Genetic distance, international experience and the performance of cross-border R&D for EMNEs

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Abstract: Cross-border R&D can contribute to the enhancement of independent innovation capabilities of emerging markets multinational enterprises (EMNEs) by benefiting from knowledge management. However, scant research exists examining the location impact of cross-border R&D for EMNEs on performance implications. This paper fills this important theoretical gap by building upon the literature of genetic distance in connection with knowledge management. We use a panel data of Chinese high-tech listed companies to empirically examine the impact of genetic distance on the performance of cross-border R&D and the role played by international experience. Our results reveal a positive relationship between genetic distance and the performance of cross-border R&D. Importantly, we highlight the motivation for cross-border R&D of EMNEs to acquire technical knowledge magnifies the positive effects of genetic distance and performance. Furthermore, our analysis indicates that international experience significantly enhanced the positive effect of genetic distance on cross-border R&D performance. We conclude this paper by discussing theoretical contributions to genetic distance, international management and knowledge management, as well as practical implications for cross-border R&D of EMNEs.

Keywords: cross-border R&D, genetic distance, international experience, innovation capability, knowledge management

1. Introduction

Emerging markets multinational enterprises (EMNEs) have received increasing attention from international business and management scholars (Luo and Zhang, 2016). In the articulation and implementation of their global strategy, EMNEs endeavor to gain competitive advantages and improve innovation capabilities (Kotabe and Kothari, 2016) through cross-border M&As (Liu and Meyer, 2020), home country urbanization (Estrin et al., 2017), and global technology transfer through partnerships (Del Giudice et al., 2017). Knowledge management plays a critical role in innovative performance for MNEs in general (Mudambi, 2002), and EMNEs in particular (Ferraris et al., 2017). Cross-border R&D can contribute to their innovative performance by benefiting from knowledge management practices in such a complex inter-organizational arrangement (Del Giudice and Maggioni, 2014).

Country distance is a common determinant in cross-border investment or international cooperation. Existing studies have found that cultural (Teixeira et al., 2008), linguistic (Ly et al., 2018), economic (Choi and Contractor, 2016), geographic (Castellani et al., 2013), institutional (Ahammad et al., 2018), knowledge (Thakur-Wernz and Samant, 2019) and market distance (Colombo et al., 2009) have potential impacts on investment or cooperation decision-making and its performance. However, the extant research remains scant about the location impact of cross-border R&D for EMNEs on performance implications. What is the mechanism by which the location of cross-border R&D impacts their performance? In this paper, we argue the literature on genetic distance may shed some revealing light on this important theoretical question. As a general measure of human heterogeneity, genetic distance comprehensively reflects the long-term differences in the inter-generational transmission characteristics of two populations in appearance, intelligence quotient, language, values, beliefs, thinking patterns, codes of conduct, customs, and social interactions (Ang and Kumar, 2014; Delis et al., 2017; Spolaore and Wacziarg, 2009). We choose genetic distance rather than cultural or institutional distance because the former can fundamentally reflect the differences between two populations (Spolaore and Wacziarg, 2009), while the latter is affected by economic exchanges and cultural blending. In other words, genetic distance is exogenous, while cultural or institutional distance may produce endogenous deviations.

Since Spolaore and Wacziarg (2009) and Guiso et al. (2009) pioneeringly explored the relationship between genetic distance, income differences, and economic interactions between countries, the impact of genes on economic activity has attracted much attention from the scholarly community. Especially in the field of international management and international trade, genetic distance has been proven to be one of the important factors affecting the bilateral trade volume. Many empirical studies have found that the genetic distance between countries or regions significantly reduces bilateral trade volume (Bove and Gokmen, 2018; Guiso et al., 2009). Because the increase in genetic distance is intuitively manifested by the large differences in values and customs, it exacerbates the communication barriers between two parties, and ultimately leads to the lack of necessary trust and thus reduces trade exchanges (Guiso et al., 2009).

Page (2007) points out that the ethnic heterogeneity of the team can bring more innovation output. The underlying logic is that ethnic heterogeneity means team members have large differences in background and preferences, often using different perspectives and heuristic strategies to think about problems, which not only helps to increase solutions to problems but also helps to improve the existing solutions; In contrast, homogeneous teams are constrained by the lack and unity of knowledge reserves, often interpreting problems from the same perspective and proposing similar solutions, which is not conducive to the improvement of existing solutions (Page, 2007; Vermeulen and Barkema, 2001). Therefore, heterogeneous teams contribute more to innovation efficiency than homogeneous teams. Along this line of thought, the impact of genetic distance on cross-border R&D performance may have two sides. On the one hand, the difference of genes will still lead to the decline of collaboration efficiency and produce negative effects (Bove and Gokmen, 2018; Guiso et al., 2009; Spolaore and Wacziarg, 2009); on the other hand, the increase of genetic distance may also improve the creativity of R&D teams (Ahern et al., 2015; Ashraf and Galor, 2013; Delis et al., 2017; Page, 2007).

How to reduce the negative effect of genetic distance on cross-border R&D performance while strengthening the positive effect? One possible way is to cultivate the international experience of EMNEs. International experience can be divided into two dimensions, one is the international experience of the enterprise itself, and the other is the individual international experience of the enterprise executives. The former includes the accumulated experience of enterprises in previous export trade, foreign investment and international cooperation, and the latter generally refers to the accumulated experience of executives in their overseas studies and work abroad. International experience can not only help enterprises familiarize themselves with overseas culture and institutional environment, reduce conflicts and frictions, alleviate the negative effects of genetic distance but also help enterprises to contact and master cutting-edge knowledge, skills and advanced management methods to improve innovation ability and efficiency (Filatotchev et al., 2011; Liu et al., 2010; Liu, 2020), amplifying the positive effect of genetic distance.

Extant research has explored cultural differences and international R&D cooperation (Choi and Contractor, 2016; Li and Xie, 2016). However, there is no study to analyze cross-border R&D from the perspective of genes. Genetic distance not only describes the differences between the two ethnic groups in cultural and other sociological characteristics but also describes the differences in biological characteristics of the two ethnic groups, which helps us to more comprehensively analyze how the comprehensive differences between the talents of the home country and the host country in cross-border R&D affect the final performance. Furthermore, the literature-based on genetic distance mainly discusses its impact on international trade and international investment, ignoring that genetic distance may affect other types of cross-border investment and international business activities. Also, for the influence of genetic distance, international experience may be both lubricant and booster, but there is no clear research on this inference.

Given this, our paper takes Chinese high-tech listed companies engaged in cross-border R&D from 2007 to 2014 as samples to empirically investigate the influence mechanism of genetic distance on cross-border R&D performance and test the moderating role of international experience. Specifically, we first examine the impact of genetic distance on cross-border R&D performance and reveal its internal mechanism. Secondly, we divide international experience into enterprise-level and individual-level, and test their moderating role in the relationship between genetic distance and cross-border R&D performance.

The contributions of this paper are summarized as follows: firstly, this paper provides empirical evidence for EMNEs engaged in cross-border R&D to choose their R&D destinations. At present, EMNEs gradually realize that it is urgent to improve their independent innovation ability, and have chosen to “going out” R&D. However, reviewing the existing research, little literature focuses on the cross-border R&D practice of EMNEs, and there lacks an understanding of how to select the R&D destination. In this paper, taking genes as the starting point, the positive and negative effects of genetic distance on cross-border R&D performance are analyzed in detail, and it is found that the heterogeneity of genes can be used as an important reference indicator for cross-border R&D site selection. Secondly, this paper enriches the theoretical results of the determinants of cross-border R&D and provides a theoretical basis for EMNEs to improve their performance of cross-border R&D. Finally, this paper expands the application of genetic distance and reveals that it plays a different role in different types of cross-border investments. Research on genetic distance is mainly focused on cross-border trade, and it is generally concluded that genetic distance hurts bilateral trade. However, there are essential differences between cross-border R&D and trade, with a strong motivation to acquire technical knowledge, especially for EMNEs. In this paper, genetic distance is included in the research of cross-border R&D, which confirms that the mechanism of genetic distance's influence on cross-border R&D is different from that of cross-border trade, indicating that the role of genetic distance depends on the purpose of international investment. In the following, we will first review the literature, then discuss our research method and findings. We will conclude this paper with contributions to theory and practice.

2. Theory, Literature, and Hypothesis

Determinants of cross-border R&D performance

Cross-border R&D in this paper refers to companies who invest R&D capital and carry out R&D activities in overseas regions. At present, the relevant research can be divided into four subjects: one is to identify the driving forces of cross-border R&D (Arvanitis and Hollenstein, 2011; Buckley et al., 2016; Deng, 2009; Dunning and Lundan, 2009); the other is to compare and analyze the advantages and disadvantages of cross-border R&D entry modes (Wang et al., 2018; Williams and Vrabie, 2018); the third is to examine cross-border R&D performance (Ferraris et al., 2019; Penner-Hahn and Shaver, 2005; Rahko, 2016); the fourth is to explore the determinants or contextual factors that affect cross-border R&D performance (Berry, 2018; Hsu et al., 2015; Hurtado-Torres et al., 2018; Iwasa and Odagiri, 2004).

The determinants of cross-border R&D are diverse and can be subdivided into the individual-level, the enterprise-level, and the country- or region-level. Identifying the factors that affect cross-border R&D performance is helpful to guide the cross-border R&D activities of EMNEs theoretically. Individual-level determinants include the international experience (Liu et al., 2010), political connections (Su et al., 2019), tenure (Tschang and Ertug, 2016), shareholding, and demographic characteristics of executives and employees. Determinants at the enterprise-level include ownership (Kevin et al., 2017), absorptive capacity (Penner-Hahn and Shaver, 2005), knowledge network embeddedness (Berry, 2018), technological diversity (Almeida and Phene, 2004), and international experience (Hsu et al., 2015). Determinants at the country- or regional-level include cultural difference (Teixeira et al., 2008), geographical distance (Castellani et al., 2013), institutional distance (Ahammad et al., 2018), genetic distance

(Ahern et al., 2015), and technological capabilities (Iwasa and Odagiri, 2004).

The influence paths of the above determinants are also multiple. They can be direct effects, indirect effects through mediating variables, or moderating effects. For example, contextual leadership and transformational leadership have a direct impact on the innovation performance of international alliances in an individual-level study (Osborn and Marion, 2009). In the enterprise-level studies, knowledge network embeddedness of the host country has a direct impact on innovation performance (Berry, 2018), while technological diversity, intraorganizational linkages (Lahiri, 2010) and international experience (Hsu et al., 2015) have a significant moderating effect. Cultural and geographical distance, institutional differences (Choi and Contractor, 2016), and the local technological strength (Iwasa and Odagiri, 2004) have a direct impact on international R&D cooperation in the country- or region-level studies.

