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Big data and emerging market firms' innovation in an open economy: The diversification strategy perspective

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ABSTRACT

Big data development encourages emerging market firms (EMFs) to diversify strategies and increase competitive advantages by acquiring resources embedded in different markets and industries. This study draws on the composition-based view (CBV) and empirically examines how EMFs integrate resources through international and business diversification to improve innovation performance in open economies. Based on the data collected from Chinese listed companies, our findings show that international diversification and related business diversification positively improve firms' innovation performance, whereas overall business diversification negatively impacts firms' innovation. International and business diversification substitute for each other to affect firms' innovation outcomes. Further research found that these results are more significant in a higher big data development environment. Moreover, we examine the moderating role of organizational slack in the relationship between diversification strategies and firms' innovation performance. This study contributes to the EMF innovation literature by highlighting the effects of diversification strategy from a CBV perspective. Firms creatively use and combine open resources to promote innovation in open economies. This study also contributes to diversification research in big data environments, arguing that EMFs that lack strong capabilities may suffer lower innovation performance if they concurrently apply international and business diversification at a high level.

1. Introduction

With the advancement of big data and economic globalization in recent years, we have witnessed a more open economy and the rapid development of enterprises' innovation (Krammer and Jimenez, 2020; Ramadani et al., 2019; Arias-Pérez et al., 2021). As reported by the World Intellectual Property Organization (WIPO), the number of global patent applications increased by 275,900 in 2020, with an annual growth rate of 7% over the past ten years. In particular, emerging market firms (EMFs), which are typically latecomers in a "catch-up game" in the global market (Cui et al., 2013; Awate et al., 2012), have made great achievements in innovation development. This is demonstrated by the fact that China's patent applications accounted for 46.4% of the world total in 2018, and the country was ranked number one for eight consecutive years, surpassing the United States, the EU-27, and Japan (WIPO, 2018).

Studies on EMFs demonstrate that government policy (Sun and Cao, 2018), R&D investment (Tse et al., 2021; Ferraris et al., 2019), and resources, such as social networks (Garud and Prabhu, 2021; Zhao, 2015) and human capital (e.g., CEO attributes), significantly influence firms' innovation. While earlier studies focus on the roles of the institutional environment and resources in forming a firm's competitiveness and promoting innovation activities (Zhang et al., 2020; Yi et al., 2017; Tan et al., 2014), recent studies have presented a composition-based view (CBV) that explains how firms, such as EMFs, handicapped by a lack of core competencies, can compete with more resourceful rivals (Li et al., 2021; Dutta and Snehvrat, 2020). As emphasized by the CBV (Luo and Child, 2015), firms with ordinary resources generate extraordinary results through their creatively use of open resources and unique integrating capabilities. The CBV provides new insight and suggests that EMFs are usually astute in identifying, leveraging, and combining external and internal resources to create a competitive advantage, but this idea still needs empirical validation.

In contrast to developed economies, most EMFs are subject to

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resource constraints and institutional deficiencies, which are more likely to advance external knowledge search (de Oliveira et al., 2021) and diversify their business to assemble resources that are available in different markets and industries to accumulate competitive advantages (Yip and McKern, 2016). For example, the Chinese vehicle enterprise Geely generated more than 9,000 authorized patents in 2020 after completing aggressive international acquisitions of companies such as Volvo and Daimler. India's Tata also acquired multiple companies and expanded in different business fields (e.g., e-commerce, hotels, and energy) to integrate diverse innovation resources. This study contributes to EMFs' innovation in open economies by examining how a firm's diversification strategy, a pathway for firms accessing and combining external resources, affects innovation development.

Recently, big data have been proven to have a high potential to facilitate a firm's diversification strategy, including international and business diversification. On the one hand, big data analytics enable firms to understand foreign markets and better integrate global resources (Cheng et al., 2020). Big data development also breaks barriers and encourages firms to establish connections across the globe (Dam et al., 2019). On the other hand, big data allows firms to scan and evaluate data from various sources; the firm with the most comprehensive information can best capture business opportunities embedded in different industries and achieve cross-field development (Shamim et al., 2020). Although big data technology provides firms with more possibilities for acquiring knowledge and resources from various markets, it also poses the threat that overdiversified resources can disperse firms' attention and create high management and coordination costs. As discussed in prior studies, organizational slack is a cushion and potential resource that can provide flexibility for firms to strengthen the use and integration of existing resources and adapt to external variations (Godoy-Bejarano et al., 2020; Symeou et al., 2019). The role of organizational slack could be more salient in a big data environment. Increasing data processing and analytics capacities enables firms to leverage organizational slack for resource configuration and innovation development. With the development of big data and firms' diversification operations in open economies, we raise the following research questions:

Q1. How do firms in open economies improve innovation through diversification strategies?
Q2. How does organizational slack moderate the effect of diversification strategies on innovation performance?

