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How do latecomer firms achieve catch-up through technology management: a comparative analysis

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The catch-up of latecomer firms has been a topic of interest because it is closely related to the changes in industry leadership. The reason why some countries are more successful in catch-up is because of their increasing mastery of technology management (TM). Therefore, to ensure successful catch-up, it is imperative for latecomer firms to understand the TM practices and TM modes across national boundaries. This paper aims to reveal the differences in TM practices and TM modes between latecomer firms and forerunner firms. This paper collected data from Chinese firms and Korean firms as latecomers and forerunners, respectively, to examine the differences in TM practices and TM modes. The results show that latecomer firms place more emphasis on grasping the condition of firms' equipment, understanding technology talents required by business, and completing files on technology information. While forerunner firms stress learning from other competitors, effective training, and constructing detailed technology information management system most. Furthermore, the relationship between TM and product innovation performance is more integrated for forerunner firms compared to latecomer firms. A key contribution of this paper is to reveal the differences in TM practices and TM modes between latecomer firms and forerunner firms, which enriches the catch-up literature from an international comparative perspective. As such, this paper is of great importance in broadening the understanding of how latecomer firms transform into global leaders.

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Introduction

The rapid catch-up of emerging economies has generated a large amount of research on the mechanism behind this phenomenon. The main focus of the literature has been on the role of government (Alam et al., 2019; Li et al., 2020; Sun and Cao, 2018), and another stream of research has largely focused on innovation (Choung et al., 2014; Gao, 2015; Lee and Malerba, 2017), especially product innovation (Landini et al., 2017; Oh and Joo, 2015). In a broad sense, this stream of literature suggests that product innovation has become critical for latecomer firms to achieve catch-up, as a firm's core competitive advantage has shifted from traditional factors such as labor and capital to product innovation.

Product innovation refers to innovation that creates new markets through the development of new products (Alegre et al., 2006). It has been argued that product innovation is necessary for latecomers, which could itself serve as a cause for catch-up (Fan, 2006). However, it has been argued that product innovation is a resource-intensive activity with high risk (Najafi-Tavani et al., 2018), and its success depends on the technology resources owned by firms (Bakar and Ahmad, 2010). Nevertheless, owning technology resources does not equal achieving product innovation, and firms need to deploy technology resources to make them useful (De Massis et al., 2018). Technology management (TM) is highly related to the use of technology resources, and thus TM plays a crucial role in product innovation (Cetindamar et al., 2009). Based on this assumption, a lot of research has been conducted with the aim of providing deeper insights into the relationship between TM and product innovation, such as TM activities and product innovation (Den Besten et al., 2020; Guglielmi et al., 2010; Kang et al., 2015), TM tools and product innovation (Foden and Berends, 2010; García-Vega and Vicente-Chirivella, 2020; Kurokawa et al., 2005), and TM functions and product innovation (Argote and Hora, 2017; Ma et al., 2022; Pilkington and Teichert, 2006).

In general, the research results show that TM is closely related to product innovation. However, the relationship between TM and product innovation is not as simple as previous research has suggested, as TM practices and TM modes differ significantly in different circumstances (Choi et al., 2012). Although the current research has shown that different countries have quite different research interests in TM fields (Choi et al., 2012), there is still a lack of in-depth studies examining the TM practices and TM modes adopted by different countries, especially by latecomers and forerunners. This leads to ineffective guidance in realizing catch-up, as TM practices and TM modes frequently change from one country to another (Radosevic and Yoruk, 2016). Therefore, this paper aims to reveal the differences in TM practices and TM modes between latecomer firms and forerunner firms, which is a particularly promising but under-researched area. This is particularly important, as it may provide a useful way for latecomers to seek and learn more effective management practices from forerunners, thus providing fruitful lessons for researchers and practitioners.

This paper addresses the cross-national issue by comparing the TM practices and TM modes of China and Korea. There are two reasons for doing so. First, it is well known that Chinese firms are latecomers, lagging behind in product innovation (Shen, 2019). Although Chinese firms have invested a lot in product innovation, they lack competitiveness, and they are still catching up with the forerunners (Lundvall and Rikap, 2022). While Korea has been one of the most successful countries in achieving catch-up, and it has approached the front rank of the developed economies (Lee, 2005). The production and manufacturing technologies of Korean firms have reached the level of advanced countries (Song and Noh, 2006), and they have finally realized independent innovation. Therefore, Korean firms have often been regarded as a representative model for other latecomers. Since China and Korea are the typical latecomer and forerunner, respectively, a better interpretation of the product innovation from the perspective of TM between Chinese firms and Korean firms can help latecomer firms to know how forerunner firms succeed.

Second, this paper chooses China and Korea to compare also due to it can establish a favorable condition for measurement invariance. China and Korea all share the Confucian culture, and they are in the same culture cluster (Minkov and Hofstede, 2012). Therefore, China and Korea share some important similarities when measured by Hofstede's model. For example, China and Korea are both hierarchical societies, which means that people in China and Korea all follow a hierarchical order. At the same time, China and Korea are two of the most collectivist countries (Hofstede, 2007), and the score of group harmony on the basis of contracts, loyalty, and commitment is high for both of them. In addition, China's and Korea's values of long-term are relatively high, which reflects the fact that Chinese and Koreans all attach importance to fostering virtues oriented toward future rewards (Hofstede, 2007). Therefore, the comparison of China and Korea is not affected by culture, which is a critical contingency factor influencing management (Song et al., 2010).

The remainder of this paper is structured as follows. Following this introduction, the relevant literature is reviewed, and the hypotheses are developed in the second section. In the third section, the research method is illustrated, including research design, sample and data, measurement, sample characteristics and reliability and validity. In the fourth section, the collected data are analyzed, and the results are reported. The final section discusses the results, offers the implications, and provides directions for future research.