Also, different determinants are not completely independent. For example, whether the host country's scientific and technological advantages can be effectively exerted depends on the absorptive capacity at the enterprise level. The complementary effects of organizational absorptive capacity and political connections enhance innovation (Kotabe et al., 2016). The influence of positive and negative effects of genetic distance in this paper also depends on the international experience at the individual level and enterprise level. Figure 1 summarizes the theoretical framework of determinants for cross-border R&D performance, of which the research contents in this paper are in bold.

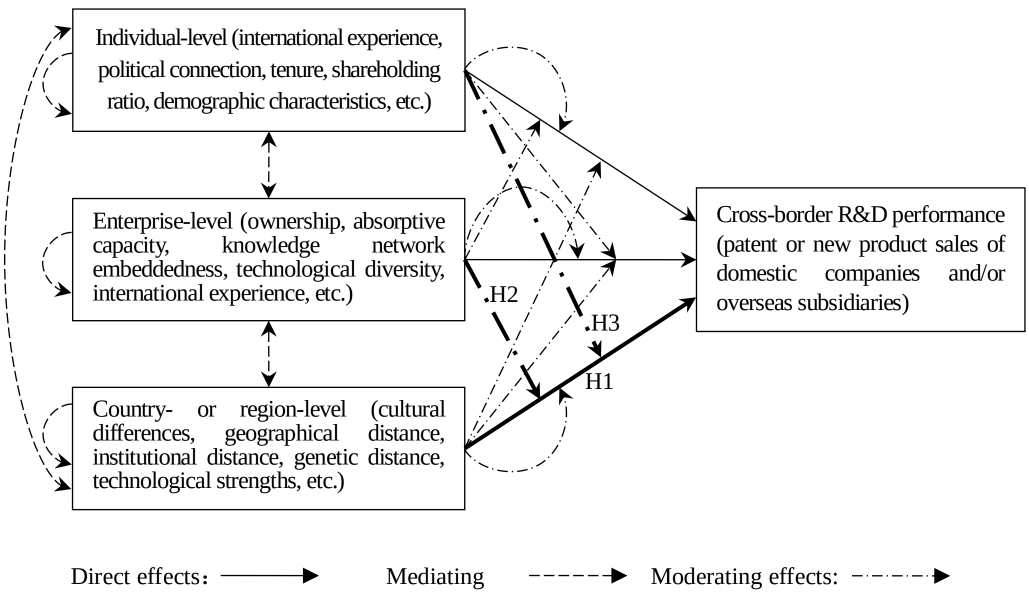

Fig 1 Theoretical framework of determinants for cross-border R&D performance

As a country- or region-level determinant, genes are gradually being used in the study of national distance and regional differences within countries, providing a new perspective for analyzing economic issues. As far as we know, there is no literature to explain the differences in cross-border R&D performance from the perspective of genetics, which is why we choose the genetic distance from many potential determinants.

Genetic distance and cross-border R&D performance

According to the knowledge-based view, tacit knowledge is an indispensable strategic resource for an enterprise to win long-term competitive advantage (Grant, 1996), and it is also the key to improving an MNE's innovation capability. However, since tacit knowledge is assumed to be “sticky”, it can only be acquired through face-to-face communication (Hakanson, 2010). This feature of tacit knowledge makes it necessary for enterprises to get close to the source of knowledge. It is the desire for tacit knowledge that drives enterprises to engage in cross-border R&D. Especially for enterprises from emerging economies, the search for strategic assets or knowledge drives them to carry out cross-border R&D (Deng, 2009; Dunning and Lundan, 2009). Genetic distance will change the transmission effect of tacit knowledge, and then affect the performance of cross-border R&D. Delis et al. (2017) believe that when analyzing genetic distance, both positive and negative effects should be considered.

From a positive perspective, first of all, genetic distance means that team members with different backgrounds and knowledge base look at problems from different perspectives. The collision of thoughts can bring many new ideas and solutions to problems (Page, 2007). For example, the R&D team expands the production possibility frontier by integrating and developing advanced knowledge and efficient production methods, thereby improving innovation efficiency (Ashraf and Galor, 2013). Second, genetic distance also means that members have their own unique innate skill advantages and knowledge accumulation, which can not only form complementary knowledge and skills, provide a solid foundation for the implementation of innovative ideas (Delis et al., 2017), but also can learn from each other to enhance their respective independent innovation capabilities. Finally, heterogeneous members caused by genetic distance create a more flexible team that can better respond to changes in the external environment (Ahern et al., 2015). Teece et al. (1997) and Broekaert et al. (2016) demonstrate the decisive role of organizational flexibility and adaptability to the environment in building competitive advantage and improving innovation performance. These effects are more prominent for EMNEs because they usually go to developed countries with advanced technology and face greater genetic differences.

In macro-level research, Ashraf and Galor (2013) find that the genetic heterogeneity of a country significantly increased technological productivity. Yan and Hu (2016) also point out that resource acquisition motivation can effectively alleviate the hindrance effect of genetic distance on OFDI, indicating that the effect of genetic distance depends on investment motivation. Cross-border R&D investment has a strong motivation for acquiring technical knowledge, so genetic distance and cross-border R&D performance may be positively correlated. In micro-level research, Delis et al. (2017) find that the genetic heterogeneity of board members can stimulate collision of thoughts and complementation of skills, thereby improving corporate performance.

From a negative perspective, the genetic distance increases barriers and mismatches in communication between R&D personnel. On the one hand, genetic distance inherits the characteristics of cultural distance, which means that people have great differences in language, values, behaviors, and business practices, which can easily cause communication barriers (Ang and Kumar, 2014; Spolaore and Wacziarg, 2016), leading to the lack of necessary trust between the two sides (Guiso et al., 2006, 2009), the direct consequence is reduced cooperation efficiency. For exploratory cross-border R&D, the misunderstanding and mistrust between the two parties can easily lead to more serious consequences, such as reducing the willingness of both parties to share knowledge and hindering the acquisition of implicit knowledge (Evangelista and Hau, 2009) and technology diffusion (Ang and Kumar, 2014; Spolaore and Wacziarg, 2009). On the other hand, genetic distance can also cause a target mismatch between teams (Ahern et al., 2015), which can occur within a single overseas R&D institution, between multiple overseas institutions, or even between the parent company and an overseas subsidiary. Mismatched goals increase the management costs of the parent company, such as the cost of resource integration caused by the reduction of shared resources among members, and the losses caused by local employees' strikes due to different value orientations. As we mentioned earlier, since EMNEs usually choose developed countries with advanced technology as their R&D host countries, these negative effects are also exacerbated as genetic distance increases.

The empirical studies that draw negative conclusions mainly come from the fields of international trade and cross-border mergers and acquisitions. Guiso et al. (2009), Bove and Gokmen (2018) have confirmed that the genetic distance between two countries will reduce mutual trust and further inhibit bilateral trade. Ahern et al. (2015) use genetic distance as an instrumental variable of cultural distance. The study finds that genetic distance significantly inhibits the scale of mergers and acquisitions of enterprises in the two countries and also reduces the joint excess returns of the two parties. Also, Spolaore and Wacziarg (2009) mention that genetic distance will exacerbate communication barriers, and then weaken the technology diffusion effect. However, Page (2007) points out that over time, members gradually learn how to seek common ground while shelving differences and collaboration becomes more tacit, which will reduce management costs. Based on the above analysis, the influence of genetic distance on cross-border R&D performance is both positive and negative, and the ultimate impact direction depends on which mechanism is dominant. Therefore, this paper proposes the following opposite hypothesis.

Hypothesis 1a: genetic distance has a positive impact on cross-border R&D performance;

Hypothesis 1b: genetic distance has a negative impact on cross-border R&D performance.

Moderating effect of international experience

The innovation practice of enterprises not only depends on the accumulation of internal technical knowledge, but also originates from external acquisition (Filatotchev et al., 2011), and "going out" is one of the important channels for EMNEs to obtain external resources. The experience can be used to lay the foundation for future cross-border investment. International experience, both at the enterprise-level and individual-level, is more helpful to EMNEs' foreign investment. Because enterprises from emerging economies usually lack overseas investment experience, internationalization experience has a more significant effect on improving overseas investment performance (Thakur-Wernz and Samant, 2019). Since executives are the ultimate makers of corporate strategic decisions, their international experience may have a more direct impact on cross-border R&D performance.

According to organizational learning theory, enterprises that are good at learning from experience have higher work efficiency (Levin, 2000). For EMNEs engaged in cross-border R&D, international experience can help them improve their innovation capabilities and efficiency. According to innovation theory, scientific research institutions, suppliers, distributors, and even peer companies are both an important source of innovation knowledge diffusion and an important driving force for innovation. EMNEs establish extensive and close ties with these foreign entities in the international cooperation can expose themselves to more advanced technological knowledge and advanced management concepts, which will not only help EMNEs improve their absorption capabilities, but also help inspire innovation. Besides, the more experience EMNEs have with overseas entities or the interaction with foreign scientists, the more familiar it is with the innovative ideas, models, and practices of overseas companies. EMNEs can improve their innovation efficiency and success rates by drawing on and introducing successful overseas experience.

International experience can also help EMNEs accumulate knowledge in entering overseas markets, enhance their ability to adapt to the new environment, and eliminate the liability of foreignness to a certain extent. On the one hand, international and experienced enterprises are exposed to more exotic cultures, which can promote enterprises to integrate into the local social and cultural environment faster, improve the communication and cooperation efficiency between home country personnel and local employees, and effectively reduce the uncertainty and cost caused by cultural differences (Hsu et al., 2015; Miller and Eden, 2006). On the other hand, the experience will become the "model" for enterprises to practice in the future, making enterprises more flexible in dealing with the relationship with overseas suppliers, customers and governments, such as forming a detailed emergency plan to deal with the possible discriminatory treatment of local governments (Miller and Eden, 2006).

Miller and Eden (2006) confirm that international experience[1] can significantly improve the ROA level of foreign commercial banks in the United States. Fu et al. (2018) pay attention to the moderating effect of international experience of enterprises and confirm that the number of overseas subsidiaries and export experience as moderating variables will significantly increase the patent output and new product sales revenue of Chinese enterprises. In summary, international experience can improve the willingness and innovation ability of cross-border investment of EMNEs. The mechanism behind it is derived from both the direct impact of knowledge accumulation and experience acquisition and the indirect impact of eliminating the liability of foreignness. Therefore, international experience can amplify the positive effects of

[1] It is measured by the time interval between the initial entry into the US market and the reporting period.

genetic distance, while mitigating the negative effects. Based on the above analysis, this paper proposes the following research hypotheses.

