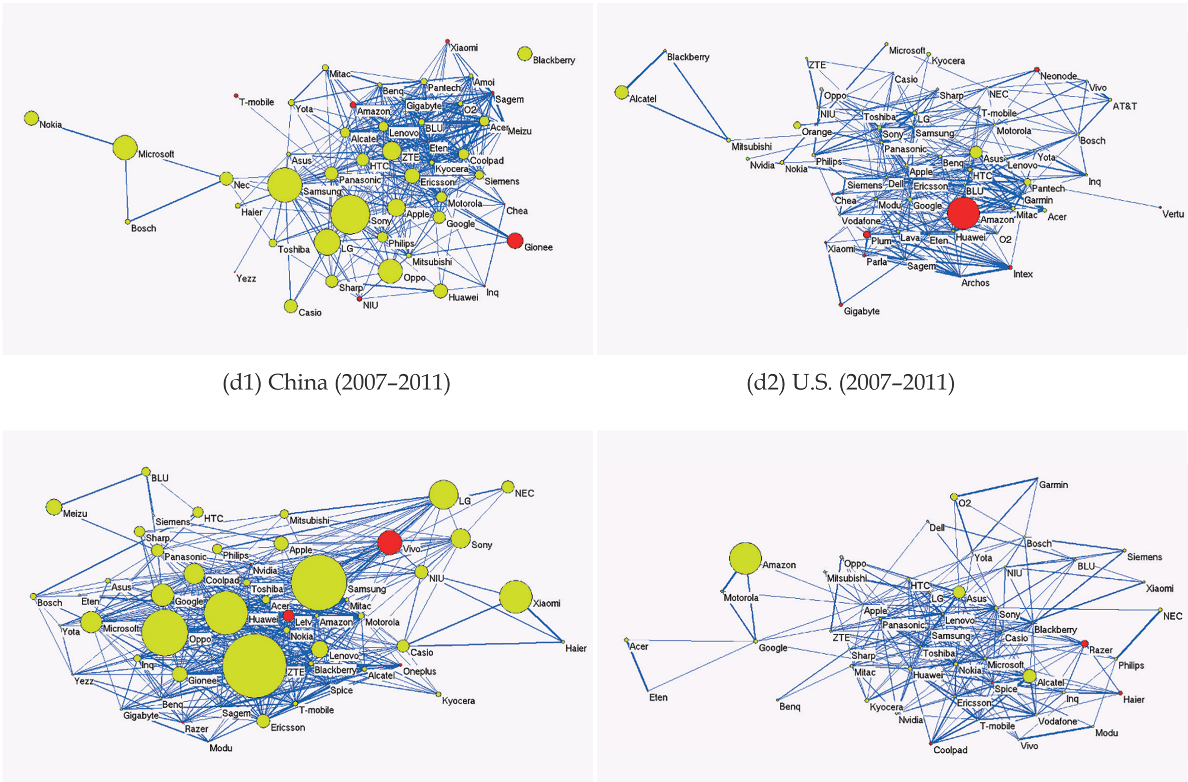
(b2) U.S. (1997–2001)



(c1) China (2002–2006)



(c2) U.S. (2002–2006)



(d1) China (2007–2011) (d2) U.S. (2007–2011)

(e1) China (2012–2016) (e2) U.S. (2012–2016)

Fig. 1. Technological competition network in China and the U.S.

Note: Only the edges corresponding to the highest 15% competitive intensity are presented.
The green vertices are the firms that already existed in last stage and the red ones are the firms that joined the network in this stage.

3.2.2. The market competition network and competitive intensity

We employ mobile phone vendors' popularity × price data during 2002–2006 to formulate the market competition network. The competitive intensity, which determines an edge's thickness in the competition network, is measured by the following arccosine function:

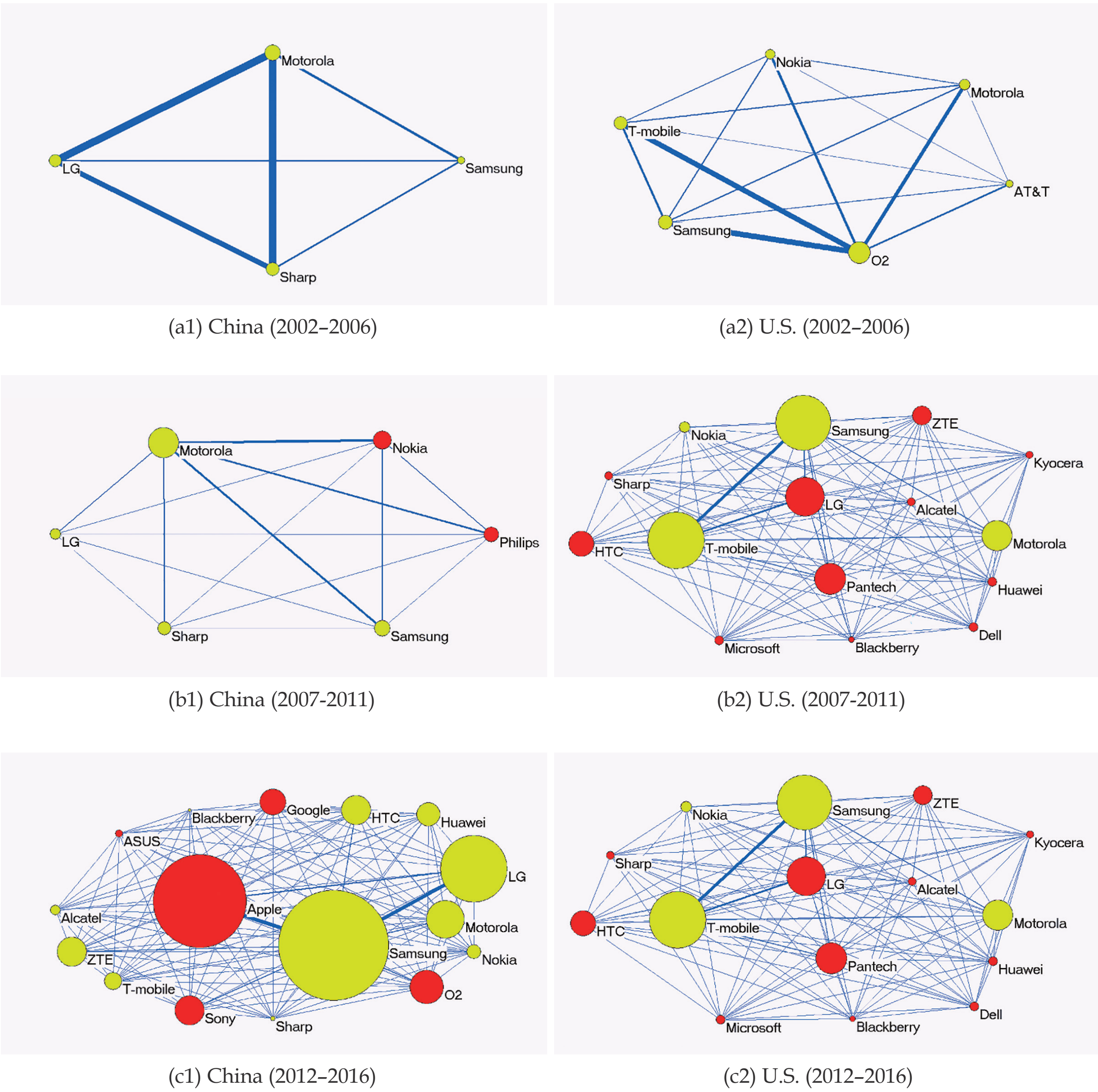
$$Poprice\_cint_{ij,k}=\pi/2\text{-}arccos(Poprice\_ratio_{i,k}*Poprice\_ratio_{j,k}),$$