Literature review and hypotheses

Catch-up. Catch-up means that the latecomer reaches and surpasses the forerunner after a period of development (Chen and Li-Hua, 2011). Latecomers are firms that lack technological capability in their own technology field, while forerunners are the firms that latecomers want to catch up with (Kwak and Yoon, 2020). The ways that latecomer firms catch up with forerunner firms have been extensively studied, and the main focus in the literature has been on the role of the government (Guennif and Ramani, 2012; Landini and Malerba, 2017; Ruan et al., 2014; Sun and Cao, 2018). It has been proved that government support for latecomer firms is crucial, and this stream of literature can be divided into two perspectives. The first perspective is based on institution theory, which argues that the institutional environment created by the government plays an important role in catch-up (Wang et al., 2014). For example, it has been proved that government aid for R&D activities contributes to catch-up (Szczygielski et al., 2017). The second perspective is based on stakeholder theory, which argues that catch-up is a collective action by multiple actors (Gao and Liu, 2012). The government can be seen as a special type of actor because it is able to motivate other types of actors with diverse interests to make them work together efficiently. This kind of research demonstrates that developing countries should learn from the national innovation system of developed countries.

Regardless of government policy or government coordination, they all aim to help firms to improve their innovation capabilities. In the catch-up process, latecomer firms may start with a typical low level of innovation capability and, on the basis of accumulation, they may evolve into value-added products in high-end segments (Choung et al., 2014). Some researchers argue

that latecomer firms go through the linear model from original equipment manufacturing (OEM) to original design manufacturing (ODM) and finally to original brand-name manufacturing (OBM) (Zhou et al. 2019). In such a process, latecomer firms may accumulate capabilities to pursue innovation that departs from the trajectories of earlier innovators, thus opening up qualitatively different segments of the international innovation frontier. Based on this understanding, Fan (2006) emphasizes that latecomer firms should prioritize building innovation capability from the very beginning in order to survive in competition with forerunners as well as other latecomer firms. Although the catch-up literature is rich in product innovation analysis (Petti et al., 2019), the literature has yet to make much connection with the literature on TM. Given that there are many challenges and opportunities for latecomer firms in product innovation, these opportunities need to be captured and converted into value through effective TM (Cetindamar et al., 2009). This paper thus links TM and product innovation in the catch-up context to reveal the differences in TM practices and TM modes between latecomer firms and forerunner firms.

Technology management. Some countries are more successful than others in catching up with the developed world, and at the heart of their successes is their growing mastery of TM (Badway, 2009). A widely used definition describes TM as "a process, which includes planning, directing, control and coordination of the development and implementation of technological capabilities to shape and accomplish the strategic and operational objectives of an organization" (NRC, 1987). Based on this understanding, TM is associated with defining the way in which a firm uses existing technology resources and acquires new technology resources (Cetindamar et al., 2016). Therefore, TM involves operating, improving and updating a firm's technology resources (Nambisan and Wilemon, 2002), and it attempts to create value by using a firm's technology resources to maximize a firm's competitiveness (Gaimon, 2008).

From the resource-based view (RBV), a firm's technology resources can be classified as the following: financial resources, physical resources, human intellectual resources, and other tangible and intangible resources (Barney, 1991). These technology resources are stocks of available resources owned or controlled by a firm that can be transformed into final products (Bakar and Ahmad, 2010). TM encompasses the management of all these critical technology resources, and thus it includes a group of practices related to technology finance management, technology equipment management, technological human resource management (THRM), technology information management, and technology achievement management (Phaal et al. 2006; Wu et al., 2012). Since superior product innovation is usually built on the effective use of a firm's technology resources (Julienti and Ahmad, 2010), it can be inferred that the higher the level of TM, the better the technology resources can be managed, and thus the higher the product innovation performance of a firm. Nevertheless, the relationship between TM and product innovation is not as straightforward as previous studies have suggested, as the TM practices and TM modes differ significantly under different circumstances (Cetindamar et al., 2009). Therefore, this paper examines the TM practices and TM modes adopted by latecomer firms and forerunner firms.

Technology finance management and product innovation. Product innovation is a capital-intensive activity, and the input of technology finance resources is necessary to conduct basic research (Gibbert et al., 2014). Firms, no matter latecomer and forerunner, with severely limited technology finance resources may be particularly vulnerable. Thus, access to technology finance resources is one of the most important factors for firms to make R&D projects successful (Kor, 2006). In order to increase the availability of technology finance resources, firms, whether latecomer or forerunner, should try to leverage technology finance management to estimate the demand for R&D funds and collect R&D funds from multiple sources (Seidel and O'Mahony, 2014). That has been proven, as the growth of automobile firms in Korea and telecommunication firms in China was driven by technology finance resources (Malerba and Nelson, 2011). Furthermore, it is also important to ensure that the acquired technology finance resources are channeled into product innovation (Greve, 2003). In the current competitive environment, both latecomers and forerunners should ensure that R&D funds are managed and evaluated with the estimated benefits of R&D results (Kwak and Yoon, 2020). That means, whatever latecomer and forerunner, the effective assessment of the utilization of R&D funds and adaptation in the funding of technologies to changing circumstances is important. Therefore, this paper proposes that the operation of technology finance management is similar for latecomer firms and forerunner firms.

H1: The operation of technology finance management has no significant differences between latecomer firms and forerunner firms.

Technology equipment management and product innovation. Technology equipment management is also important for product innovation (Wang et al., 2008). Traditionally, technological development is seen as the introduction of sophisticated machinery and equipment. However, the acquisition of sophisticated machinery and equipment does not automatically lead to successful product innovation (Figueiredo, 2010), and it should go hand in hand with technology equipment management. In particular, when capital for the purchase of state-of-the-art equipment is in short supply, technology equipment management should be paid more attention in order to improve product innovation performance (Ebersberger et al., 2021). The technology equipment management tasks differ in different levels of innovation capability (Figueiredo, 2010). The basic innovation capability requires recognition, planning and regulation of equipment status following preventive maintenance. At a higher level of innovation capability, a firm is required to make minor adaptations in equipment to adjust to its local raw materials and to own breakdown maintenance. The advanced innovation capability requires timely information about equipment and the generation and application of novel mathematical models to support equipment maintenance (Figueiredo, 2003). For latecomer firms, the level of innovation capability is relatively low, they always lack infrastructure, and they tend to introduce sophisticated machinery and equipment. After acquiring sophisticated machinery and equipment, latecomer firms always start by grasping the condition of the equipment, controlling the equipment, and modifying the equipment to create basic manufacturing capabilities. While forerunner firms always have higher innovation capability, and thus they may put more emphasis on learning from other competitors about how to use advanced equipment and how to make effective maintenance decisions. These provide opportunities to set new benchmarks in cost and quality of product innovation, which can lead to significant competitive advantage. These practices are proven to be the best technology equipment management practices employed in Korean firms (Song and Noh, 2006). Therefore, this paper proposes that the operation of technology equipment management has significant differences between latecomer firms and forerunner firms.