Hypothesis 2a: EMNEs with international experience will enhance the positive impact of genetic distance on cross-border R&D performance;

Hypothesis 2b: EMNEs with international experience will reduce the negative impact of genetic distance on cross-border R&D performance.

Absorbing returnees or transnational entrepreneurs is helpful to improve international experience and stimulate innovation for EMNEs (Zapata-Barrero and Rezaei, 2020). Therefore, recruiting returnees to join the top management team is another way for EMNEs to quickly enrich their international experience. The importance of executives' international experience is mainly reflected in four aspects: First, executives' overseas learning, training, and business practice experience make them the best carrier for overseas advanced technology transfer and play the role of "knowledge broker". Executives can integrate the acquired new knowledge with the original knowledge and skills of the enterprise and reshape it, which can improve the innovation ability of EMNEs (Filatotchev et al., 2011; Liu et al., 2010). Second, the deep and extensive connections accumulated by executives in overseas studies and work have broadened their relationship networks (Carpenter and Fredrickson, 2001; Liu et al., 2010), which is not only conducive to the future financing, M&A and overseas sales of EMNEs (Giannetti et al., 2014) but also helps them to understand the technological development trends in time (Liu et al., 2010), acquire more heterogeneous resources and form complementary with the original resources (Filatotchev et al., 2011). Third, overseas experience cultivates the global leadership and international vision of executives (Carpenter and Fredrickson, 2001), not only motivating enterprises to pursue innovation and break the original mindset when faced with difficulties (Slater and Dixon-Fowler, 2009) but also encouraging enterprises to consider independent innovation capabilities as their core competitiveness for long-term development and establish a correct outlook on growth (Giannetti et al., 2014), which will increase the innovation results of EMNEs. Fourth, managers with international experience have a stronger sense of intellectual property protection due to the influence and baptism of the concept of marketization and tend to patent innovations. Therefore, under the same R&D investment, the number of patent applications will increase, and more innovation output will be formed.

Similar to the international experience of enterprises, the overseas experience of executives also helps to weaken the liability of foreignness, because executives with an overseas background have a deeper understanding of exotic cultures. They already have personal experience in dealing with cross-ethnic and cross-cultural communication barriers, which is of practical help to improve the working efficiency of transnational teams and create a good organizational atmosphere.

In the existing literature, Carpenter and Fredrickson (2001) find that the international experience of executives will significantly increase the intensity of overseas investment by American companies. Giannetti et al. (2014) also confirm that there is a positive correlation between executives' international experience and the innovation and financial performance of Chinese companies. Liu and Giroud (2016) also point out that returnees are knowledge carriers, which can make up for the lack of international experience and enhance mutual trust with local partners. Liu et al. (2010) and Filatotchev et al. (2011) have all found that the role of returnee executives in promoting innovation in Chinese high-tech enterprises cannot be underestimated. Not only do they have higher patented assets, but they also generate significant knowledge spillovers. Roth (1995) finds that the CEO's international experience has a significant moderating effect and can bring higher returns to the company's global investment. Daily et al. (2000) have similar conclusions. In summary, the international experience of executives brings the advantages of knowledge transfer, network effects, vision development, and concept innovation. It can also overcome the liability of foreignness and has the effect of amplifying the positive effect of genetic distance and mitigating the negative effect. Based on the above analysis, this paper proposes the following research hypotheses.

Hypothesis 3a: Company executives with international experience will enhance the positive impact of genetic distance on cross-border R&D performance;

Hypothesis 3b: Company executives with international experience will weaken the negative impact of genetic distance on cross-border R&D performance.

Figure 2 summarizes the theoretical model of this paper.

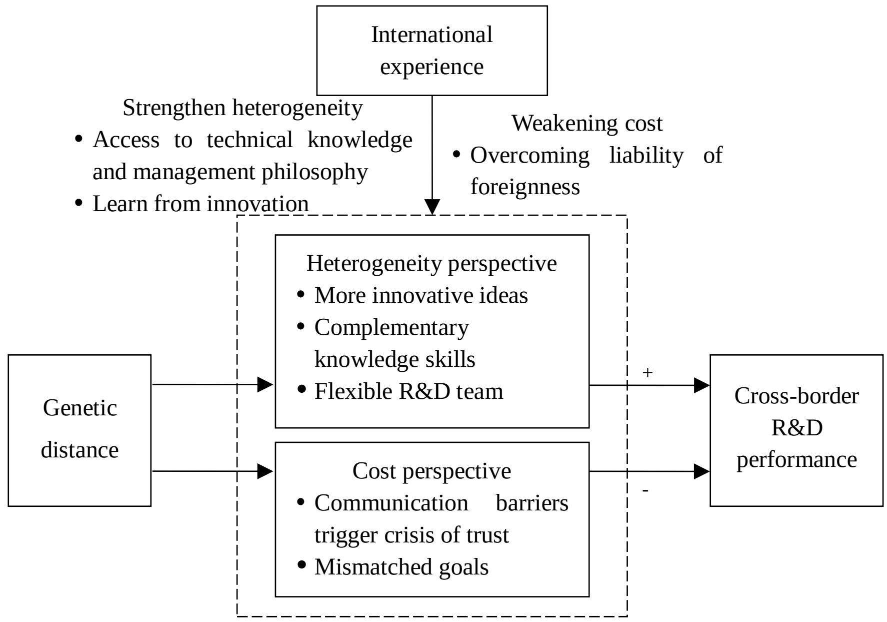

Fig 2 Theoretical model

3. Research Design

Sample and database

This paper selects Chinese A-share high-tech listed companies engaged in cross-border R&D between 2007 and 2014 as the sample. The selection of samples is based on two considerations: first, the high-tech companies have the characteristics of agglomeration of innovation factors and high levels of innovation activity, and in recent years have gradually become the "main force" of cross-border R&D; second, the choice takes into account the need for consistent statistical analysis and dynamic analysis.

For the identification of high-tech industries, this paper draws on the classification standards of (Todo and Shimizutani, 2008), covering electrical machinery and equipment manufacturing, chemical raw materials and chemical products manufacturing, computer, communications and other electronic equipment manufacturing, automotive manufacturing, software and information technology services, railways, ships, aerospace and other transportation equipment manufacturing, general equipment manufacturing, research and experimental development, pharmaceutical manufacturing, instrumentation manufacturing, professional technical services, special equipment manufacturing, a total of 12 industries.

For the identification of cross-border R&D, this paper combines Penner-Hahn and Shaver (2005) and related research on overseas investment, including four types: The first is that the parent company has set up a new subsidiary overseas and the subsidiary's business scope involves R&D activities; The second is the establishment of an independent overseas R&D center; Third, the parent company conducts cooperative R&D with overseas enterprises or scientific research institutions by establishing overseas joint laboratories or other modes; The fourth is that the parent company obtains control of the overseas company through acquisition and the latter's business scope involves R&D activities. Based on the above screening criteria, a total of 1347 observations were obtained for 338 companies.

Patent information in this paper comes from the CSMAR database. Missing values are filled using the patent database of China National Intellectual Property Administration (CNIPA). The original data of genetic distance is from the Alfred database. The identification of cross-border R&D and international experience at the enterprise level is obtained by manually reviewing the annual reports of listed companies and supplemented by the company's official website or large portals. International experience of the individual level is compiled through the relevant data in the CSMAR database; other company information comes from the CSMAR and Wind databases, and the data of provincial institutional environment comes from Fan Gang's “NERI INDEX of Marketization of China's Provinces 2011 Report”.

Models and variables

Patent data have the characteristics of overdispersion (see descriptive statistics below), Poisson regression underestimates the standard error and overestimate the significance (Almeida and Phene, 2004) when dealing with similar problems, while negative binomial regression will relax the hypothesis of the same distribution of mean and variance, and add additional parameters for the non-observable heterogeneity (Lahiri, 2010), so this paper uses negative binomial regression to estimate. To investigate the persistence of genetic distance and international experience in influencing cross-border R&D performance, this paper makes a short-term dynamic analysis. To alleviate the disturbance of outliers, all continuous variables in the controls are also winsorized at the 1% and 99% levels. The empirical models are as follows:

$$E(PAPPLY/IAPPLY_{i,t/t+1/t+2} \mid \mathbf{x}_{i,t}, \boldsymbol{\beta}) = \exp(\beta_0 + \beta_1 Gene_{i,t} + \beta_2 Controls_{i,t} + \varepsilon_{i,t}) \quad (1)$$

$$\begin{aligned} &E(PAPPLY/IAPPLY_{i,t/t+1/t+2} \mid \mathbf{x}_{i,t}, \boldsymbol{\gamma}) \\ &= \exp(\gamma_0 + \gamma_1 Gene_{i,t} + \gamma_2 Exp_{i,t} + \gamma_3 Gene_{i,t} \times Exp_{i,t} + \gamma_4 Controls_{i,t} + \varepsilon_{i,t}) \end{aligned} \quad (2)$$

Where *PAPPLY* and *IAPPLY* represent cross-border R&D performance, *Gene* represents genetic distance, *Exp* represents international experience, and *Controls* represents control variables. The sign and significance of β_1 in Equation (1) determine the test results of Hypothesis 1, and γ_3 in Equation (2) determines the test results of Hypothesis 2 and Hypothesis 3. The measurement method of each variable is explained below, and key variables are summarized in Table 1.

Cross-border R&D performance. The number of patents and sales revenue of new products of the parent company or subsidiaries can be used as proxy variables to measure cross-border R&D performance. Limited to data availability, this paper uses the number of patent applications of listed companies and their subsidiaries in China to measure cross-border R&D performance. Therefore, cross-border R&D performance to a large extent characterizes the innovation capabilities of EMNEs that carry out cross-border R&D activities. It reflects the role of cross-border R&D in enhancing the innovation capabilities of EMNEs. Since patents contain more technologies and can better reflect cross-border R&D, this paper constructs the following two variables: (1) The number of patent applications (*PAPPLY*) is equal to the total number of patent applications applied by listed companies and their home country subsidiaries in that year, including invention patents, utility models and designs;(2) The number of invention patent applications (*IAPPLY*) is equal to the number of invention patent applications applied by listed companies and their home country subsidiaries in that year.