where $Poprice\_ratio_{i,k}=Poprice_{i,k}/\ \Sigma_{s=1}^{nk} Poprice_{s,k}$ and n_k is the number of mobile phone vendors that run businesses in country k. $Poprice\_ratio_{i,k}$ is an alternative variable of i's market share. Obviously, $Poprice\_cint_{ij,k}$ will take a high (low) value if the market shares of mobile phone vendors i and j in country k are both high (low) and a medium value if one mobile phone vendor's market share in country k is high and the other is low. This measurement corresponds to the fact that the business activities of large mobile phone vendors, such as Apple and Samsung, usually attract more attention from consumers. However, for small mobile phone vendors whose market shares are relatively low, their business activities are usually ignored by consumers. We also use the logarithm of competitive intensity (In$Poprice_cint_{ij,k}$) in the following empirical analysis. Similarly, we introduce In$Hitprice_cint_{ij,k}$, that is, the logarithm of hit × price, as an alternative variable to measure competitive intensity. The variables are also calculated based on five-year moving windows.

We formulate market competition network based on $Poprice\_cint_{ij,k}$ and $Poprice_{i,k}$, which determine the thickness of the edges and size of the vertices, respectively. Since there are fewer mobile phone vendors in the market competition network than those in technological competition network, Figure 2 presents all edges of the former. Figure 2 shows trends similar to Figure 1, such as the increasing number of firms and increasingly monopolistic competition. However, it seems difficult for a firm to finally become a mobile phone vendor, even if it has previously applied for a large number of patents.

To investigate how the overall effect of i's ego-network impacts its market performance, we also introduce In$Sum_poprice_cint_{i,k}$ and In$Sum_hitprice_cint_{i,k}$, which are the logarithms of the sum of market competitive intensity that i encounters.

The calculations of competitive intensity are all based on annual data from t-4 to t.



(a1) China (2002–2006) (a2) U.S. (2002–2006)

(b1) China (2007-2011) (b2) U.S. (2007-2011)

(c1) China (2012–2016) (c2) U.S. (2012–2016)

Fig. 2. Market competition network in China and the U.S.

Note: All edges corresponding to any competitive intensity levels are presented.

3.3. The competitiveness of competitors

Since several competitors may impact a focal firm's technological and market performance through the competition network, we measure the competitiveness of all *i*'s competitors using the following variables.

In$No_tech_compet_{i,k}$ is the logarithm of the number of firms that compete against *i* in patenting. Firms may face more intensive competition if there are more competitors. This variable includes only the main competitors of *i*. We set a threshold[2] for *i*'s competitors, leaving only those ranked above the threshold being considered. Similarly, we introduce In$No_market_compet_{i,k}$ to represent the logarithm of the number of market competitors of *i*.

In$Pat_compet_{ij,k}$ is the logarithm of the number of patents that *i*'s competitor *j* filed, which may use the patentable technologies of *i*. We also introduce In$Poprice_compet_{ij,k}$ and In$Hitprice_compet_{ij,k}$ to measure the market performance achieved by *i*'s competitor *j*.

Then, we sum up In$Pat_compet_{ij,k}$, In$Poprice_compet_{ij,k}$, and In$Hitprice_compet_{ij,k}$, respectively, and acquire ,In$Sum_pat_compet_{i,k}$ In$Sum_poprice_compet_{i,k}$, and In$Sum_Hitprice_compet_{i,k}$ to measure the summed technological and market performance of *i*'s competitors whose competitive intensity with *i* ranks in the top 25% of all *i*'s competitors.

The above variables are also based on five-year moving windows that cover the years from *t*-4 to *t*, lagging our independent variables by one year. As our dependent and independent variables do not overlap in time, we could preclude endogeneity when running the regression to a certain extent.

3.4. Control variables

We control for a number of variables that might affect our estimates of interest as follows.

InPat_premob_i is the logarithm of the number of patents that *i* filed before it entered the mobile phone industry, which will be introduced into the regression model when analyzing technological competition.

$Entry\_year_i$ is the year when *i* officially entered the mobile phone industry. This variable is measured as the application year of the first mobile phone patent by *i* when we analyze technological competition and as the issuing year of the first mobile phone model by *i* when we analyze market competition.