H2: The operation of technology equipment management has significant differences between latecomer firms and forerunner firms. Latecomer firms put the most emphasis on grasping the condition of firms' equipment, while forerunner firms stress learning from other competitors on equipment most.

THRM and product innovation. Product innovation requires technological human resources to generate original ideas, develop creative approaches and seize new opportunities, especially in the early stages of product innovation (Liu et al., 2017). Technological human resources are composed of a team of employees with suitable qualifications and rich experience in product innovation, and the quality of technological human resources is very important (Martín-de Castro et al., 2013). Nevertheless, latecomer firms often face the constraint of a lack of qualified technology human resources, and this is one of the main reasons why the productivity of latecomer's technology employees lags behind that of forerunners (Gao and Jefferson, 2007). Therefore, in order to improve the quality of technological human resources, understanding the technological talents required by businesses and making a development strategy of talents are important for latecomer firms (Schaefer, 2020). While forerunner firms are furnished with a large amount of technological human resources, most of their technological employees suffer from more work tension (Kim and Seong, 2010). Therefore, it is important for forerunner firms to adopt strategic human resource management practices, such as training, to help technological employees reduce their work tension (Haneda and Ito, 2018). Korean firms perform very well in this regard. The team leaders in Korean firms put more effort into the strategic planning of technological employees' development, which is conducive to motivate technological employees' commitment (Kim et al., 1999). Therefore, this paper proposes that the operation of THRM has significant differences between latecomer firms and forerunner firms.

H3: The operation of THRM has significant differences between latecomer firms and forerunner firms. Latecomer firms put the most emphasis on understanding the technology talents required by business, while forerunner firms stress effective training the most.

Technology information management and product innovation. Technology information is very important in product innovation because it is always related to decision-making, such as the appropriate type and quantity of new products (Abrantes and Figueiredo, 2015). Firms with different levels of innovation capability have different technology information management tasks (Vick et al., 2015). Firms away from the innovation frontier rely heavily on external R&D arrangements as the provenience of product innovation (Giachetti and Pira, 2022), while firms at the world innovation frontier always implement large amounts of product innovation projects to challenge industrial standards and establish leadership (Figueiredo, 2010). This indicates that the technology information management of latecomer firms is fundamentally different from that of forerunner firms. For latecomer firms, which are away from the innovation frontier, acquiring foreign technologies from forerunner firms may be the initial activity in their product innovation process to participate in the global R&D division (Hobday et al., 2004). In order to identify, assimilate and apply new technologies, latecomer firms should absorb technology information and complete the technology information file (Chang et al., 2012; Giachetti and Pira, 2022). Latecomer firms that adopt such practices can continuously accumulate new knowledge (Petti et al., 2019). This is one of the key reasons why Chinese firms have been able to produce competitive products (Yu et al., 2015). While forerunner firms, which are at the world innovation frontier, need to recognize their target market and understand customer requirements in order to develop more radical new products (Chen and Li-Hua, 2011). The analysis requires forerunner firms to construct detailed technology information systems and transfer the acquired information into product innovation (Amin et al., 2021). These are the important reasons for Korean firms to approach the front rank of product innovation (Tsai and Wang, 2008). Therefore, this paper proposes that the operation of technology information management has significant differences between latecomer firms and forerunner firms.

H4: The operation of technology information management has significant differences between latecomer firms and forerunner firms. Latecomer firms put the most emphasis on completing files on technology information, while forerunner firms stress on constructing detailed technology information management system most.

Technology achievement management and product innovation. Successful product innovation also stems from a firm's past technology achievements. Product innovation is path-dependent, and existing technology achievements can serve as fundamental resources for exploring creative ideas for both latecomer firms and forerunner firms (Jang et al., 2009; Rosiello and Maleki, 2021). For latecomer firms, product innovation usually comes from minor improvements in the acquisition of foreign technologies (Chung and Lee, 2015). Therefore, latecomer firms should use their technology achievements through technology achievement management to embrace, absorb and improve foreign technologies (Dantas and Bell, 2011). For forerunner firms, the development of new strategic orientations is essential for them to open up new opportunities and sustain firm growth. In this case, forerunner firms should also pay attention to technology achievement management in order to make full use of the accumulated technology achievements to create new products. As a result, latecomer firms and forerunner firms are all supposed to integrate technology achievement management into product innovation to recognize, create, and apply technology achievements (Rhee et al. 2010). Moreover, as an important kind of knowledge asset, technology achievements can constrain the direction of firms' product innovation. As a result, both latecomer firms and forerunner firms should make efforts to broaden and deepen technology achievements to enhance their ability to comprehend new knowledge (Kiamehr et al., 2015). In this way, all latecomer firms and forerunner firms should pay attention to technology achievement management in order to support the transformation of technology achievements (Alegre et al., 2013). Therefore, this paper proposes that the operation of technology achievement management is similar for latecomer firms and forerunner firms.

H5: The operation of technology achievement management has no significant differences between latecomer firms and forerunner firms.

The correlations between TM and product innovation. It turns out that the technology resources are usually deficient (Mathews, 2002), and latecomer firms tend to lack valuable, rare, inimitable and non-substitutable technology resources (Hobday, 2005). To overcome the severe technology resource barriers in product innovation, the most important issue for latecomer firms is to acquire technology resources (Li and Kozhikode, 2008). Thus, latecomer firms need to search internally and externally to acquire critical technology resources (Amankwah-Amoah et al., 2019; Li and Valentini, 2023), which means that they may put more emphasis on some specific TM practices related to resource

acquisition. While for forerunner firms, their technology resources are always plentiful (Mathews, 2002). Under such conditions, they generally tend to consider how to make their technology resources more valuable and rare, hard to imitate and difficult to substitute, with the purpose of erecting entry barriers for latecomer firms (Gloria and Ding, 2008). As a result, maximizing the value of the owned technology resources becomes important for forerunner firms to earn above-normal returns (Evanschitzky et al., 2012). Value maximization requires an integral usage of TM practices. For instance, the integral usage of TM practices can make the best use of technology resources to formulate product-positioning strategies (Song and Noh, 2006). It should be noted that one of the most important reasons for the success of Korean firms is the emphasis on holistic TM practices (Hung and Tang, 2008). Therefore, forerunner firms' TM is more relevant to product innovation.