Genetic distance. In short, genetic distance calculates the difference in allele frequencies across a set of loci. A gene is a DNA sequence that encodes protein information. A locus is the position of a gene on a chromosome. An allele is a smaller concept. It is a form of a gene and controls a certain trait, such as human skin, pupil color (Giuliano et al., 2014) or blood type (Ang and Kumar, 2014). Allele frequency refers to the frequency of gene variants or alleles in the sample population, such as the probability of pupil color being brown or blue (Ashraf and Galor, 2013). In practice, neutral alleles are generally selected for calculation, mainly because neutral alleles have random mutations and evolve at a constant rate (Spolaore and Wacziarg, 2011), which more objectively reflects the internal evolutionary history of the ethnic group and excludes the pressure imposed by the external environment (Giuliano et al., 2014).

In terms of calculation methods, the current mainstream is the Fst and Nei's calculation methods. If a new gene mutation occurs in the survey interval, the Fst calculation method is more accurate; Nei's method is more accurate if the genetic variation mainly comes from drift and mutations (Ang and Kumar, 2014). Given the actual situation of modern human evolution, this paper draws on the practice of Ang and Kumar (2014), uses the Fst algorithm in benchmark regression, and puts the Nei algorithm in the robustness test. This paper calculates genetic distance based on the dominant ethnic groups in two countries or regions. The correspondence between countries and ethnic groups refers to the Alfred database and the CIA Factbook country-to-ethnic correspondence table. The formula for calculating Fst is (Guiso et al., 2009; Reynolds et al., 1983):

$$Gene\_Fst_{ij} = \frac{\sum_m \sum_k \left(p_{imk} - p_{jmk}\right)^2}{2\sum_m \left(1 - \sum_k p_{imk} p_{jmk}\right)} \tag{3}$$

Where p_{imk} represents the frequency of the k-th allele at the m-th locus in the dominant population of country or region i. p_{jmk} represents the frequency of the k-th allele at the m-th locus in the dominant population of the country or region j.

Nei's calculation formula is (Nei, 1978):

$$Gene\_Nei_{ij} = -\ln\left(\frac{J_{ij}}{\sqrt{J_i J_j}}\right) \tag{4}$$

Where $J_{ij} = \frac{1}{m}\sum_m \sum_k p_{imk} p_{jmk}$, $J_i = \frac{1}{m}\sum_m \sum_k p_{imk}^2$ and $J_j = \frac{1}{m}\sum_m \sum_k p_{jmk}^2$. The definition of p_{imk} and p_{jmk} is consistent with the formula (3).

Spolaore and Wacziarg (2009, 2011), Ang and Kumar (2014) all introduce the concept of relative genetic distance to measure the genetic heterogeneity between countries *i* and *j*. Different from the absolute genetic distance in formulas (3) and (4), the relative genetic distance needs to determine a technological frontier country or region, and then calculate the difference between the genetic distance of *i* and *j* relative to the technological frontier. Spolaore and Wacziarg (2009) point out that relative genetic distance is more practical when examining the effect of technology diffusion because the relative differences between the two countries/regions and the frontier country or region can capture the effect of technology diffusion and learning. Referring to the practices of the above literature, this paper uses the United States as a technologically advanced country to construct the relative genetic distance. The calculation formula is as follows:

$$Gene\_RFst_{ij} = \left| Gene\_Fst_{i,US} - Gene\_Fst_{j,US} \right| \tag{5}$$

$$Gene\_RNei_{ij} = \left| Gene\_Nei_{i,US} - Gene\_Nei_{j,US} \right| \tag{6}$$

International experience. This paper defines international experience from two dimensions: the enterprise level and the executive level. (1) The measurement of enterprise international experience (Exp_lc and Exp_lc^{robust}) is equal to the total number of overseas investment entities of listed companies in that year. Considering that some overseas investments are for tax avoidance purposes and limited experience can be accumulated during the investment process, the robustness test excludes investment entities in places such as BVI and Cayman Islands. (2) We use the following two measures for executive international experience: construct a dummy variable Exp_tm in the benchmark regression, and take 1 when the directors, supervisors, and senior managers (TMT) of listed companies have overseas employment and study experience, otherwise, take 0; *Exp_tm*^{robust} is constructed and used in the robustness test, which is equal to the number of TMT who have the above-mentioned overseas background.

Control variables. Based on previous research (Colombo et al., 2009; Lahiri, 2010; Tzabbar and Vestal, 2015), this paper adds company and regional control variables to the econometric models, including: (1) *Age*, the difference between the reporting year and the year of establishment; (2) state ownership (*State*), whether it is a state-owned enterprise; (3) venture capital (*VC*), whether it is funded by VC or PE; (4) the size of the enterprise (*Size*), the natural logarithm of total assets; (5) absorptive capacity (*Capability*), the ratio of R&D expenditures to main business income; (6) return on assets (*ROA*), the ratio of net profit to total assets at the end of the year; (7) executive education (*Edu*), chiefly the education of CEO, president and general manager, supplemented by the education of the chairman when it is missing; (8) operating cash flow (*Cashflow*), the ratio of cash flow to operating income; (9) the average tenure of TMT (*Tenure*), the ratio of the total tenure of TMT (calculated in years) to the number of TMT; (10) the degree of equity concentration (*TOP*), the sum of the shareholding of the top five shareholders; (11) institutional environment of the parent company's location (*Institution*), which is measured by the total score of the marketization process published by Fan et al. (2011). The missing value is predicted by the quadratic exponential smoothing method. Also, industry, province and year effects are controlled in the models.

Table 1 Definition and data source of key variables in the regression

Variable	Definition	Data Source
PAPPLY	The total number of patent applications applied by listed companies and their home country subsidiaries in one year, including invention patents, utility models and designs	CSMAR & CNIPA
IAPPLY	The number of invention patent applications applied by listed companies and their home country subsidiaries in one year	

Gene_Fst	According to Reynolds et al. (1983) and Guiso et al. (2009), see formula (3)	Alfred
Gene_Nei	According to Nei (1978), see formula (4)	
Gene_RFst	According to Spolaore and Wacziarg (2009, 2011) and Ang and Kumar (2014), see formula (5) and (6)	
Gene_RNei		
Exp_lc	The total number of overseas investment entities of listed companies in one year	Annual reports of listed companies
Exp_tm	A dummy variable, take 1 if TMT has overseas work or study experience, take 0 if otherwise	CSMAR

4. The Benchmark Regression Results

Descriptive statistics

Table 2 is the descriptive statistics for the key variables in this paper. It can be seen from the mean and standard deviation that listed companies engaged in cross-border R&D generally have higher patent output. The companies in the sample have an average of 177 patent applications per year, and the number of invention patent applications is approximately 91. The standard deviation is also large, indicating a large difference within the sample. The average value of *Exp_lc* indicates that the sample observations have an average of about 5.4 overseas investment entities each year, but this number is far less than the standard deviation, indicating that there are some differences in the international experience of the sample companies. Statistical results of *Exp_tm* show that about 61.4% of the executives in the observations have an overseas background.

From the correlation coefficient, absolute and relative genetic distance are significantly positively related to patents, indicating that genetic distance may have the effect of improving cross-border R&D performance. There is also a significant positive relationship between international experience and patents, indicating that international experience is crucial to the improvement of cross-border R&D performance.

Table 2 Descriptive statistics

Variable	Mean	Std	1	2	3	4	5	6	7	8
PAPPLY	177.057	534.995	1.000							
IAPPLY	91.427	391.725	0.928^{***}	1.000						
Gene_Fst	0.183	0.166	0.259^{***}	0.232^{***}	1.000					
Gene_RFst	0.088	0.066	0.127^{***}	0.094^{***}	0.515^{***}	1.000				
Gene_Nei	0.117	0.133	0.335^{***}	0.318^{***}	0.862^{***}	0.449^{***}	1.000			
Gene_RNei	0.055	0.061	0.103^{***}	0.053^{*}	0.535^{***}	0.752^{***}	0.675^{***}	1.000		
Exp_lc	5.446	11.700	0.494^{***}	0.514^{***}	0.220^{***}	0.146^{***}	0.275^{***}	0.086^{***}	1.000	
Exp_tm	0.614	0.487	0.094^{***}	0.084^{***}	-0.079^{***}	-0.005	-0.083^{***}	-0.052^{*}	0.133^{***}	1.000

Note：*** p<0.01，** p<0.05，* p<0.1.

Results of Hypothesis 1

Table 3 reports the regression results of Fst genetic distance and cross-border R&D performance. The odd number column uses *PAPPLY* as the dependent variable, and the even number column uses *IAPPLY* as the dependent variable. In columns (1) to (6), genetic distance and all control variables are measured for year t when the dependent variable is measured for year t, t+1, and t+2. The results show that the effect of *Gene_Fst* is significant and positive (p<0.01), indicating that the influence mechanism of genetic distance in cross-border R&D is different from international trade and cross-border mergers and acquisitions. That is, the positive effects of genetic heterogeneity are greater than the negative effects of communication barriers, and this positive effect has short-term persistence. Take column (1) as an example, when the genetic distance increases by one standard deviation, the total number of patent applications increases by about 18 ($\approx 0.619 \times 177.057 \times 0.166$); take column (2) as an example, when the genetic distance increases by one standard deviation, the number of invention patent applications increased by about 10 ($\approx 0.706 \times 91.427 \times 0.166$). The coefficient Alpha in each model is significant (p<0.01), confirming that the negative binomial model is better than the

Poisson model.