$Establish\_year_i$ is the year when *i* was established.

$OECD_i$ is a dummy variable that takes 1 if *i*'s home country is a member of the Organisation for Economic Co-operation and Development (OECD), and 0 otherwise.

The summary statistics of the variables are presented in Table 1.

3.5. The regression model

After classifying the data into country cohorts, the competitive intensity in different countries may generate impacts of different magnitudes, for example, operating in the U.S., which has the highest global gross domestic product (GDP), may have greater impact on technological and market performance than in South Korea. Accordingly, we take countries' patent counts in the mobile phone industry as a weight when empirically analyzing technological competition and countries' GDP when analyzing market competition. We employ the weighted least squares (WLS) regression model in the following empirical analysis and assign the countries with more mobile phone patents and higher GDPs higher weights.

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[2] The thresholds are set as 25% and 50%. We also use other thresholds (*e.g.*, 15%, 20%, 30% …), which did not yield essentially different empirical results.

Table 1
Summary statistics and correlation matrix of variables.

Variable	Mean	Std. dev.	Min	Max	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Technological competition														
1. In$Pat_{i,k,t+1}$	2.07	1.68	0	7.96										
2. In$Pat_{i,k}$	3.72	1.97	0	9.81	0.80									
3. In$Pat_{j,k}$[a]	3.61	1.65	0.69	9.11	0.50	0.60								
4. In$No_tech_compet_{i,k}$	1.66	0.93	0	3.69	0.33	0.37	-[b]							
5. In$Sum_pat_compet_{i,k}$	6.56	2.23	0	10.95	0.14	0.62	-[b]	0.73						
6. In$Sum_tech_cint_{i,k}$	1.48	0.66	0.29	3.21	0.27	0.28	-[b]	0.96	0.65					
7. In$Tech_cint_{ij,k}$[a]	0.21	0.17	2.01e-5	0.94	0.50	0.13	0.21	-[b]	-[b]	-[b]				
8. $OECD_i$	0.79	0.40	0	1	0.11	0.16	0.04	-0.14	-0.16	-0.15	-0.05			
9. $Establish\_year_i$	1945.18	51.20	1847	2013	-0.12	-0.18	-0.02	0.11	0.17	0.12	-0.02	-0.46		
10. $Entry\_year_i$	2001.21	8.03	1983	2017	-0.13	-0.19	-0.01	0.13	0.19	0.14	-0.05	-0.34	0.72	
11. InPat_premob_i	7.86	2.83	0	12.38	0.21	0.22	0.10	-0.06	-0.06	-0.07	0.005	-0.46	-0.51	-0.15
Market competition														
1. In$Poprice_{i,k,t+1}$	2.73	1.99	0.06	7.78										
2. In$Poprice_{i,k}$	2.73	1.61	0.08	7.92	0.68									
3. In$Poprice_{j,k}$[a]	2.70	1.37	0.06	6.87	0.50	0.66								
4. In$No_market_compet_{i,k}$	0.81	0.68	0	2.83	0.22	0.52	-[b]							
5. In$Sum_poprice_compet_{i,k}$	4.28	1.78	0.11	8.51	0.12	0.17	-[b]	-0.07						
6. In$Sum_poprice_cint_{i,k}$	0.0003	.001	5.89e-6	0.01	-0.08	-0.07	-[b]	-0.26	0.40					
7. In$Poprice_cint_{ij,k}$[a]	1.22e-5	3.53e-5	1.04e-10	0.0004	-0.19	-0.22	-0.06	-[b]	-[b]	-[b]				
8. $OECD_i$	0.83	0.38	0	1	0.03	0.02	-0.05	-0.21	0.27	0.10	0.16			
9. $Establish\_year_i$	1947.85	39.39	1847	2012	0.04	0.14	-0.03	0.18	-0.22	-0.10	-0.12	-0.38		
10. $Entry\_year_i$	1997.84	4.70	1999	2019	0.37	0.49	0.03	0.40	-0.43	-0.43	-0.16	-0.16	0.31	
Market competition														
1. In$Hitprice_{i,k,t+1}$	20.84	2.28	12.54	25.38										
2. In$Hitprice_{i,k}$	20.67	2.31	15.75	26.51	0.70									
3. In$Hitprice_{j,k}$[a]	19.98	1.90	15.52	25.85	0.41	0.69								
4. In$No_market_compet_{i,k}$	0.82	0.66	0	2.83	0.41	0.66	-[b]							
5. In$Sum_hitprice_compet_{i,k}$	22.49	2.47	15.92	27.57	-0.09	0.02	-[b]	-0.25						
6. In$Sum_hitprice_cint_{i,k}$	0.0003	.001	3.75e-6	0.01	-0.19	-0.09	-[b]	-0.31	0.37					
7. In$Hitprice__cint_{ij,k}$[a]	1.30e-5	4.41e-5	8.34e-12	0.001	-0.20	-0.21	-0.07	-[b]	-[b]	-[b]				
8. $OECD_i$	0.83	0.38	0	1	0.07	0.02	-0.10	-0.26	0.29	0.08	0.13			
9. $Establish\_year_i$	1948.11	39.53	1847	2012	-0.04	0.001	0.10	0.15	-0.25	-0.09	-0.17	-0.47		
10. $Entry\_year_i$	1997.52	4.76	1999	2019	0.54	0.71	0.07	0.70	-0.37	-0.33	-0.22	-0.21	0.23	

Note: [a] *i* is the leader and *j* is the follower in the competition relationship between them.
[b] The correlation coefficient is unavailable because the two variables do not appear in the common dataset.
[c] We provide only the summary statistics of the observations whose competitive intensity ranks at the top 25% of all observations.