H6: For forerunner firms, TM is more relevant to product innovation.

Methods

Research design. This paper was designed based on the assumption that the TM practices and TM modes used in different countries are different, and the aim was to test this assumption using samples of Chinese firms and Korean firms as a means to learn how latecomers achieve successful catch-up in product innovation from the perspective of TM. Therefore, this paper follows the research design of international comparative research.

International comparative research has long been acknowledged as a difficult undertaking (Knight et al., 2003). International comparative research is concerned with identifying similarities and differences between two or more countries, and the samples used in this type of research should ensure that any differences observed are not due to sample differences (Hult et al., 2008). It is argued that when designing international comparative research, careful attention should be focused on the sample to ensure comparability across different countries (He et al., 2008). It is argued that comparability across countries can be achieved by matching samples (Reynolds et al., 2003). Matching involves making samples from different countries as similar as possible in terms of their demographic characteristics (Chidlow et al., 2015).

For this research purpose, a three-step research design was followed. First, previous literature on TM and product innovation was reviewed to construct a conceptual model. In this paper, five dimensions of TM were considered: technology finance management, technology equipment management, THRM, technology information management, and technology achievement management. The conceptual model for the comparison of Chinese firms and Korean firms was shown in Fig. 1. Second, questionnaires were developed to measure TM and product innovation performance. Third, following the guidelines of international comparative research (Reynolds et al., 2003), the data were collected.

Sample and data. To achieve the research objectives, data were collected from Chinese high-technology firms and Korean high-technology firms. High-technology firms are knowledge-intensive, and they need to achieve catch-up to a greater extent (Mathews, 2002). In the catch-up process, high-technology firms always tend to generate highly innovative products, and TM plays a crucial role in the development of new products. These provide a favorable context for this research. For the Korean sample, all firms are from the automotive industry (9 firms, 29.03%) and the electrical machinery and equipment industry (22 firms, 70.97%), which are the typical industry that has achieved catch-up (Malerba and Nelson, 2011). Questionnaires to firms were sent to firms in these two industries, which are either internationally renowned firms or suppliers of these internationally renowned firms. All of them have a leading technology level in their own industry. While for the Chinese samples, they come from the aircraft and spacecraft industry (24 firms, 50.00%), the automobile industry (10 firms, 20.84%), the electrical machinery and apparatus industry (6 firms, 12.50%), the pharmaceutical industry (4 firms, 8.33%) and the machinery and equipment industry (4 firms, 8.33%). For China, these industries still have technology gaps with international advanced level. The firms in these industries are still catching up.

In this paper, respondents were asked to complete the questionnaire on TM and product innovation performance. The respondents were senior managers who undertook extensive responsibilities for TM and product innovation, and thus they had a more synthetic understanding of TM and product innovation performance. With the aim to avoid common method variance (CMV), the respondents of different variables in this paper were not identical, for example, the respondents of TM were managers of TM, and the respondents of product innovation performance were managers of R&D departments.

Responses were received from 48 Chinese firms and 31 Korean firms. The response rates were 0.68 and 0.44, respectively (some questionnaires were unusable due to missing values). The sample size was sufficient to run statistical analysis at the firm level. Non-response bias is a common problem in survey methodology. Following previous procedures, the firm size of participating firms and non-participating firms was compared by *t*-test, and the results showed that there were no statistically significant differences, suggesting that there was no serious non-response bias in the survey.

Measurement. The questionnaire was developed following the common procedures. First, the extant research on TM and product innovation was reviewed, and the items designed to measure TM and product innovation performance were identified. Second, since all scales were originally developed in English, a double-translation method was used to translate the original scales into Chinese for the respondents in China and Korean for the respondents in Korea. Based on the research background, some items were re-edited in order to fit the current research context. Third, a pilot test was carried out to assess the quality of the questionnaire. The questionnaire was tested using a sample of four Chinese high-technology firms and three Korean high-technology firms. Based on their feedback, some modifications were made in terms of wording and format. The final questionnaire contained 36 items using a 5-point Likert scale with 1 = "strongly disagree", 3 = "neutral", and 5 = "strongly agree".

An instrument developed by Wu et al. (2012) was adapted to measure TM. This instrument was chosen because it was comprehensive to measure TM from RBV. Product innovation performance was measured by four items adapted from Alegre and Chiva (2008). The measurement was developed from innovation efficacy and innovation efficiency. The adaptation is necessary mainly because the survey was conducted with Chinese and Korean respondents. Some words and even sentences have been changed to improve understanding.

Sample characteristics. In order to achieve comparability between countries, the firm size and type of industry were matched, and the results are shown in Tables 1 and 2. As shown in Table 1, there was a similarity in the distribution of firm size between the Chinese and Korean samples, even after applying the criterion of dividing them into three types, including small,