Table 3 Regression results of Fst genetic distance and cross-border R&D performance

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	PAPPLY	*IAPPLY*	*PAPPLY*	*IAPPLY*	*PAPPLY*	*IAPPLY*
	t		t+1		t+2	
Gene_Fst	0.619***	0.706***	0.736***	0.823***	0.667***	0.742***
	(0.230)	(0.249)	(0.220)	(0.235)	(0.222)	(0.247)
Age	0.007	0.016	0.005	0.014	0.008	0.015
	(0.009)	(0.010)	(0.009)	(0.010)	(0.009)	(0.011)
State	0.017	0.164	0.084	0.263***	0.179*	0.369***
	(0.095)	(0.101)	(0.093)	(0.101)	(0.092)	(0.104)
VC	-0.136	-0.178*	-0.127	-0.171*	-0.101	-0.236**
	(0.087)	(0.098)	(0.079)	(0.090)	(0.088)	(0.102)
Size	0.848***	0.945***	0.799***	0.877***	0.760***	0.827***
	(0.039)	(0.041)	(0.037)	(0.039)	(0.040)	(0.043)
Capability	3.816***	7.318***	2.630***	5.964***	1.601*	4.375***
	(0.886)	(0.996)	(0.838)	(0.954)	(0.825)	(0.948)
ROA	1.003	1.803**	3.314***	3.761***	3.947***	4.687***
	(0.780)	(0.847)	(0.773)	(0.862)	(0.743)	(0.823)
Edu	-0.002	-0.057	0.037	-0.000	0.031	-0.011
	(0.041)	(0.047)	(0.039)	(0.045)	(0.038)	(0.045)
Cashflow	0.137	0.307	-0.121	0.170	-0.025	0.057
	(0.342)	(0.371)	(0.318)	(0.363)	(0.329)	(0.360)
Tenure	0.019	-0.016	0.001	-0.055	-0.013	-0.074**
	(0.031)	(0.035)	(0.030)	(0.035)	(0.032)	(0.037)
TOP	-0.002	-0.003	-0.002	-0.003	-0.005*	-0.006*
	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)
Institution	0.050	0.057	0.065	0.087	0.103	0.150
	(0.069)	(0.072)	(0.067)	(0.076)	(0.085)	(0.099)
Constant	-14.697***	-18.219***	-13.346***	-16.509***	-12.257***	-14.975***
	(0.888)	(1.026)	(0.888)	(1.029)	(0.908)	(1.044)
Ind/Prov/Year FE	Y	Y	Y	Y	Y	Y
Pseudo R^2	0.101	0.123	0.098	0.114	0.092	0.103
Alpha	0.971***	1.134***	0.935***	1.131***	0.949***	1.160***
N	1,096	1,096	1,112	1,112	1,112	1,112

Note: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Table 4 reports the regression results of Fst relative genetic distance and cross-border R&D performance. The *Gene_RFst* coefficient is significant and positive (p<0.01), indicating that whether it is absolute genetic distance or relative genetic distance, it will significantly improve the company's cross-border R&D performance and be sustainable in the short term. The absolute value of the coefficient of relative genetic distance is greater than the absolute genetic distance, suggesting that the relative genetic distance has a greater direct contribution to performance, which coincides with extant research on the view that relative genetic distance has a stronger economic interpretation. Specifically, taking column (1) as an example, when the relative genetic distance increases by one standard deviation, the total number of patent applications increases by about 26 ($\approx 2.260 \times 177.057 \times 0.066$); Take column (2) as an example. When the relative genetic distance increases by one standard deviation, the number of invention patent applications increases by about 13 ($\approx 2.191 \times 91.427 \times 0.066$). In summary, H1a is supported.

Table 4 Regression results of Fst relative genetic distance and cross-border R&D performance

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	PAPPLY	*IAPPLY*	*PAPPLY*	*IAPPLY*	*PAPPLY*	*IAPPLY*
	t		t+1		t+2	
Gene_RFst	2.260^{***}	2.191^{***}	2.084^{***}	2.137^{***}	2.207^{***}	1.993^{***}
	(0.590)	(0.649)	(0.570)	(0.628)	(0.595)	(0.684)
Age	0.008	0.016	0.005	0.014	0.008	0.014
	(0.009)	(0.010)	(0.009)	(0.010)	(0.009)	(0.011)
State	0.016	0.149	0.079	0.236^{**}	0.173^{*}	0.339^{***}
	(0.095)	(0.102)	(0.094)	(0.101)	(0.091)	(0.103)
VC	-0.163^{*}	-0.203^{**}	-0.152^{*}	-0.196^{**}	-0.124	-0.255^{**}
	(0.086)	(0.097)	(0.079)	(0.090)	(0.088)	(0.102)
Size	0.851^{***}	0.962^{***}	0.815^{***}	0.905^{***}	0.773^{***}	0.853^{***}
	(0.037)	(0.038)	(0.035)	(0.038)	(0.039)	(0.043)
Capability	3.896^{***}	7.507^{***}	2.663^{***}	6.061^{***}	1.541^{*}	4.380^{***}
	(0.907)	(1.015)	(0.849)	(0.967)	(0.837)	(0.955)
ROA	0.616	1.394	3.002^{***}	3.411^{***}	3.587^{***}	4.324^{***}
	(0.789)	(0.866)	(0.781)	(0.874)	(0.759)	(0.852)
Edu	0.002	-0.056	0.042	0.005	0.039	-0.006
	(0.041)	(0.047)	(0.039)	(0.045)	(0.038)	(0.044)
Cashflow	0.219	0.389	-0.038	0.259	0.065	0.145
	(0.343)	(0.371)	(0.318)	(0.362)	(0.325)	(0.358)
Tenure	0.022	-0.011	0.006	-0.049	-0.006	-0.066^{*}
	(0.031)	(0.035)	(0.030)	(0.035)	(0.032)	(0.037)
TOP	-0.002	-0.002	-0.002	-0.002	-0.004^{*}	-0.006^{*}
	(0.003)	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)
Institution	0.037	0.042	0.055	0.076	0.084	0.133
	(0.070)	(0.074)	(0.067)	(0.076)	(0.082)	(0.096)
Constant	-14.873^{***}	-18.704^{***}	-13.814^{***}	-17.265^{***}	-12.617^{***}	-15.561^{***}
	(0.876)	(0.996)	(0.862)	(0.991)	(0.881)	(1.020)
Ind/Prov/Year FE	Y	Y	Y	Y	Y	Y
Pseudo R^2	0.102	0.124	0.098	0.114	0.092	0.103
Alpha	0.964^{***}	1.129^{***}	0.933^{***}	1.130^{***}	0.944^{***}	1.158^{***}
N	1,096	1,096	1,112	1,112	1,112	1,112

Note: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Results of Hypothesis 2 and 3

The regression results in Table 5 show the moderating effect of international experience at the enterprise level. In Panel A, the coefficient of *Gene_FstxExp_lc* is significantly positive in each model, indicating that international experience at the enterprise level can strengthen the positive impact of genetic distance on cross-border R&D performance. This conclusion shows that the company's previous experience in cross-border investment, export trade, and international cooperation has a strong reference role for cross-border R&D, which may alleviate communication barriers and mismatched goals caused by foreign cultures, and make companies fewer detours. It can also help companies improve their innovation capabilities and efficiency. Interestingly, the coefficient of *Exp_lc* is significantly negative in some models, probably because its direct effect is absorbed by *Gene_FstxExp_lc*. In Panel B, the interaction term *Gene_RFstxExp_lc* constructed from relative genetic distance is also significantly positive, further confirming the moderating role of enterprise international experience. Therefore, Hypothesis 2a is supported.

Table 5 Regression results of Fst (relative) genetic distance, enterprise international experience and cross-border R&D performance

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	PAPPLY	*IAPPLY*	*PAPPLY*	*IAPPLY*	*PAPPLY*	*IAPPLY*
	t		t+1		t+2	
Panel A						
Gene_Fst	0.365	0.304	0.531**	0.462*	0.489**	0.382
	(0.249)	(0.266)	(0.236)	(0.251)	(0.235)	(0.257)
Exp_lc	-0.011***	-0.011***	-0.012***	-0.012***	-0.000	-0.002
	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)
Gene_FstxExp_lc	0.047***	0.062***	0.044***	0.060***	0.023*	0.044***
	(0.010)	(0.011)	(0.010)	(0.010)	(0.012)	(0.013)
Constant	-14.558***	-17.568***	-13.373***	-16.068***	-11.525***	-13.731***
	(1.006)	(1.139)	(0.985)	(1.131)	(1.029)	(1.147)
Controls/Ind/Prov/Year	Y	Y	Y	Y	Y	Y
Pseudo R^2	0.102	0.125	0.099	0.115	0.092	0.104
Alpha	0.961***	1.116***	0.926***	1.114***	0.946***	1.148***
N	1,096	1,096	1,112	1,112	1,112	1,112

			Panel B			
Gene_RFst	1.943***	1.723**	1.829***	1.718***	1.890***	1.504**
	(0.608)	(0.670)	(0.585)	(0.645)	(0.615)	(0.701)
Exp_lc	-0.005	-0.001	-0.006**	-0.003	-0.001	0.002
	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)
Gene_RFstxExp_lc	0.159***	0.188***	0.154***	0.192***	0.123**	0.164***
	(0.041)	(0.042)	(0.033)	(0.039)	(0.051)	(0.056)
Constant	-14.501***	-17.543***	-13.696***	-16.402***	-11.941***	-14.292***
	(1.048)	(1.185)	(1.012)	(1.164)	(1.011)	(1.137)
Controls/Ind/Prov/Year	Y	Y	Y	Y	Y	Y
Pseudo R^2	0.102	0.124	0.099	0.114	0.093	0.104
Alpha	0.961***	1.122***	0.930***	1.123***	0.941***	1.150***
N	1,096	1,096	1,112	1,112	1,112	1,112

Note: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

The regression results in Table 6 show the moderating role of international experience at the executive level. Combining the estimation results of *Gene_FstxExp_tm* and *Gene_RFstxExp_tm*, it can be found that internationally experienced executives have a positive effect on expanding the positive effects of genetic distance while reducing the negative impact, and then have a significant contribution to strengthening the positive impact of genetic distance on cross-border R&D performance. Therefore, Hypothesis 3a is supported.