4. Empirical Results

Table 2 employs the regression models that empirically test the effects of the technological competition network. Each observation is processed based on the summed value of a focal firm's competitors whose competitive intensity ranks at the top 25% and 50% of all competitors of that focal firm. The dependent variable is firm *i*'s technological performance (In$Pat_{i,k,t+1}$). We introduce two key independent variables, In$No_tech_compet_{i,k}$ and In$Sum_pat_compet_{i,k}$, to represent the impact of competitors on the focal firm's technological performance (In$Pat_{i,k,t+1}$). As shown in Models 2 and 5, both In$No_tech_compet_{i,k}$ and In$Sum_pat_compet_{i,k}$ significantly increase In$Pat_{i,k,t+1}$, which indicates the positive roles of the number of competitors and their summed technological performance on focal firms' technological performance. However, these impacts are transmitted through the competition network to a large extent, because the parameter estimates of interaction terms In$Sum_tech_cint_{i,k}$×In$No_tech_compet_{i,k}$ and In$Sum_tech_cint_{i,k}$×In$Sum_pat_compet_{i,k}$ are significantly positive in Models 3 and 6. The key role of competitive intensity is also confirmed by reducing the absolute value of the parameter estimates for In$No_tech_compet_{i,k}$ (from 0.1194 in Model 2 to 0.0641 in Model 3, and from 0.1719 in Model 5 to 0.0794 in Model 6) and In$Sum_pat_compet_{i,k}$ (from 0.0963 in Model 2 to 0.0614 in Model 3, and from 0.1216 in Model 5 to 0.0233 in Model 6) after introducing the interaction terms. This suggests that the large impact of competitors on

Table 2
Regression analysis of the mediating effect of technological competitive intensity in firms' ego-networks.

	Model 1 (25%)	Model 2 (25%)	Model 3 (25%)	Model 4 (50%)	Model 5 (50%)	Model 6 (50%)
Dependent variable	In$Pat_{i,k,t+1}$	In$Pat_{i,k,t+1}$	In$Pat_{i,k,t+1}$	In$Pat_{i,k,t+1}$	In$Pat_{i,k,t+1}$	In$Pat_{i,k,t+1}$
Constant	58.2064 (0.0915)	26.5343 (0.0924)	25.2730 (0.0927)	58.1928 (0.0913)	9.6621 (0.0954)	-2.0097 (0.0954)
t	Yes	Yes	Yes	Yes	Yes	Yes
Country	Yes	Yes	Yes	Yes	Yes	Yes
Firm	Yes	Yes	Yes	Yes	Yes	Yes
$OECD_i$	-1.8376 (0.0016)	-1.8786 (0.0016)	-1.8637 (0.0016)	-1.8130 (0.0016)	-1.6561 (0.0016)	-1.7067 (0.0016)
$Establish\_year_i$	-0.0023 (0.00001)	-0.0029 (0.00001)	-0.0026 (0.00001)	-0.0022 (0.00001)	-0.0019 (0.00001)	-0.0017 (0.00001)
$Entry\_year_i$	0.0098 (0.0001)	0.0122 (0.0001)	0.0109 (0.0001)	0.0097 (0.0001)	0.0143 (0.0001)	0.0113 (0.0001)
InPat_premob_i	-0.0189 (0.0001)	-0.0207 (0.0001)	-0.0148 (0.0001)	-0.0191 (0.0001)	-0.0298 (0.0001)	-0.0202 (0.0001)
In$Pat_{i,k}$	0.7132 (0.00003)	0.7402 (0.00003)	0.7398 (0.00004)	0.7162 (0.00003)	0.7206 (0.00003)	0.7102 (0.00003)
In$No_tech_compet_{i,k}$		0.1194 (0.0001)	0.0641 (0.0001)		0.1719 (0.00008)	0.0794 (0.0002)
In$Sum_pat_compet_{i,k}$		0.0963 (0.0001)	0.0614 (0.0001)		0.1216 (0.0001)	0.0233 (0.0001)
In$Sum_tech_cint_{i,k}$ × In$No_tech_compet_{i,k}$			0.0819 (0.0001)			0.1925 (0.0001)
In$Sum_tech_cint_{i,k}$ × In$Sum_pat_compet_{i,k}$			0.0306 (0.00004)			0.0851 (0.00004)
R^2	0.7761	0.7779	0.7782	0.7759	0.7779	0.7792
F	99,999.00	99,999.00	99,999.00	99,999.00	99,999.00	99,999.00
Prob > F	0.00	0.00	0.00	0.00	0.00	0.00
No. of obs.	7,189	7,189	7,189	7,695	7,695	7,695

Note: The parameter estimates are all significant at the 1% level.

the focal firm's technological performance is transmitted through the competitive intensity between them. The greater the competitive intensity is, the higher is the impact that competitors would have on the focal firm through their competitive relationship. H1 is thus supported. However, since the above mediating effects are significantly positive, Table 2 provides evidence against H2.

We run a similar regression analysis for the cases of market competition and take In$Poprice_{i,k,t+1}$ and In$Hitprice_{i,k,t+1}$ as the dependent variables. As shown in Table 3, the parameter estimates of interaction terms In$Sum_poprice_cint_{i,k}$×In$No_market_compet_{i,k}$, In$Sum_poprice_cint_{i,k}$×In$Sum_poprice_compet_{i,k}$, and In$Sum_hitprice_cstren_{i,k}$×In$Sum_hitprice_compet_{i,k}$, which represent the mediating effects of market competitive intensity, are all significantly negative (see Models 3 and 6). The absolute values of the parameter estimates of In$No_market_compet_{i,k}$, In$Sum_poprice_compet_{i,k}$, and In$Sum_hitprice_compet_{i,k}$ are all significantly reduced after introducing their corresponding interaction terms into the regression model. This confirms the significant mediating effect of market competitive intensity. Therefore, the case of market competition supports H1 as well. As market competition network generates a negative mediating effect, it also provides evidence for H2.

Table 3
Regression analysis of the mediating effect of market competitive intensity in firms' ego-networks.