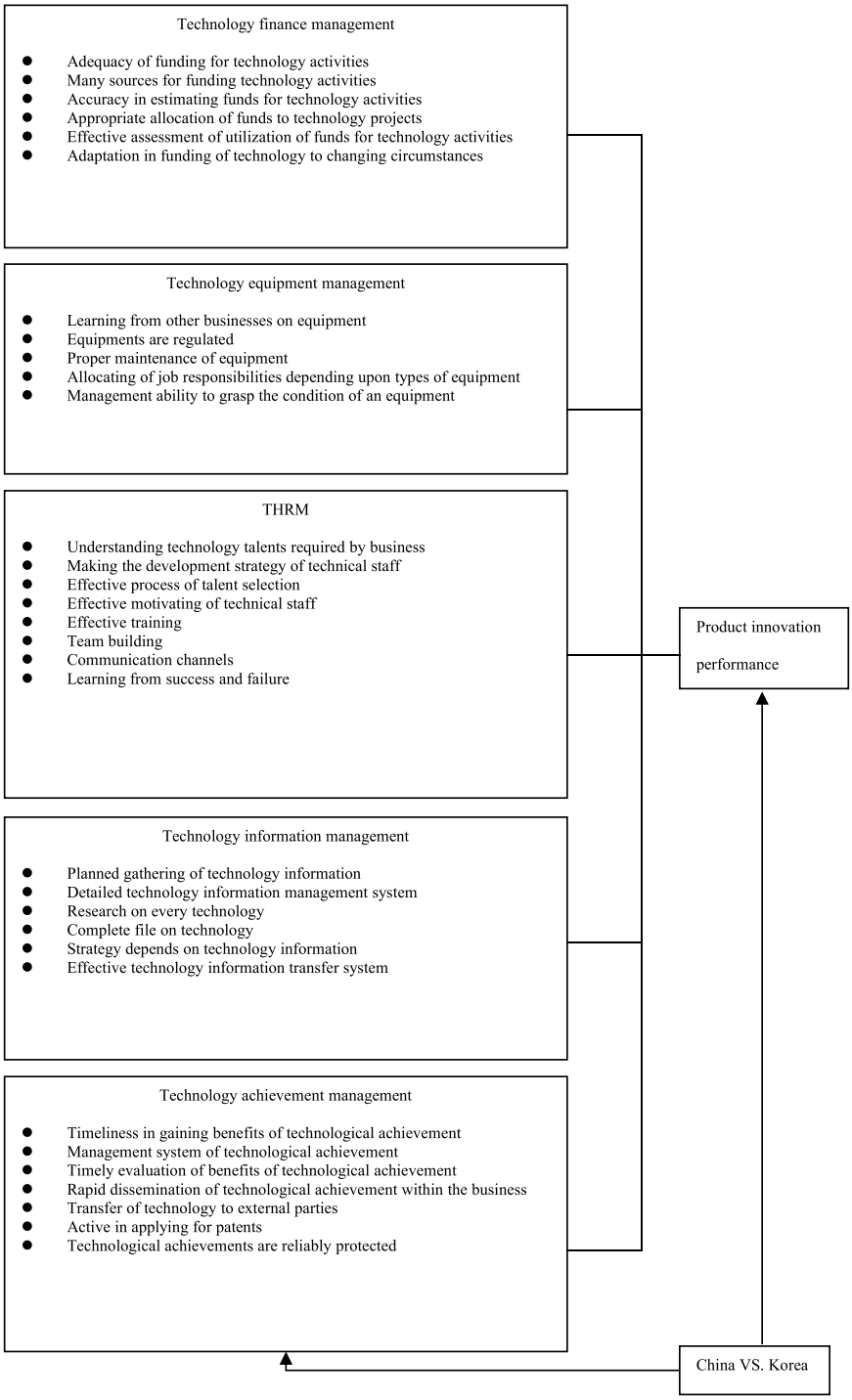

Fig. 1 Conceptual model. Conceptual model for China and Korea comparison.

medium and large. Small firms accounted for 27.08% of the Chinese sample and 29.03% of the Korean sample, and medium firms accounted for 33.34% of the Chinese sample and 32.26% of the Korean sample. In this paper, firms with more than 1000 employees were classified as large firms, and the large firms in the Chinese sample and Korean sample were 39.58% and 38.71%, respectively.

This paper followed the classification of the Organization for Economic Co-operation and Development (OECD) to divide the research sample into high-technology industry (e.g., aircraft and spacecraft, and pharmaceuticals) and medium-high-technology industry (e.g., machinery and equipment, and electrical machinery and apparatus). There was also a similarity in the distribution of the type of industry between the Chinese sample and the Korean sample. As shown in Table 2, 52.08% of the firms in the Chinese sample were in the high-technology industry, and 47.92% were in the medium-high-technology industry. In the Korean sample, there were 48.38% high-technology industry firms and 51.62% medium-high-technology industry firms.

Furthermore, international comparative research highlights that matching must produce groups that are as similar as possible on relevant backgrounds (Reynolds et al., 2003). Cultural difference is an important relevant background in cross-country comparability analysis (Douglas and Craig, 2006). However, as

Table 1 Characteristics of the sample (size).

	Frequency		%	
	China	Korea	China	Korea
Small	**13**	**9**	**27.08**	**29.03**
Less than 100	4	2	8.33	6.45
101–200	4	4	8.33	12.90
201–300	5	3	10.42	9.68
Medium	**16**	**10**	**33.34**	**32.26**
301–500	5	4	10.42	12.90
501–700	6	4	12.50	12.90
701–1000	5	2	10.42	6.46
Large	**19**	**12**	**39.58**	**38.71**
1001–3000	6	5	12.50	16.13
3001–5000	4	3	8.33	9.68
More than 5001	9	4	18.75	12.90
Total	**48**	**31**	**100**	**100**

Table 2 Characteristics of the sample (type of industry).

	China		Korea	
	Frequency	%	Frequency	%
High-technology industries	25	52.08	15	48.38
Medium-high-technology industries	23	47.92	16	51.62
Total	48	100	31	100

argued above, the comparison of China and Korea is not affected by culture. Therefore, in this paper, countries were matched on cultural factors, and these factors did not contaminate or explain the observed relationships.

Therefore, the samples in this paper can remove demographic differences, and such comparability could reduce the likelihood that the sample differences are the cause of any observed differences between the national groups on the variables of interest.

Reliability and validity. SPSS 24 was used for data analysis. Reliability analysis was carried out on the Chinese sample and Korean sample separately. The Cronbach's α values of TM and product innovation performance were all above 0.70 in both the Chinese and Korean samples, which exceeded Nunnally's (1978) standard, indicating that the reliability of the measurement was acceptable.

In order to ensure content validity, this paper generated items from important academic journals, and the initial questionnaire was sent to several scholars who were familiar with this research field. In addition, the initial questionnaire was also sent to several executives for their remarks. Based on the assessments of scholars and executives, the questionnaire was reworded for some items to avoid unclear statements. These interview results ensured content validity.