Table 6 Regression results of Fst (relative) genetic distance, executive international experience and cross-border R&D performance

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	PAPPLY	*IAPPLY*	*PAPPLY*	*IAPPLY*	*PAPPLY*	*IAPPLY*
	t		t+1		t+2	
			Panel A			
Gene_Fst	0.158	0.012	0.312	0.236	-0.043	-0.217
	(0.358)	(0.368)	(0.348)	(0.378)	(0.342)	(0.391)
Exp_tm	0.027	0.034	0.024	0.035	0.018	0.024
	(0.081)	(0.090)	(0.078)	(0.085)	(0.074)	(0.086)
Gene_FstxExp_tm	0.787*	1.134**	0.721*	0.985**	1.198***	1.527***
	(0.453)	(0.457)	(0.438)	(0.462)	(0.441)	(0.488)
Constant	-14.399***	-17.705***	-12.658***	-15.685***	-11.485***	-14.091***
	(0.982)	(1.094)	(0.998)	(1.134)	(0.978)	(1.091)
Controls/Ind/Prov/Year	Y	Y	Y	Y	Y	Y
Pseudo R^2	0.102	0.123	0.098	0.113	0.093	0.104
Alpha	0.970***	1.134***	0.938***	1.133***	0.935***	1.138***
N	1,060	1,060	1,076	1,076	1,076	1,076
			Panel B			
Gene_RFst	0.424	0.800	0.275	1.265	0.440	1.565
	(0.960)	(1.034)	(0.900)	(0.987)	(0.872)	(1.025)
Exp_tm	-0.005	0.005	-0.008	0.005	-0.007	0.001

	(0.079)	(0.089)	(0.076)	(0.085)	(0.072)	(0.086)
Gene_RFstxExp_tm	3.005**	2.351*	2.949***	1.548	2.984***	0.936
	(1.219)	(1.272)	(1.134)	(1.218)	(1.069)	(1.200)
Constant	-14.829***	-18.560***	-13.393***	-16.835***	-12.247***	-15.214***
	(0.928)	(1.009)	(0.922)	(1.036)	(0.890)	(1.014)
Controls/Ind/Prov/Year	Y	Y	Y	Y	Y	Y
Pseudo R^2	0.103	0.123	0.099	0.113	0.094	0.104
Alpha	0.960***	1.131***	0.933***	1.134***	0.930***	1.143***
N	1,060	1,060	1,076	1,076	1,076	1,076

Note: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Comparing the results of Table 5 and Table 6, we find that the coefficient of the interaction term for executives' international experience is greater than the coefficient at the enterprise level, suggesting that the role of executive international experience in strengthening the effect of genetic distance is more prominent. There may be two reasons: First, according to the upper echelons theory, executives are the ultimate decision-makers of enterprise strategy. This attribute means that enterprise strategic decisions are viewed as reflections of executive characteristics. Naturally, compared with the internationally experienced companies, the executive's overseas background has a more important role in determining the level of performance; Second, the international experience of executives and enterprises has the role of transferring and acquiring cutting-edge technological knowledge. Also, internationally experienced executives have interpersonal network effects and a stronger sense of innovation and intellectual property protection, so under the same conditions, they will significantly increase patent output.

5. Robustness Test

The robustness test of this paper is divided into seven parts: First, we change the measurement method of genetic distance and adopt Nei's method to prove that the conclusions of this paper are not restricted by specific algorithms. Second, the enterprise-level measurement of international experience is adjusted to exclude the investment locations for tax avoidance. We also use the number of TMT with an overseas background as a new measure at the individual level and replace the original variable. Third, Giuliano et al. (2014) believe that geographical distance is strongly related to genetic distance. Their study finds that the effect of genetic distance on trade no longer exists when the geographic distance is controlled. If the above view is true, the significant role of genetic distance in this paper may be an illusion caused by our neglect of geographic distance. To eliminate this endogenous problem, we add geographic distance to the control variable[2] and reestimate each model. Fourth, companies' cross-border investment decisions may be affected by the financial crisis. For this reason, we have removed the sample from 2008 to 2009 to exclude the economic turbulence from interfering with the research results. Fifth, we calculate the true moderation effect of international experience to further confirm the reliability of our research results. Sixth, considering that we think the increase in genetic distance helps EMNEs acquire complementary knowledge skills, we use a mediating effect test to verify this. Finally, since the research conclusions of this paper are different from the relevant literature in the field of international trade, we use the variable of linguistic distance to interpret the influencing path of communication barriers in Figure 2 to explain why this inconsistent conclusion arises. With reference to Guiso et al. (2009) and Spolaore and Wacziarg (2009), the variable of linguistic distance is measured by the number of common roots or nodes of language families, and the

[2] It is equal to the natural logarithm of the spherical distance between the capital of each country and Beijing. When the sample involves China's Hong Kong, Macao and Taiwan,the geographical distance is equal to the natural logarithm of the spherical distance between each of them and Beijing. The data is taken from CEPII.

data is taken from Ethnologue.

Table 7 reports the results of Nei's (relative) genetic distance. Panel A is the main effect test. The estimated results of *Gene_Nei* and *Gene_RNei* are similar to Fst. Not only are the coefficients significantly positive, but the absolute value of the relative distance coefficient is greater than the absolute distance, suggesting that genetic distance has a significant positive impact on cross-border R&D performance and relative genetic distance may have a stronger interpretation. Panel B is a test of the moderating effects of *Exp_lc*. It is found that enterprise international experience has a significant positive moderating effect in general and contributes more to invention patents. Panel C is a moderating effect test of *Exp_tm* and found that the interaction terms are significantly positive ($p<0.01$). In conclusion, the results of this paper do not depend on the specific algorithm of genetic distance.

Table 7 Regression results of Nei's (relative) genetic distance

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	PAPPLY	*IAPPLY*	*PAPPLY*	*IAPPLY*	*PAPPLY*	*IAPPLY*
	t		t+1		t+2	
Panel A: Main Effects						
Gene_Nei	0.763***	0.869***	0.767***	0.951***	0.647***	0.854***
	(0.234)	(0.276)	(0.230)	(0.276)	(0.240)	(0.296)
Gene_RNei	2.155***	1.500**	1.933***	1.340**	1.754***	0.872
	(0.584)	(0.638)	(0.552)	(0.608)	(0.566)	(0.634)
Panel B: Moderating Effects of *Exp_lc*						
Gene_NeixExp_lc	0.030***	0.039***	0.032***	0.042***	0.010	0.024**
	(0.010)	(0.011)	(0.009)	(0.010)	(0.011)	(0.012)
Gene_RNeixExp_lc	0.091	0.257***	0.050	0.217**	0.024	0.180**
	(0.086)	(0.098)	(0.082)	(0.102)	(0.072)	(0.081)
Panel C: Moderating Effects of *Exp_tm*						
Gene_NeixExp_tm	1.553***	2.163***	1.451***	2.140***	1.693***	2.414***
	(0.510)	(0.562)	(0.487)	(0.548)	(0.489)	(0.576)
Gene_RNeixExp_tm	4.635***	4.383***	4.388***	4.080***	4.368***	3.629***
	(1.202)	(1.252)	(1.110)	(1.192)	(1.047)	(1.135)

Note: Robust standard errors in parentheses, *** $p<0.01$, ** $p<0.05$, * $p<0.1$, the table contains 36 regression models.

Panel A in Table 8 reports the regression results of Exp_lc^{robust} as a moderator. Exp_lc^{robust}

excludes investment locations for tax avoidance based on *Exp_lc*. It is found that the coefficient sign and significance of each interaction term are similar to the original models, indicating that investment in tax havens has a limited role in promoting technological innovation. In Panel B, we change the measurement method for the international experience of executives. Exp_tm^{robust} is used to measure the number of TMT with overseas background and is an indicator of the degree of international experience. It is found that the interaction terms constructed by Exp_tm^{robust} are significantly positive in some models, but the interpretation is not as good as *Exp_tm*, which shows that for cross-border R&D companies, whether TMT has international experience is more important than the degree to which TMT has international experience, but it is undeniable that companies with more overseas backgrounds still have certain advantages.

Table 8 Regression results of changing the measure of international experience

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	PAPPLY	*IAPPLY*	*PAPPLY*	*IAPPLY*	*PAPPLY*	*IAPPLY*
	t		t+1		t+2	
Panel A: Moderating Effects of Exp_lc^{robust}						
$Gene\_FstxExp\_lc^{robust}$	0.063***	0.081***	0.060***	0.079***	0.024*	0.048***
	(0.012)	(0.014)	(0.013)	(0.013)	(0.015)	(0.016)
$Gene\_RFstxExp\_lc^{robust}$	0.240***	0.256***	0.240***	0.268***	0.189**	0.227***
	(0.058)	(0.058)	(0.049)	(0.056)	(0.074)	(0.077)
$Gene\_NeixExp\_lc^{robust}$	0.037***	0.044***	0.040***	0.050***	0.010	0.025*
	(0.011)	(0.015)	(0.011)	(0.013)	(0.012)	(0.013)
$Gene\_RNeixExp\_lc^{robust}$	0.093	0.274**	0.049	0.226**	0.021	0.185**
	(0.085)	(0.118)	(0.077)	(0.114)	(0.067)	(0.084)
Panel B: Moderating Effects of Exp_tm^{robust}						
$Gene\_FstxExp\_tm^{robust}$	0.176	0.197*	0.168	0.155	0.332***	0.321***
	(0.110)	(0.114)	(0.107)	(0.115)	(0.113)	(0.122)
$Gene\_RFstxExp\_tm^{robust}$	0.408	0.146	0.369	-0.083	0.520*	0.009
	(0.338)	(0.342)	(0.309)	(0.317)	(0.302)	(0.316)
$Gene\_NeixExp\_tm^{robust}$	0.318**	0.381***	0.330***	0.366***	0.465***	0.491***
	(0.125)	(0.136)	(0.121)	(0.137)	(0.133)	(0.150)
$Gene\_RNeixExp\_tm^{robust}$	0.745**	0.638*	0.756**	0.460	0.888***	0.534*
	(0.335)	(0.338)	(0.302)	(0.310)	(0.300)	(0.305)

Note: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1, the table contains 48 regression models.

Table 9 reports the regression results for controlling geographic distance. The results show that geographic distance does dilute the effect of genetic distance to a certain extent. The reason may be that geographic distance forms a geographical barrier and determines the migration route of the ancestors of the ethnic group, and then changes the mutation, drift and evolution direction of the gene, which plays a significant role in distinguishing between the ethnic groups (Giuliano et al., 2014). Statistically, geographic distance is also highly correlated with genetic distance, with a correlation coefficient between 0.412 and 0.734 and significant at the 1% level. However, it should be emphasized that controlling geographical distance is not enough to eliminate the effect of genetic distance, and the positive effect of genetic distance on cross-border R&D performance is still valid. Therefore, the control of geographic distance will not change the empirical results of this paper.