	Model 1 (25%)	**Model 2 (25%)**	**Model 3 (25%)**	**Model 4 (50%)**	**Model 5 (50%)**	**Model 6 (50%)**
Dependent variable	In$Poprice_{i,k,t+1}$	In$Poprice_{i,k,t+1}$	In$Poprice_{i,k,t+1}$	In$Hitprice_{i,k,t+1}$	In$Hitprice_{i,k,t+1}$	In$Hitprice_{i,k,t+1}$
Constant	123.0887 (0.00001)	181.5919 (0.00001)	158.3421 (0.00001)	340.1005 (0.0003)	1020.135 (0.0003)	753.5327 (0.0003)
t	Yes	Yes	Yes	Yes	Yes	Yes
Country	Yes	Yes	Yes	Yes	Yes	Yes
Firm	Yes	Yes	Yes	Yes	Yes	Yes
$OECD_i$	-1.4117 (6.62e-07)	-1.2101 (6.59e-07)	-1.9764 (6.56e-07)	-1.8386 (2.89e-06)	-4.1311 (2.75e-06)	-3.2854 (2.66e-06)
$Establish\_year_i$	-0.0088 (2.47e-09)	-0.0082 (2.46e-09)	-0.0086 (2.43e-09)	-0.0156 (1.53e-08)	-0.0277 (1.46e-08)	-0.0212 (1.41e-08)
$Entry\_year_i$	-0.0147 (6.92e-09)	-0.0117 (5.78e-09)	-0.0194 (5.74e-09)	-0.1127 (1.22e-07)	-0.1622 (1.16e-07)	-0.1270 (1.13e-07)
In$Poprice_{i,k}$	0.5969 (1.30e-08)	0.5774 (1.41e-08)	0.6135 (1.41e-08)			
In$Hitprice_{i,k}$				0.4758 (9.73e-09)	0.4975 (1.26e-08)	0.6462 (1.29e-08)
In$No_market_compet_{i,k}$		-0.2137 (1.81e-08)	-0.0055 (2.10e-08)		-0.4039 (1.92e-08)	-0.4607 (1.86e-08)
In$Sum_poprice_compet_{i,k}$		0.2000 (1.82e-08)	0.0680 (1.95e-08)			
In$Sum_hitprice_compet_{i,k}$					0.8732 (1.63e-08)	0.4035 (1.91e-08)
In$Sum_poprice_cint_{i,k}$ × In$No_market_compet_{i,k}$			-226.1927 (0.0001)			-49.0604 (0.0001)
In$Sum_poprice_cint_{i,k}$ × In$Sum_poprice_compet_{i,k}$			-1.6521 (0.00002)			
In$Sum_hitprice_cint_{i,k}$ × In$Sum_hitrice_compet_{i,k}$						-38.9639 (6.01e-06)
R2	0.5285	0.5338	0.5442	0.6124	0.6497	0.6716
F	99,999.00	99,999.00	99,999.00	99,999.00	99,999.00	99,999.00
Prob > F	0.00	0.00	0.00	0.00	0.00	0.00
No. of obs.	5,406	5,406	5,406	6,976	6,976	6,976

Note: The parameter estimates are all significant at the 1% level.

To test H3, we investigate how a pair of firms interact through their competitive relationship. We take each edge that corresponds to a competitive relationship in Figures 1 and 2 as an observation. For each edge that connects a pair of firms, we classify the firm whose performance is in the leading (following) position into the leader (follower) cohort. Then, we calculate the differences in performance between the pairs of leaders and followers, and use these differences as the dependent variables. These differences increase or decrease if the competitive intensity generates an asymmetric mediating effect and remain constant if a symmetric mediating effect is generated. We compare the magnitude of the impact of the leader's and follower's performances on this difference in their competitive relationship.

Table 4 presents the regression results. Model 1 analyzes the case of technological competition and shows the parameter estimate of the leader's interaction, while the parameter estimate of the follower's $\text{In}Tech\_cint_{ij,k}\times\text{In}Pat_{j,k}$ is -1.4229. If the mediating effect generated by competitive intensity is symmetric, the sum of the above two parameter estimates should be zero and the performance difference remains constant after controlling for other impact factors. From Table 5, we conduct an F-test of the above null hypothesis, which is rejected at the 1% significance level. Therefore, competitive intensity generates a greater positive role in mediating the impact of the leader's technological performance on the performance difference, which will increase accordingly. Therefore, the case of technological competition provides evidence for H3.

Model 2 investigates the case of market competition using the same analytical principle as that in Model 1. Although the absolute value of the parameter estimate of $\text{In}Poprice\_cint_{ij,k}\times\text{In}Poprice_{i,k}$ is greater than that of $\text{In}Poprice\_cint_{ij,k}\times\text{In}Poprice_{j,k}$, we do not reject the null hypothesis at the 5% significance level, but reject it at the 10% level. The F-test in Table 5 does not reject the null hypothesis that the sum of the parameter estimates of $\text{In}Hitprice\_cint_{ij,k}\times\text{In}Hitprice_{i,k}$ and $\text{In}Hitprice\_cint_{ij,k}\times\text{In}Hitprice_{j,k}$, which are given by Model 3, are zero even at the 10% significance level. Accordingly, the case of market competition does not provide evidence for H3.

5. Robustness Checks

To test the robustness of our empirical results, we employ an alternative model setting and data processing. We first take the performance of the leader as the dependent variable and investigate how the follower's performance affects that of the leader through their competitive relationship. Then, we switch between the leader and follower and re-run the regression. As Models 1 and 2 in Table 6 show, the parameter estimates of $\text{In}Tech\_cint_{ij,k}\times\text{In}Pat_{i,k}$ and $\text{In}Tech\_cint_{ij,k}\times\text{In}Pat_{j,k}$ are both significantly positive, suggesting that technological competitive intensity generates significantly positive mediating effects on leaders' and followers' technological performance. These results correspond with Table 2.