The research was conducted in China and Korea, with similar national cultures, which provided favorable conditions for cross-national comparisons. In addition, several measures were taken in this paper to ensure measurement in-variance. For example, at the questionnaire development stage, the translations were made by native speakers who were bilingual in English and Chinese/Korean. This paper further compared the Chinese questionnaire and Korean questionnaire and was satisfied with the consistency of the meaning of each item. In addition, the sampling procedures for the Chinese and Korean samples were similar. Therefore, it can be assumed that the statistical results can be compared based on the established measurement in-variance.

Results

Descriptive results. The details in regard to the means, standard deviations and rankings of the TM items are given separately for Chinese firms and Korean firms in Table 3.

As can be seen in Table 3, Chinese firms and Korean firms offer interesting contrasts in TM. There is greater variability with respect to technology equipment management, THRM, and technology information management. In technology equipment management, Chinese firms put more emphasis on management ability to grasp the equipment condition (Mean = 4.0208, Ranking = 1) while placing the least importance on learning from other businesses on equipment (Mean=3.7292, Ranking = 5). In contrast, Korean firms put more emphasis on learning from other businesses on equipment (Mean = 3.7742, Ranking = 1) and place the least importance on management ability to grasp the equipment condition (Mean = 3.3871, Ranking = 5). Hence, H2 is fully supported.

In the THRM, Chinese firms give more weight to the following items: understanding technology talents required by business (Mean = 4.0833, Ranking = 1), learning from success and failure (Mean = 3.7971, Ranking = 2), and making the development strategy of technical staff (Mean = 3.7708, Ranking = 3). While Korean firms give more weight to the following items: effective training (Mean = 3.7419, Ranking = 1), effective motivating of technical staff (Mean = 3.6774, Ranking = 2), and team building (Mean = 3.6129, Ranking = 3). Hence, H3 is fully supported.

In technology information management, the item of completing file on technology (Mean = 3.7500, Ranking = 1) is the most important for Chinese firms, and the items of constructing detailed technology information management system (Mean = 3.4375, Ranking = 5) and researching on every technology (Mean = 3.4167, Ranking = 6) are at the last two. While for Korean firms, the item of constructing a detailed technology information management system (Mean = 3.4516, Ranking = 1) is the most important, and the items of researching every technology (Mean = 3.1935, Ranking = 5) and constructing effective technology information transfer system (Mean = 3.1613, Ranking = 6) are at the last two. Hence, H4 is fully supported.

It can also be noted that there are no significant differences in the rankings of technology finance management and technology achievement management between Chinese firms and Korean firms. Hence, H1 and H5 are supported that the operation of technology finance management and technology achievement management have no significant differences between Chinese firms and Korean firms.

Correlation results. In reality, firms are more likely to improve product innovation by using multiple TM practices simultaneously. Therefore, technology finance management, technology equipment management, THRM, technology information management, and technology achievement management are all expected to correlate positively with product innovation performance. The correlation results are presented in Table 4.

Considering the correlations between TM and product innovation performance, there are also significantly different results between Chinese firms and Korean firms. For Korean firms, it can be observed that technology achievement management ($\beta = 0.909$, $p < 0.01$), technology finance management ($\beta = 0.908$, $p < 0.01$), technology equipment management ($\beta = 0.885$, $p < 0.01$), technology information management ($\beta = 0.886$, $p < 0.01$), and THRM ($\beta = 0.877$, $p < 0.01$) are all highly correlated with product

Table 3 Means and standard deviations of TM items of Chinese and Korean firms.

	China high-tech firms				Korea high-tech firms				
	Ranking	Mean	Std. deviation	N	Ranking	Mean	Std. deviation	N	Differences
Technology finance management									
Adequacy of funding for technology activities	2	3.7500	0.93399	48	1	3.4839	0.81121	31	1
Many sources for funding technology activities	1	3.8125	0.93754	48	3	3.2903	1.07062	31	−2
Accuracy in estimating funds for technology activities	5	3.5625	1.02949	48	6	2.9355	0.99785	31	−1
Appropriate allocation of funds to technology projects	3	3.6875	0.92613	48	2	3.3548	1.05035	31	1
Effective assessment of utilization of funds for technology activities	6	3.5417	1.00970	48	4	3.2581	1.06357	31	2
Adaptation in funding of technology to changing circumstances	4	3.6250	1.08422	48	5	3.0000	1.06458	31	−1
Technology equipment management									
Learning from other businesses on equipment	5	3.7292	0.93943	48	1	3.7742	0.76200	31	4
Equipments are regulated	2	3.9792	0.88701	48	3	3.4516	0.92516	31	−1
Proper maintenance of equipment	4	3.7708	0.8565	48	2	3.4839	1.02862	31	2
Allocating job responsibilities depending upon types of equipment	3	3.9167	0.87113	48	4	3.4194	0.99244	31	−1
Management ability to grasp the condition of an equipment	1	4.0208	0.75764	48	5	3.3871	0.91933	31	−4
THRM									
Understanding technology talents required by business	1	4.0833	0.94155	48	5	3.4516	0.85005	31	−4
Making the development strategy of technical staff	3	3.7708	0.99444	48	7	3.3871	0.88232	31	−4
Effective process of talent selection	4	3.7083	0.98841	48	4	3.5484	0.96051	31	0
Effective motivating of technical staff	8	3.5833	0.87113	48	2	3.6774	0.97936	31	6
Effective training	5	3.7500	0.86295	48	1	3.7419	0.96498	31	4
Team building	5	3.7500	1.02105	48	3	3.6129	0.91933	31	2
Communication channels	7	3.6667	0.90703	48	5	3.4516	0.76762	31	2
Learning from success and failure	2	3.7917	0.98841	48	8	3.3226	0.90874	31	−6
Technology information management									
Planned gathering of tech-info	3	3.6458	1.04147	48	4	3.3226	0.87129	31	−1
Detailed tech-info management system	5	3.4375	1.10908	48	1	3.4516	0.92516	31	4
Research on every technology	6	3.4167	1.02798	48	5	3.1935	0.83344	31	1
Complete file on technology	1	3.7500	1.08176	48	3	3.3871	1.14535	31	−2
Strategy depends on tech-info	2	3.6875	0.97099	48	2	3.4194	0.76482	31	0
Effective tech-info transfer system	4	3.5833	0.94155	48	6	3.1613	0.96943	31	−2
Technology achievement management									
Timeliness in gaining benefits of technological achievement	4	3.6667	1.01758	48	3	3.2258	1.02338	31	1
Management system of technological achievement	3	3.8542	0.98908	48	4	3.1613	0.96943	31	−1
Timely evaluation of benefits of technological achievement	5	3.6458	0.97827	48	5	3.129	0.95715	31	0
Rapid dissemination of technological achievement within the business	6	3.4792	1.14835	48	6	3.0645	1.12355	31	0
Transfer of technology to external parties	7	3.1250	1.17826	48	7	3.0000	0.96609	31	0
Active in applying for patents	2	4.0000	0.94531	48	2	3.4194	0.84751	31	0
Technological achievements are reliably protected	1	4.0625	1.0191	48	1	3.7097	0.97275	31	0