Table 9 Regression results for controlling geographical distance

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	PAPPLY	*IAPPLY*	*PAPPLY*	*IAPPLY*	*PAPPLY*	*IAPPLY*
	t		t+1		t+2	
Panel A: Main Effects						
Gene_Fst	0.414^{*}	0.385	0.622^{***}	0.588^{**}	0.499^{**}	0.462^{*}
	(0.241)	(0.255)	(0.235)	(0.247)	(0.244)	(0.272)
Gene_RFst	2.322^{***}	0.981	2.376^{***}	1.410	2.310^{***}	0.888
	(0.864)	(0.845)	(0.845)	(0.886)	(0.884)	(0.958)
Gene_Nei	0.575^{**}	0.581^{**}	0.626^{***}	0.711^{**}	0.458^{*}	0.585^{*}
	(0.236)	(0.278)	(0.234)	(0.279)	(0.246)	(0.307)
Gene_RNei	1.749^{***}	0.697	1.614^{***}	0.606	1.334^{**}	0.044
	(0.590)	(0.615)	(0.562)	(0.588)	(0.567)	(0.601)
Panel B: Moderating Effects of *Exp_lc*						
Gene_FstxExp_lc	0.052^{***}	0.068^{***}	0.047^{***}	0.064^{***}	0.026^{**}	0.049^{***}
	(0.011)	(0.011)	(0.010)	(0.011)	(0.012)	(0.014)
Gene_RFstxExp_lc	0.160^{***}	0.205^{***}	0.152^{***}	0.202^{***}	0.123^{**}	0.180^{***}
	(0.042)	(0.042)	(0.034)	(0.039)	(0.052)	(0.057)
Gene_NeixExp_lc	0.034^{***}	0.045^{***}	0.035^{***}	0.047^{***}	0.013	0.029^{**}
	(0.010)	(0.011)	(0.009)	(0.010)	(0.011)	(0.012)
Gene_RNeixExp_lc	0.117	0.309^{***}	0.073	0.270^{***}	0.050	0.232^{***}
	(0.081)	(0.085)	(0.079)	(0.090)	(0.069)	(0.075)
Panel C: Moderating Effects of *Exp_tm*						
Gene_FstxExp_tm	0.738	1.020^{**}	0.687	0.892^{*}	1.124^{***}	1.383^{***}
	(0.455)	(0.456)	(0.439)	(0.456)	(0.432)	(0.467)
Gene_RFstxExp_tm	3.080^{**}	2.113^{*}	3.032^{***}	1.382	3.021^{***}	0.632
	(1.251)	(1.283)	(1.154)	(1.220)	(1.088)	(1.192)
Gene_NeixExp_tm	1.531^{***}	2.103^{***}	1.430^{***}	2.069^{***}	1.636^{***}	2.287^{***}

	(0.512)	(0.560)	(0.488)	(0.545)	(0.482)	(0.561)
Gene_RNeixExp_tm	4.489***	4.077***	4.258***	3.797***	4.188***	3.255***
	(1.202)	(1.211)	(1.103)	(1.145)	(1.030)	(1.079)

Note: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1, the table contains 72 regression models.

Table 10 reports the regression results after excluding the samples from 2008 to 2009. Compared with the results of original models, the coefficient sign, size, and significance of each variable have not changed significantly, proving that the impact of the financial crisis will not have a substantial impact on the conclusions.

Table 10 Regression results excluding financial crisis

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	PAPPLY	*IAPPLY*	*PAPPLY*	*IAPPLY*	*PAPPLY*	*IAPPLY*
	t		t+1		t+2	
Panel A: Main Effects						
Gene_Fst	0.524**	0.599**	0.549**	0.603**	0.584**	0.601**
	(0.236)	(0.254)	(0.222)	(0.239)	(0.233)	(0.259)
Gene_RFst	1.981***	1.621**	1.652***	1.597**	2.004***	1.663**
	(0.615)	(0.675)	(0.580)	(0.650)	(0.615)	(0.707)
Gene_Nei	0.636**	0.717**	0.524**	0.663**	0.557**	0.701**
	(0.253)	(0.293)	(0.236)	(0.286)	(0.260)	(0.322)
Gene_RNei	1.852***	1.007	1.510***	0.807	1.735***	0.812
	(0.624)	(0.655)	(0.544)	(0.602)	(0.593)	(0.676)
Panel B: Moderating Effects of *Exp_lc*						
Gene_FstxExp_lc	0.050***	0.065***	0.043***	0.058***	0.022	0.042***
	(0.013)	(0.013)	(0.011)	(0.011)	(0.014)	(0.016)
Gene_RFstxExp_lc	0.208***	0.207***	0.160***	0.172***	0.225***	0.262***
	(0.049)	(0.052)	(0.049)	(0.049)	(0.049)	(0.054)
Gene_NeixExp_lc	0.030***	0.037***	0.032***	0.041***	0.009	0.021*
	(0.010)	(0.012)	(0.010)	(0.010)	(0.011)	(0.012)
Gene_RNeixExp_lc	0.072	0.193*	0.039	0.167*	0.031	0.189*
	(0.090)	(0.102)	(0.074)	(0.090)	(0.082)	(0.098)
Panel C: Moderating Effects of *Exp_tm*						
Gene_FstxExp_tm	0.684	1.027**	0.563	0.774	0.893*	1.230**
	(0.481)	(0.489)	(0.457)	(0.488)	(0.461)	(0.513)
Gene_RFstxExp_tm	3.334**	2.359*	3.352***	1.371	2.648**	0.585
	(1.333)	(1.389)	(1.214)	(1.326)	(1.159)	(1.316)
Gene_NeixExp_tm	1.631***	2.046***	1.510***	1.994***	1.346**	2.005***
	(0.559)	(0.615)	(0.510)	(0.576)	(0.525)	(0.619)
Gene_RNeixExp_tm	4.996***	4.006***	5.024***	4.046***	4.005***	3.275***
	(1.275)	(1.301)	(1.107)	(1.203)	(1.094)	(1.225)

Note: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1, the table contains 72 regression models.

Extant research thinks that the moderating effect of a nonlinear model can not only look at the interaction coefficient and its p value, but also calculate the true moderation effect and corresponding Z value at each observation in the sample, and draw the scatter diagram within the range of dependent variable (Caner and Tyler, 2015; Wiersema and Bowen, 2009). Based on the above considerations, we first estimate the moderating effect model and then calculate the true moderation effect of each observed value[3] and its z-statistic value. Our calculation results are plotted in Figure 3.

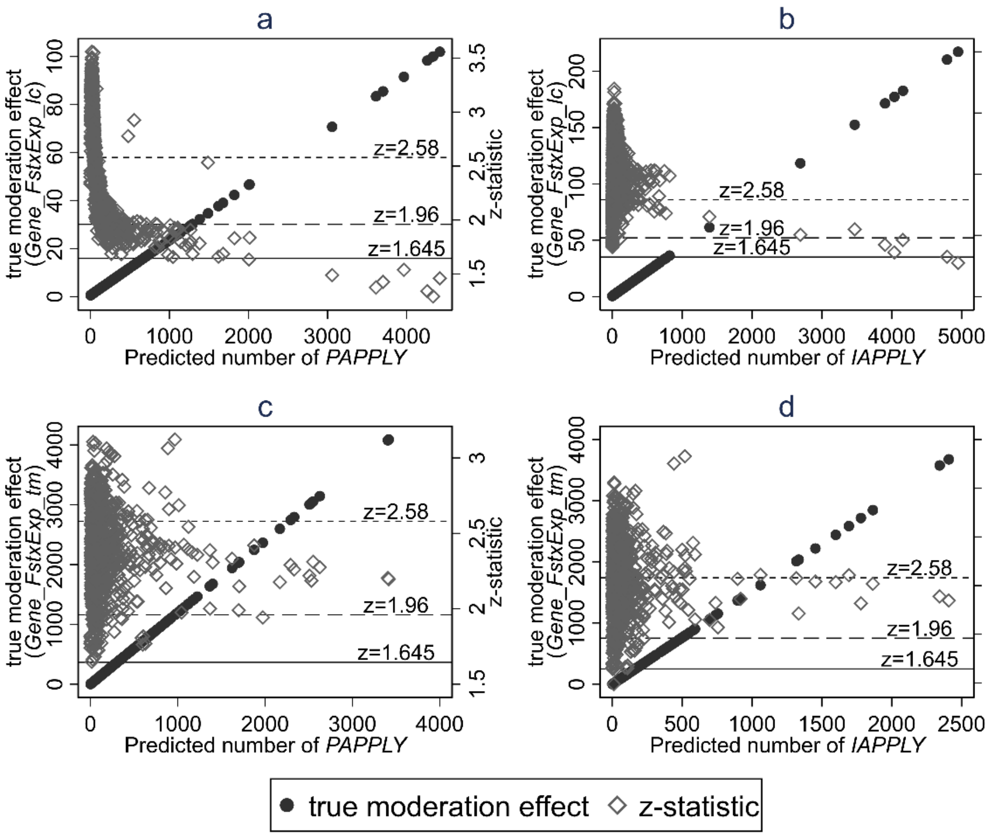

Fig 3 True moderation effect of international experience

Figure 3a shows the true moderation effect of *Exp_lc* on the relationship between *PAPPLY* and *Gene_Fst*. The results show that the true moderation effect is positive and 964 observations are significant at the 5% level, which accounts for 86.69% of the regression sample. Figure 3b, c, and d have similar results compared with a, that is, the true moderation effects of international experience are positive. The results also show that 1090, 1015 and 1012 observations are

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[3] If $E(PAPPLY \mid \mathbf{x},\boldsymbol{\gamma}) = \exp(y)$ and $y = \gamma_0 + \gamma_1 Gene + \gamma_2 Exp + \gamma_3 Gene \times Exp + \gamma_4 Controls + \varepsilon$, then true moderation effect= $\frac{\partial E(PAPPLY \mid \mathbf{x},\boldsymbol{\gamma})}{\partial Gene \partial Exp} = \exp(y)\left[\gamma_3 + (\gamma_1 + \gamma_3 Exp)(\gamma_2 + \gamma_3 Gene)\right]$.

significant at the 5% level, accounting for 98.02%, 94.33% and 94.05% respectively. These results once again demonstrate international experience at the enterprise and individual level has a significant positive moderating effect on the relationship between genetic distance and cross-border R&D performance.

Some related studies find that distance, heterogeneity and diversification imply the accumulation of diversified knowledge (Ashraf and Galor, 2013), which can bring new ideas and complementary skills of team members (Delis et al., 2017; Page, 2007). We think these viewpoints also apply to our study. To verify our arguments, we conduct a mediating effect test according to Baron and Kenny (1986), in which the mediating variable is defined as knowledge diversity, measured by the logarithm of the total number of IPC in invention patents and utility models applied by listed companies during the reporting period. Our test results are shown in Table 11.

Table 11 The mediating effect of knowledge diversity

Variable	(1)	(2)	(3)	(4)	(5)
	Diversity	*lnPAPPLY*	*lnPAPPLY*	*lnIAPPLY*	*lnIAPPLY*
			Panel A		
Gene_Fst	0.302^{**}	0.980^{***}	0.332^{*}	0.857^{***}	0.253
	(0.144)	(0.254)	(0.170)	(0.253)	(0.193)
Diversity			1.097^{***}		1.097^{***}
			(0.040)		(0.046)
Sobel Test		2.092^{**}		2.090^{**}	
			Panel B		
Gene_RFst	0.813^{**}	3.013^{***}	0.615	3.100^{***}	1.009^{**}
	(0.406)	(0.658)	(0.382)	(0.632)	(0.456)
Diversity			1.099^{***}		1.094^{***}
			(0.040)		(0.045)
Sobel Test		1.996^{**}		1.994^{**}	

Note: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

The results show that knowledge diversity plays a mediating role between genetic distance and cross-border R&D performance, indicating that genetic distance significantly increases the knowledge diversity of EMNEs, which in turn improves cross-border R&D performance.