The parameter estimates of $\text{In}Poprice\_cint_{ij,k}\times\text{In}Poprice_{j,k}$, $\text{In}Poprice\_cint_{ij,k}\times\text{In}Poprice_{i,k}$, and $\text{In}Hitprice\_cint_{ij,k}\times\text{In}Hitprice_{i,k}$ in Models 3, 4, and 6 are all significantly negative, suggesting a negative mediating effect of market competitive intensity on leaders' and followers' market performance. Therefore, Models 3, 4, and 6 present results that are in line with Table 3. Although Model 5 presents essentially opposite results, where the parameter estimate of $\text{In}Hitprice\_cint_{ij,k}\times\text{In}Hitprice_{j,k}$ is significantly positive, its absolute value in Model 5 is only 1.6746, which is much lower than that of $\text{In}Hitprice\_cint_{ij,k}\times\text{In}Hitprice_{i,k}$ in Model 6 (-330.4845), suggesting this positive mediating effect is ignorable. Therefore, the empirical results in Tables 3 and 6 match to a large extent.

The absolute value of the parameter estimates of $\text{In}Tech\_cint_{ij,k}\times\text{In}Pat_{j,k}$ (0.0093 in Model 1) is much

Table 4
Regression analysis of the asymmetric mediating effect of competitive intensity on the impact between leaders' and followers' performances.

	Technological competition	Market competition	
	Model 1	**Model 2**	**Model 3**
Dependent variable	$\text{In}Pat_{i,k,t+1}-\text{In}Pat_{j,k,t+1}$	$\text{In}Poprice_{i,k,t+1}-\text{In}Poprice_{j,k,t+1}$	$\text{In}Hitprice_{i,k,t+1}-\text{In}Hitprice_{j,k,t+1}$
Constant	-54.0422 (0.1875)	-100.6536 (4.47e-06)	-103.5295 (0.00002)
t	Yes	Yes	Yes
Country	Yes	Yes	Yes
Firm	Yes	Yes	Yes
Impact of the leader			
$OECD_i$	-0.0198 (0.0001)	0.2145 (7.29e-09)	-0.0323 (1.12e-08)
$Establish\_year_i$	0.0058 (8.69e-07)	0.0032 (1.01e-10)	0.0110 (1.54e-10)
$Entry\_year_i$	-0.0321 (4.44e-06)	-0.0254 (4.93e-10)	-0.1082 (7.16e-10)
$\text{In}Pat\_premob_i$	0.1264 (9.93e-06)		
$\text{In}Tech\_cint_{ij,k} \times \text{In}Pat_{i,k}$	1.4554 (0.0001)		
$\text{In}Poprice\_cint_{ij,k} \times \text{In}Poprice_{i,k}$		14,953.34 (0.0003)	
$\text{In}Hitprice\_cint_{ij,k} \times \text{In}Hitprice_{i,k}$			10,364.96 (0.0002)
Impact of the follower			
$OECD_j$	0.5420 (0.0008)	0.0772 (6.72e-08)	-1.3882 (3.91e-07)
$Establish\_year_j$	0.0078 (8.76e-06)	0.0083 (1.48e-09)	-0.0035 (3.81e-09)
$Entry\_year_j$	-0.0445 (0.0001)	-0.0004 (3.17e-09)	-0.0848 (9.01e-09)
$\text{In}Pat\_premob_j$	0.1453 (0.0001)		
$\text{In}Tech\_cint_{ij,k} \times \text{In}Pat_{j,k}$	-1.4229 (0.0001)		
$\text{In}Poprice\_cint_{ij,k} \times \text{In}Poprice_{j,k}$		-14,253.46 (0.0003)	
$\text{In}Hitprice\_cint_{ij,k} \times \text{In}Hitprice_{j,k}$			-10,055.05 (0.0002)
R^2	0.4063	0.0910	0.2646
F	99,999.00	99,999.00	99,999.00
Prob > F	0.00	0.00	0.00
No. of obs.	26,711	4,841	4,804

Note: *i* acts as the leader and *j* as the follower in the competition relationship between them.

Table 5
Testing the asymmetric mediating effect suggested in Table 4.

Variable	Parameter estimate	Null hypothesis	F-statistics	Prob>F	Reject null hypothesis
In*Tech_cint*$_{ij,k}$× In*Pat*$_{i,k}$	β_0=1.4554	$\beta_0+\beta_1=0$	13.4457***	2.46e-4	Yes
In*Tech_cint*$_{ij,k}$× In*Pat*$_{j,k}$	β_1=-1.4229				
In*Poprice_cint*$_{ij,k}$× In*Poprice*$_{i,k}$	β_0=14,953.34	$\beta_0+\beta_1=0$	3.1432*	0.0763	Yes
In*Poprice_cint*$_{ij,k}$× In*Poprice*$_{j,k}$	β_1=-14,253.46				
In*Hitprice_cint*$_{ij,k}$× In*Hitprice*$_{i,k}$	β_0=10,364.96	$\beta_0+\beta_1=0$	0.6423	0.4229	No
In*Hitprice_cint*$_{ij,k}$× In*Hitprice*$_{j,k}$	β_1=-10,055.05				

Note: *** and * denote that the values of the F-statistics are significant at the 1% and 10% levels, respectively.

lower than that of In$Tech_cint_{ij,k}$×In$Pat_{i,k}$ (0.0359 in Model 2), suggesting that competitive intensity generates a greater effect in mediating the impact of the leader's technological performance on that of the follower. This would reduce the difference between the leader and the follower, which appears to conflict with the results in Table 4. However, the greater parameter estimate of In$Pat_{i,k}$ (0.8837 in Model 1) compared with that of In$Pat_{j,k}$ (0.6534 in Model 2) suggests that the equal increases of In$Pat_{i,k}$ and In$Pat_{j,k}$ would enlarge the difference between In$Pat_{i,k,t+1}$ and In$Pat_{j,k,t+1}$, which offsets the reduction of the performance difference caused by interaction terms In$Tech_cint_{ij,k}$×In$Pat_{j,k}$ and In$Tech_cint_{ij,k}$×In$Pat_{i,k}$. Models 3, 4, 5 and 6 exhibit the same trend as Models 1 and 2. Therefore, the empirical results in Table 6 do not conflict with the results in Table 4.