innovation performance ($\beta > 0.700$, $p < 0.01$). While for Chinese firms, only technology achievement management ($\beta = 0.791$, $p < 0.01$) and THRM ($\beta = 0.771$, $p < 0.01$) are highly correlated with product innovation performance ($\beta > 0.700$, $p < 0.01$). Hence, H6 is fully supported.

Furthermore, Table 4 shows that, for Korean firms, almost all TM practices are highly correlated with product development cycle and product success rate ($\beta > 0.700$, $p < 0.05$), while technology equipment management ($\beta = 0.682$, $p < 0.01$) is not highly correlated with product leadership and THRM ($\beta = 0.699$, $p < 0.01$) is not highly correlated with product cost. In contrast, only some TM practices are highly correlated with product innovation performance in Chinese firms. For Chinese firms, THRM ($\beta = 0.732$, $p < 0.01$) and technology achievement management ($\beta = 0.715$, $p < 0.01$) are highly correlated with product leadership, and THRM ($\beta = 0.793$, $p < 0.01$) and technology achievement management ($\beta = 0.779$, $p < 0.01$) are highly correlated with product success rate.

The results showed that the TM modes of latecomer firms and forerunner firms are different. For Korean firms, technology finance management, technology equipment management, THRM, technology information management, and technology achievement management are highly correlated with product innovation performance. While for Chinese firms, only THRM and technology achievement management are highly correlated with product innovation performance. Therefore, the transformation of TM mode from latecomer to forerunner can be developed as shown in Fig. 2. The bolder lines mean that technology finance

Table 4 Correlations of TM and product innovation performance of Chinese and Korean firms.

Variables	Sample	Technology finance management	Technology equipment management	THRM	Technology information management	Technology achievement management
Product leadership	China ($N = 48$)	0.495***	0.593***	0.732***	0.661***	0.715***
	Korea ($N = 31$)	0.737***	0.682***	0.799***	0.732***	0.735***
Product development	China ($N = 48$)	0.411***	0.481***	0.555***	0.493***	0.586***
cycle	Korea ($N = 31$)	0.778***	0.781***	0.760***	0.749***	0.842***
Cost of product	China ($N = 48$)	0.497***	0.480***	0.496***	0.558***	0.564***
	Korea ($N = 31$)	0.779***	0.761***	0.699***	0.753***	0.751***
Product success rate	China ($N = 48$)	0.613***	0.696***	0.793***	0.606***	0.779***
	Korea ($N = 31$)	0.868***	0.868***	0.774***	0.849***	0.831***
Product innovation	China ($N = 48$)	0.603***	0.673***	0.771***	0.692***	0.791***
performance	Korea ($N = 31$)	0.908***	0.885***	0.877***	0.886***	0.909***

***$p < 0.01$.

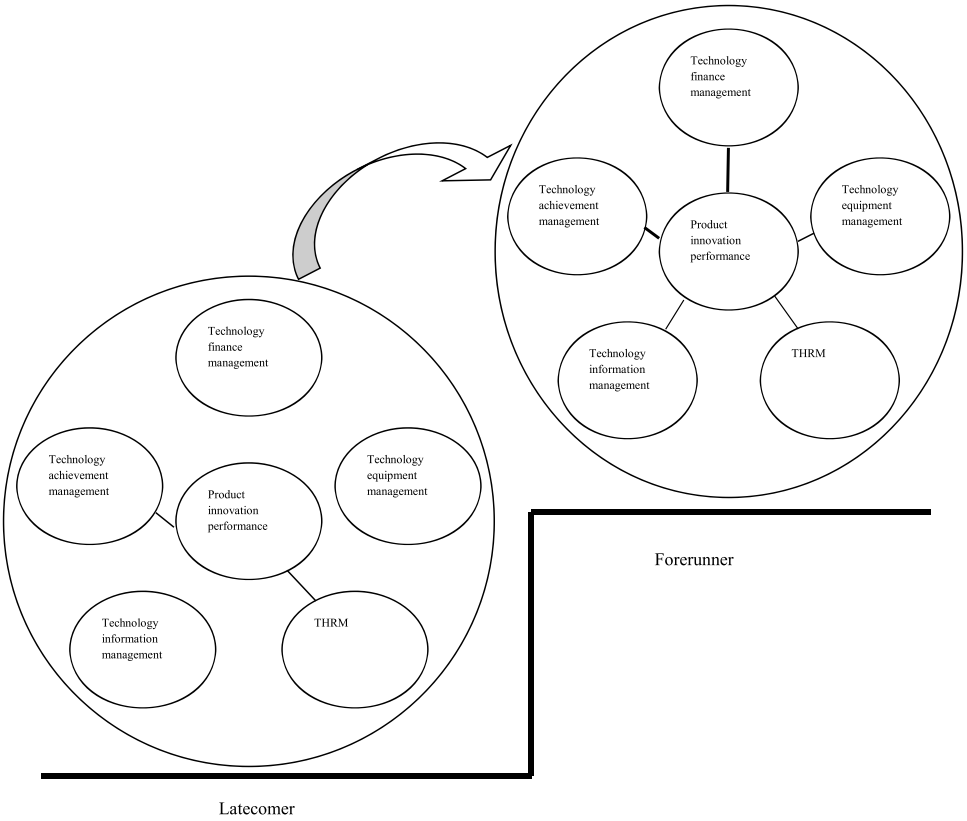

Fig. 2 The transformation of TM mode. The transformation of TM mode from latecomer to forerunner.