Table 12 reports the test results of linguistic distance and cross-border R&D performance. The results show that there is a negative and significant relationship between linguistic distance and cross-border R&D performance, which is consistent with Ly et al. (2018) and our theoretical model. That means the heterogeneity perspective dominates the relationship between genetic distance and cross-border R&D performance, while the cost perspective dominates the relationship between linguistic distance and cross-border R&D performance. In the field of international trade, we think communication and mutual trust are usually more important than innovation, which explains why country distance always acts as a restraint in this research field.

Table 12 Regression results of linguistic distance and cross-border R&D performance

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	PAPPLY	*IAPPLY*	*PAPPLY*	*IAPPLY*	*PAPPLY*	*IAPPLY*
	t		t+1		t+2	
Panel A: measurement method from Guiso et al. (2009)						
LD_G	-0.966^{***}	-1.054^{***}	-0.967^{***}	-1.018^{***}	-1.104^{***}	-1.163^{***}
	(0.277)	(0.308)	(0.271)	(0.297)	(0.278)	(0.317)
Panel B: measurement method from Spolaore & Wacziarg (2009)						
LD_SW	-2.191^{***}	-1.763^{***}	-2.233^{***}	-1.640^{***}	-2.492^{***}	-1.730^{***}
	(0.598)	(0.584)	(0.567)	(0.585)	(0.563)	(0.628)

Note: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1, the table contains 8 regression models.

Conclusion and Discussion

How country difference affect cross-border trade and investment activities have always been the focus of scholars' attention (Castellani et al., 2013; Choi and Contractor, 2016; Giuliano et al., 2014; Ly et al., 2018; Reuer and Lahiri, 2014; Teixeira et al., 2008). We provide new insights into the relationship between country distance and outward foreign direct investment performance by using genetic distance as the antecedent of investment performance. As a biological concept, gene has been introduced into economic studies in recent years. Genetic distance covers the differences between two populations in human physiological, psychological, social, cultural, and commercial characteristics, which is an exogenous variable that reflects the long-term comprehensive differences between the two countries or regions. Different from the previous literature, this paper incorporates genetic distance into the analytical framework of cross-border R&D. It is found that the role of genetic distance on cross-border R&D is different from that on cross-border trade (Bove and Gokmen, 2018; Guiso et al., 2009), and genetic distance can significantly improve cross-border R&D performance. This result is consistent with Page (2007), who believes that innovation comes from the diverse perspectives and heuristics used by R&D teams in searching for solutions, so ethnic and cognitive diversity can bring more innovation and enhance the innovation capability of the organization.

This paper also finds that international experience plays an important moderating role in the above relationship. International experience can release the "dividend" of cross-border R&D brought by genetic distance, whether it is the experience accumulated by enterprises in export trade, foreign investment and international cooperation (Hsu et al., 2015) or the experience accumulated by senior executives while working or studying abroad (Liu et al., 2010). From the perspective of heterogeneity, international experience can help EMNEs to access new technological knowledge and management philosophy, and further strengthen the positive effect of genetic distance on cross-border R&D performance. From the perspective of cost, international experience helps EMNEs become familiar with exotic cultures, accumulate experience in cross-cultural cooperation, and eliminate the liability of foreignness, which indirectly strengthens the positive effect of genetic distance on cross-border R&D performance.

Theoretical contributions

This study makes four theoretical contributions by: (1) articulating the concept of cross-border R&D by offering theoretical underpinnings from genetic distance and knowledge management literature; (2) investigating the influence of genetic distance on cross-border R&D performance by taking into account the heterogeneity and cost perspective; (3) providing an enhanced understanding of the impact of genetic distance on cross-border R&D for EMNEs by considering the international experience of both individuals and enterprise-levels; and (4) expanding studies on cross-border R&D in EMNEs contexts.

First, our research contributes to a nuanced understanding of cross-border R&D by juxtaposing the genetic distance literature and knowledge management literature. The previous research on knowledge management in complex inter-organizational arrangements tends to focus on M&A (Liu and Meyer, 2020), strategic alliance or joint ventures without paying attention to the other organizational form such as cross-border R&D (Del Giudice and Maggioni, 2014). Our findings suggest the genetic distance literature may offer important theoretical underpinnings to understanding cross-border R&D and knowledge management. In doing so, our study extends the recent discussion on genetic distance and international trade by connecting genetic distance with knowledge management in a complex inter-organizational arrangement, such as cross-border R&D. In addition, our findings offer further insights into cross-border R&D by highlighting that genetic distance can be understood beyond the conventional approach in studying international trade. Thus, we propose that cross-border R&D constitutes as an important organizational form for knowledge management in complex inter-organizational arrangements.

Second, our findings shed light on the understanding of the impact of genetic distance on cross-border R&D performance. By distinguishing between heterogeneity and cost perspectives, our findings suggest that the influence of genetic distance on cross-border R&D performance differs depending upon the motivational and behavioral contexts. The closer relationship and interactions between cross-border R&D teams demand the contributing partners to develop the flexible arrangement, mutual trust and effective communication mechanisms to drive cross-border R&D performance. In contrast, previous studies found genetic distance negatively affects international trade (Delis et al., 2017; Spolaore and Wacziarg, 2009). Our results reveal genetic distance can significantly improve cross-border R&D performance in EMNEs contexts. Our research contributes to advancing the understanding of genetic distance and cross-border R&D in EMNEs contexts, especially by underscoring the different influences of behavioral and motivational factors.

Third, our study contributes to the knowledge management literature from a multiple level perspective of international experience. Specifically, international experience at the enterprise level can release the "dividend" of cross-border R&D brought by genetic distance to a greater extent through the knowledge accumulated in export trade, foreign investment and international cooperation. International experience accumulated by senior executives while working or studying abroad at the individual level can lead to better cross-border R&D performance by executives acting as "knowledge brokers" to transfer knowledge. The nuanced understanding derived from our study points to the distinctive characteristics of international experience with regard to gaining competitive advantages in cross-border R&D for EMNEs. Further, our study joined the recent studies that have examined the role played by global mobility of international talent (Liu, 2020). In particular, our findings lend support to recent research that highlights the importance of global talent management for EMNEs (Liu and Meyer, 2020).

Fourth, our research contributes to cross-border R&D literature in EMNEs contexts. By highlighting the EMNEs contexts, the role of cross-border R&D can be understood by taking into account the contextual factors, and the development of EMNEs is associated with the motivation for technical knowledge in international contexts (Luo and Zhang, 2016), which is quite different from MNEs in developed countries. Furthermore, the antecedents affecting cross-border R&D in EMNEs contexts are also unclear, so how to improve cross-border R&D performance of EMNEs still needs to be tested. Our study fills the current research gap by investigating the impact of genetic distance, returnees and overseas investment experience on cross-border R&D performance. Our results not only have important enlightenment for Chinese MNEs' cross-border R&D but also have reference value for MNEs in emerging economies or developing countries to improve cross-border R&D performance. Our study further highlights the importance of EMNEs to implement globalization strategies.

Managerial and policy implications

The implications of this conclusion for enterprises and governments are as follows: first, managers should recognize the role of knowledge management in improving cross-border R&D

performance. Communication barriers may lead to poor knowledge transfer, hinder knowledge sharing, and seriously reduce the efficiency of R&D despite heterogeneous R&D members or returnees bring cutting-edge and complementary knowledge. Managers need to pay attention to the transfer and integration of knowledge within the organization. Managers can integrate the specialized knowledge possessed by each individual within the organization through organizational mechanisms, such as using organizational rules, organizational routines, or group problem solving and decision making to improve the efficiency of knowledge integration (Grant, 1996), and guide team members to coordinate and learn from each other (Kapoor and Kwanghui, 2007).

Second, enterprises should pay attention to the positive role of genetic distance in cross-border R&D, and put more cross-border R&D investments in countries or regions that are genetically different from their home country. This paper finds that genetic heterogeneity not only brings collision of thoughts, complementary skills, and flexible organization but also leads to communication barriers and mismatched goals. The positive effects of the former outweigh the negative effects of the latter, which can improve cross-border R&D performance in general. This finding means that in terms of location selection for cross-border R&D, searching for countries or regions with genetic differences from home country as investment destinations can better play the role of cross-border R&D in enhancing independent innovation capabilities.

Third, enterprises should strengthen the ability to handle cultural conflicts, and the government should build a platform to deepen cultural exchanges between the two countries or regions. Although the overall effect of genetic distance on cross-border R&D performance is positive, its negative side cannot be ignored. Enterprises and governments need to create conditions to remove communication barriers and distrust caused by these barriers to maximize innovation space. For enterprises, cross-cultural integration should be valued, and cross-cultural training should be used to promote positive interaction between domestic employees and overseas team members. For the government, it is necessary to actively carry out cross-cultural exchanges and cooperation, such as organizing cultural exchange activities or establishing cultural exchange mechanisms, to deepen the understanding of each other's culture.

Fourth, enterprises should accelerate the accumulation of international experience. This paper finds that international experience can not only improve innovation efficiency through access to advanced ideas and open up international horizons but also enhance the ability of enterprises to enter new markets and adapt to new environments to eliminate the liability of foreignness, which has the function of enlarging the positive effect of genetic distance and reducing the negative effect. At the enterprise level, enterprises should actively “going out” and participate in international exchanges and cooperation. On an individual level, enterprises should recruit returnees and cultivate high-tech professionals with overseas background, and increase the proportion of local staff in overseas R&D teams.

Directions for future research

Future research can be further expanded from the following two directions: First, due to the characteristics of cross-border R&D, the research sample of this paper is confined to high-tech enterprises and ignores the exploration of non-high-tech enterprises. If future research can include all types of enterprises in the regression sample, and compare the cross-border R&D performance of samples in different industries, it may further enrich the theoretical results of cross-border R&D. Second, there is still a lack of systematic analysis on the antecedents of cross-border R&D, and empirical research based on the context of emerging economies is rare. Therefore, future research can supplement this research area by combining case study and empirical analysis to provide more theoretical contributions and managerial implications for EMNEs' cross-border R&D.

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