6. Discussion

6.1. Determinants of the mediating effect of technological and market competition networks

As the results show, the competitive intensity embedded in a competition network plays a significant mediating role for competition. However, the effects of competitive intensity are different. Some effects are even opposite, especially when mediating the influence of firm performance, suggesting that the competitive context determines the role of competition network. Our study summarizes the role of competition network in two competitive contexts, that is, the technological competition and market competition.

Firms' competitive strategies may be different in these two competitive contexts. In the context of the former, the firms' aim may be to gain advantage in design and exploration of new technologies against their competitors, which requires that the firms have to timely focus on cutting-edge technologies and recruit first-rate scientists (Aghion *et al.*, 2005; Acemoglu and Akcigit, 2012; Galvin *et al.*, 2020). While the latter requires that firms attempting to win more market share may have to increase the popularity of their products (Dobrev, 2007; Adegbesan, 2009; Czakon and Czernek-Marszałek, 2021). Therefore, to adapt to different competitive contexts, firms may need to take different competitive strategies, leading to different functioning of the competition networks. Technological competitive intensity seems to result in a beneficial interaction with technological performance, while market competitive intensity seems to lead to a win-or-lose result. This may be because consumers' income and the market size usually remain constant in the short term, leading to the fact that an increase in one competitor's market share reduces another competitor's market share. Therefore, the mediating effect of market competitive intensity is negative. By comparison, the scale of technology is not constant because the overall increase of the patent count in a technological field can either be high or low in the short term. When a firm predicts that a technological

Table 6
Regression analysis of the mediating effect of competitive intensity on the impact between the leaders' and followers' performances.

	Technological competition		Market competition			
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
Dependent variable	In$Pat_{i,k,t+1}$	In$Pat_{j,k,t+1}$	In$Poprice_{i,k,t+1}$	In$Poprice_{j,k,t+1}$	In$Hitprice_{i,k,t+1}$	In$Hitprice_{i,k,t+1}$
Constant	123.3206 (0.0334)	81.0603 (83.0668)	122.4508 (3.68e-06)	140.1399 (4.45e-06)	-49.1767 (0.00003)	233.724 (0.00003)
t	Yes	Yes	Yes	Yes	Yes	Yes
Country	Yes	Yes	Yes	Yes	Yes	Yes
Firm	Yes	Yes	Yes	Yes	Yes	Yes
Impact of the leader						
$OECD_i$	-1.0770 (0.0026)		1.7103 (9.73e-08)		12.4074 (3.27e-07)	
$Establish\_year_i$	-0.0097 (5.86e-06)		0.0078 (1.25e-09)		-0.0577 (9.45e-09)	
$Entry\_year_i$	0.0224 (0.00002)		0.0007 (2.66e-09)		0.0863 (1.99e-08)	
InPat_premob_i	-0.0583 (0.0004)					
In$Pat_{i,k}$	0.8837 (0.00001)					
In$Poprice_{i,k}$			0.4928 (3.19e-09)			
In$Hitprice_{i,k}$					0.6762 (1.02e-08)	
In$Tech_cint_{ij,k}$ × In$Pat_{i,k}$		0.0359 (0.00001)				
In$Poprice_cint_{ij,k}$ × In$Poprice_{i,k}$				-777.5645 (0.00004)		
In$Hitprice_cint_{ij,k}$ × In$Hitprice_{i,k}$						-330.4845 (0.00002)
Impact of the follower						
$OECD_j$		0.6813 (0.0004)		0.3218 (5.49e-08)		-5.5958 (4.83e-07)
$Establish\_year_j$		-0.0047 (3.40e-06)		-0.0035 (7.19e-10)		-0.1248 (4.68e-09)
$Entry\_year_j$		0.0184 (8.03e-06)		-0.0050 (2.17e-09)		0.0215 (1.20e-08)
InPat_premob_j		-0.0542 (0.0001)				
In$Pat_{j,k}$		0.6534 (0.00001)				
In$Poprice_{j,k}$				0.3614 (2.45e-09)		
In$Hitprice_{j,k}$						0.6573 (8.81e-09)
In$Tech_cint_{ij,k}$ × In$Pat_{j,k}$	0.0093 (0.00001)					
In$Poprice_cint_{ij,k}$ × In$Poprice_{j,k}$			-1,548.422 (0.00004)			
In$Hitprice_cint_{ij,k}$ × In$Hitprice_{j,k}$					1.6746 (0.00002)	
R^2	0.8272	0.7588	0.6670	0.6315	0.4917	0.5893
F	99,999.00	99,999.00	99,999.00	99,999.00	99,999.00	99,999.00
Prob > F	0.00	0.00	0.00	0.00	0.00	0.00
No. of obs.	27,587	27,587	5,338	5,509	5,338	5,509

Note: *i* acts as the leader and *j* as the follower in the competition relationship between them.

field has potential, it is more likely to temporally increase patent applications, which will lead to its competitors following and, thus, creating a positive mediating role for technological competitive intensity. Accordingly, the competition context determines how competition network functions on the firms' performance, and leads to different mediating effect of the technological and market competition networks.

Technological certainty and market uncertainty may be another reflection of competition contexts differences, and thus lead to different functioning of the competition network. Although technology appears to be infinite and the market limited, we find that competitive intensity provides a better explanation for technological competition in our empirical results, which provide evidence for the technological certainty. As shown in Table 2, the R^2s of the regressions are all above 0.77, while the R^2s in Table 3 are between 0.52 and 0.67. Therefore, compared with technological performance, a firm's market performance is more unpredictable, as it may be affected by more interference factors and is more uncertain. This also explains why Nokia's mobile phone business suddenly failed in the 2010s, while its long-standing accumulation of mobile-related technologies continues to affect the market. Furthermore, the unexpected collapse of Kodak's camera business did not prevent the lasting prosperity of its imaging techniques. Accordingly, if we differentiate the technology from the market, we will see essentially different effects generated by the technology and market competition networks with different extent of certainties.