management and technology achievement management are more relevant to product innovation performance in Korean firms. The transformation configuration suggests that there are fundamental differences in the TM mode between latecomers and forerunners. It shows that at the beginning of the catch-up, latecomer firms do not form an integral TM mode to manage technology resources, and this leads to the firms' existing resources could not be fully utilized. While forerunner firms stress the importance of TM integrally and apply TM practices synthetically to implement product innovation. The transformation of the TM mode from latecomer to forerunner provides an example for latecomer firms to imitate. Latecomer firms can follow the TM mode of forerunner firms to manage and accumulate technology resources, which is an effective way to achieve successful catch-up. However, it should also be noted that exact copying is almost impossible. Some TM practices are often difficult to replicate and need to be adapted to the conditions, norms and values of latecomers. Therefore, latecomers need to make some adjustments to adapt the TM practices to local conditions.

Discussions and conclusions

The main objective of this paper is to reveal the differences in TM practices and TM modes between latecomer firms and forerunner firms. Therefore, this paper examines the means, standard deviations and rankings of TM items and further compares the correlations between TM and product innovation performance to reveal the TM characteristics of latecomer firms and forerunner firms. The results show that latecomer firms put more emphasis

on grasping the condition of firms' equipment, understanding technology talents required by business, and completing files on technology information. While forerunner firms, on the other hand, stress learning from other competitors, effective training, and constructing detailed technology information management system most. Furthermore, the TM modes of latecomers and forerunners are different. Compared to latecomer firms, the relationship between TM and product innovation performance of forerunner firms behaves as a more integrated mode.

This paper makes several theoretical contributions. First, this paper integrates the RBV into the TM and develops an integrative TM framework that can serve as a micro-foundation for empirical research. The TM has received considerable attention from both academics and practitioners. Researchers have developed a set of management activities and processes from different perspectives to describe the framework of TM, including project appraisal (Lopes and Flavell, 1998), product design (Haas and Kleingeld, 1999), technology assessment (Pretorius and De Wet, 2000), business process reengineering (Wu, 2002), knowledge management (Liao, 2003), etc. However, from the TM perspective, the TM framework should have the following characteristics: better connect with the increasingly important RBV, better connect strategic (macro) and project (micro) levels, and better describe how work is done (Levin and Barnard, 2008). Based on this understanding, this paper further explains that TM is composed of five sub-processes, including technology finance management, technology equipment management, THRM, technology information management, and technology achievement management. The proposed TM framework offers several benefits in understanding TM because it is a highly flexible TM framework, which can be customized by any organization (manufacturing organization or service organization) and applicable at any level (i.e., business unit or department unit) and at any size (small firms or large firms).

Second, this paper contributes to catch-up theory by illuminating a new perspective for the research of catch-up. To the best knowledge, this paper is among the first to provide insight into the differences in TM practices and TM modes across latecomers and forerunners. Previous research has indicated that there are substantial differences between developed countries and developing countries in the major topics of TM research (Cetindamar et al., 2009). This paper further reveals that TM practices and TM modes are also context-dependent, which are likely to be reflected in the researchers' agendas of latecomers and forerunners. The results are important for us to know how latecomer firms and forerunner firms operate and further provide important insights into how latecomer firms achieve successful catch-up. This paper thus contributes to shifting the focus of catch-up research from the study of latecomers or forerunners to the comparison of the differences between latecomers and forerunners.

Third, the results developed here can also contribute to the RBV. There have been calls for a comparison of different processes of resource utilization in different contexts (Barney et al., 2011). This paper finds that the technology resources deployment practices of latecomers such as China are different from forerunners such as Korea, and the underlying mechanisms through which TM relates to product innovation performance are also different. These results suggest that resource management has different characteristics in different contexts, which provide a better understanding of the contingent conditions of the RBV. Thus, this paper offers a promising new perspective for investigating the generalizability of the findings in RBV. Furthermore, by bridging TM and RBV, this paper establishes a straightforward framework that clarifies what capabilities are needed to use technology resources, which can provide a solid foundation for research on how firms manage technology resources.

As far as managerial implications are concerned, this paper provides the TM mode of forerunner firms, which can serve as an example for latecomer firms to follow. Latecomer firms should focus on developing the linkages between technology finance management, technology equipment management, and technology information management and product innovation. The detailed practices can be assessing the utilization of funds for product innovation activities, estimating funds for product innovation activities, learning from other businesses on equipment, and researching every technology. In particular, latecomer firms must pay special attention to cultivate the correlations between technology finance management and product innovation and technology achievement management and product innovation, as these relationships are of vital importance for forerunner firms.

This paper is not without its limitations. First, although the samples in this paper are found to be rather similar in terms of size as well as the type of industry, other controls may need to be considered to further ensure a better match between the Chinese sample and the Korean sample. Second, the sample size of Chinese firms and Korean firms is still small, and the sample size can be expanded in order to improve the representativeness of the samples. Third, it is a limitation that the samples are limited to a specific sector. Future research can extend the results to other settings, which may provide more generalizable insights. In addition, it would also be interesting to examine the research results in more latecomers and forerunners, which may provide more variation and gain more understanding of TM practices and TM modes. Fourth, the parsimonious model may omit some variables. Future research could complement the research results by taking a different perspective. Finally, the questionnaire could be refined to focus on the most significant differences between latecomers and forerunners.

Limitations notwithstanding, this paper has found that the focus of TM practices and TM modes of latecomers, e.g., Chinese firms and forerunners, e.g., Korean firms are different. This paper can be seen as a first step in investigating how to achieve catch-up from the perspective of TM, and it is hoped that further research can be done to gain a better understanding of this topic.

Data availability

The datasets are not publicly available, as full confidentiality was assured in the questionnaire instructions, but are available from the corresponding author on reasonable request.

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Author contributions

YL and WW conceived and wrote the manuscript. YK acquired the data.

Competing interests

The authors declare no competing interests.

Ethical approval

This paper does not contain any study with human participants performed by any of the authors.

Informed consent

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Additional information

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