6.2. Decomposition of the asymmetric network effect

Since most existing studies, such as Skilton and Bernardes (2015) and Zhang and Guan (2019), have focused on the impact of the structure of competition network on firm performance, namely its holistic effect, we go a step further by decomposing this effect. We discover the asymmetric mediating effect generated by the technological competition network, which is an important contribution to the existing theory on competition networks. By decomposing the competition network and studying the one-to-one competitive relationship between leaders and followers, we find evidence for the existence of an asymmetric mediating effect generated by the technological competition network, which is greater on the performance of the leader than on that of the follower. This may be a key factor that enlarges the technological performance gap between a leader and its follower, and verifies the existence of a trickle-down effect that awards more benefits to the leader. In comparison, the market competition network plays a symmetric mediating effect, which contributes equally to the market performances of the leader and follower.

The above conclusions partially correspond with the results in studies by Arthur (1993), Shankar and Bayus (2003), who investigated the effect of Stackelberg leader-follower structure in the competition context that mixes the technological and market competitions. They found that once a particular product technology gains a small lead over other competing technologies in terms of wining the number of customers, it is more likely that the technology used by more customers will finally govern the industry. Thus, even if there is an inferior product with a lead in attracting more customers, it will ultimately win out over a superior product. But obviously, the above literature did not tell us whether the customers' choices are determined either by the technology or by the product. We go a step further by discovering that it is the former that plays a key role in bringing the win-or-lose results to the leader and follower. This finding may have generality by accounting for the technology heterogeneity, since Shankar and Bayus (2003) focused on the video game industry, where the occurrence of technology revolution is very frequent, while we investigate the mobile phone industry, where a generation of technology tends to govern for relatively a longer period of time[3].

Unlike existing studies (*e.g.*, Bengtsson and Kock, 1999; Skilton and Bernardes, 2015; Zhang and Guan, 2019) that focused on the direct effect of the competition network, we pay more attention to the mediating effect of competitive intensity, which were mostly ignored by existing literatures. Since the network does not produce knowledge and information, but usually acts as the conduit of them, it is more likely to play a mediating role. Our empirical results show that the mutual influence between competitors is mostly transmitted by their competitive relationship, which provides evidence for the existence of the mediating effect. This can be seen by comparing the parameter estimates in Tables 2 and 3. From Table 2, after introducing interaction term $\text{In}Sum\_tech\_cint_{i,k}\text{In}No\_tech\_compet_{i,k}$, the parameter estimate of $\text{In}No\_tech\_compet_{i,k}$, which represents the direct effect of the competitor on the focal firm, reduces from 0.1719 in Model 5 to 0.0794 in Model 6. Other parameter estimates that represent the direct effects on the focal firm also significantly reduce after accounting for their interactions with competitive intensity. Therefore, our study provides evidence for the mediating role of competitive intensity, suggesting that when investigating the impact between competitors, the characteristics of their competitive relationship (*e.g.*, competitive intensity) should firstly be accounted for.

7. Conclusions, Implications, and Limitations

7.1. Main findings

This study employs 109 firms' patent data and market sales data from different countries to formulate technological and market competition networks. We examine the role of competitive intensity in mediating these firms' performances. We also introduce indicators to measure the competitive intensity. The results show that both the technological and market competition networks have gone through an evolution process from sparse to dense, that is, from individual firm to several firms that compete. There are essential differences in the mechanisms of technological and market competition networks. Although both networks generate significant mediating effects, they work in opposite directions. Competitive intensity plays a positive role in mediating the impact between competitors' technological performances, while negatively mediate the impact between competitors' market performances. The technological competitive intensity generates an asymmetric mediating effect between the leader and its follower(s), which enlarges the gap between their technological performances, while market competitive intensity generates a symmetric mediating effect.

7.2. Research implications

The theoretical implication is, when investigating the impact of competitive relationships, firms' status should be accounted for. Competition may generate essentially different impacts on the leaders and their followers; however, this point was mostly ignored in existing studies. Since competition usually manifests in multiple aspects, where a bundle of competitors is involved, the social network analysis is an important tool for describing the characteristics of the competition contexts. We pay more attention to the mediating role of competitive intensity and do not consider the impact of competition network structure,

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[3] For example, the launch of Symbian system occurred in 1998, it was almost 10 years later when the iOS was launched. While 14 years have passed since the launch of Android system, which are still widely used by almost all mobile phone vendors except Apple.

which is the focus of the literature, in studies such as those of Skilton and Bernardes (2015) and Zhang and Guan (2019). Because competitive relationship exists between any pair of firms that target the same market, the competition network is mostly cohesive and has a stable structure, making it meaningless to investigate the impact of network structure.

Additionally, our study has an important practical implication: business managers should not always view their competitors as enemies. The relationship between competitors is often one of sharing weal and woe. In most competitive relationships, firms can collect useful information from competitors. When creating a development strategy, firm managers need to account for competitors' behaviors, carefully analyze the significance of their behaviors, and adjust their strategies in a timely manner. Since the competitive intensity embedded in the technological competition network are more likely to lead to a win-or-lose result between firms, the customers' cognitive lock-in about the technology should be additionally noted and delicately utilized. Firms with competing technology standards should attempt to build their installed customer bases as quickly as possible (Hill, 1997).

7.3. Limitations and future researches

This study also has limitations. First of all, since we have only studied the competition network in the mobile phone industry and compared the results with that in the video game industry, the representativeness of the conclusions still needs to be verified by investigating more industries. We account for only the technological and market competition, while firms usually compete against each other in more facets, such as the human resources recruitment, technological standard setting and financial support. Thus, we need to develop additional competition networks by further exploring other characteristics of the competition contexts. Moreover, we should account for the cross-effect of the competition networks. Due to the data limitations, this study does not investigate how technological (market) competition network functions on firms' market (technological) performance. Therefore, it may have missed out the potential cross-effect, which may also be a key effect that should be accounted for. To fill this research gap, future studies should try to correspond the product with the technology that is embedded in it, and study the cross-effect generated by the interaction between technological and market competition networks.

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