To answer these questions, we collect data from Chinese listed companies from 2009 to 2018 and empirically examine the effects of international and business diversification on firms' innovation performance. The Chinese context is appropriate and advantageous for the following reasons. First, China is the largest emerging economy and an active player in global innovation. Second, international and business diversification strategies are commonly adopted by Chinese companies (Elia et al., 2020; Weng et al., 2019) to accelerate learning and resource accumulation in open economies. Finally, big data is growing rapidly in China and improves firms' capabilities of sourcing diversified resources, which provides a good context for us to investigate firms' innovation in response to big data development. Our results suggest that (1) international and business diversification have different effects on a firm's innovation in an open economy, and these two diversification strategies interact to influence a firm's innovation, and (2) organizational slack positively moderates the relationship between a firm's diversification strategies and innovation performance.

This study contributes to research on EMFs' innovation in open economies by adopting the CBV perspective and fills the gap by exploring how firms creatively use open resources and combine the resources they possess to generate competitive advantages. In addition, we focus on two diversification strategies in big data environments that are suggested as approaches for firms accumulating outward resources (Chen et al., 2014); this departs from much of the literature, which either focuses on the international side (Mendoza et al., 2019; Xu et al., 2020; Batsakis et al., 2018) or the business diversification-based side (Orlando et al., 2018; Holzmayer and Schmidt, 2020). We also enrich existing diversification studies by theorizing our framework in an emerging market context. Moreover, our study provides new evidence that organizational slack, representing firms' internal potential resources, is complementary to the resources obtained from diversification strategies that benefit firms' innovation development.

The remainder of this paper is organized as follows. In Section 2, we review EMFs' innovation in open economies from the CBV perspective and discuss the role of big data in promoting firms' international and business diversification to acquire open resources. Section 3 presents our research hypotheses. In Section 4, we describe the sample, data, and model specifications. In Section 5, we report and discuss the results of the empirical research and further examine the results by distinguishing between subsamples of strong and weak big data environments. Finally, we conclude the paper by summarizing the main findings, contributions, research implications, and future research directions.

2. Theoretical background

2.1. EMFs' innovation in an open economy: a composition-based view

The CBV emphasizes that firms can distinctively and creatively leverage and compose external or internal resources to generate specific advantages and a unique development path for growth (Luo and Child, 2015). CBV logic is distinct from the resource-based view (RBV). The RBV underscores that superior strategic resources need to be possessed and owned by the firm (Chahal et al., 2020) and does not address how the firm manages its resources to enhance its strengths. The CBV also contrasts with the knowledge-based view (KBV). The CBV emphasizes a wider range of ordinary resources that can be composited to create superior competitive offerings and is not limited to knowledge resources (Mejri et al., 2018).

The CBV provides new insights to explain EMFs' innovation development in open economies. As latecomers in the global market, EMFs lack core technologies and advanced managerial skills and face financial and market constraints (de Oliveira and Rodil-Marzábal, 2019). For example, China's innovation experiences the process from imitation to innovation (Yip and McKern, 2016); firms at earlier stages usually pursue incremental innovations by observing and learning from others. EMFs are motivated to proactively search for and use open resources to mitigate disadvantages and improve their competitiveness to catch up with rivals and developed countries; that is, EMFs are dedicated to accumulating various knowledge and resources scattered in different markets and fields to promote their innovation development. In addition, as noted by Luo and Child (2015), EMFs have a tradition of applying a yin-yang philosophy, which fits the CBV logic of embracing diversity and quickly reacting to uncertainties. Given that many EMFs still suffer resource insufficiency, a composition-based strategy remains necessary and crucial to EMFs in current open economies (Sun et al., 2021).

2.2. Big data, diversification strategy, and open resource acquisition

Recently, the rapid growth of information technology has promoted data generation at an unprecedented rate (Lin et al., 2020). Big data, which is described as having characteristic of volume, velocity, and value (Rehman et al., 2016), have been found to have significant effects on value creation in the process of production and management (Benzidia et al., 2021; Raguseo, 2018) and to greatly enhance a firm's ability to capture valuable knowledge and resources that are available in the open market (Elisa et al., 2021; Yaqoob et al., 2016). A firm's leveraging of big data can exploit new opportunities and promote the transformation from a traditional factor- and investment-driven entity to one driven by innovation.

Diversification strategy refers to how a firm diversifies its business into different regions or product fields. It has been an important way for firms to share various resources embedded in different markets and enterprises (Hitt et al., 1997; Cincera and Ravet, 2014). Diversification strategy includes international diversification, which connotes that a firm operates its business in a broader global environment, and business diversification indicates that a firm's business is extended to a new industry or product market. Despite the differences between the two diversification strategies, both can increase a firm's store of knowledge and resources that were not previously available within the organization.

The rise of big data pushes a firm's diversification to new heights. As reported by China's Ministry of Commerce, the country's foreign direct investment (FDI) has increased more than sevenfold in the last ten years (CNUCED, 2018). Additionally, many EMFs, such as Alibaba, Tata, and Baidu, are devoted to their diversified business expansion owing to benefiting from big data development. Through international diversification, firms can better acquire foreign resources (mostly strategic assets), accelerate organizational learning, and leverage these factors in their innovation practices (Christofi et al., 2019). Business diversification also enables a firm to obtain and accumulate resources, such as technology, services, and customers, distributed among industries. Business diversification can be further divided into related business diversification and unrelated business diversification (Orlando et al., 2018), defined as firms diversifying their businesses in relevant or irrelevant industrial fields (Rumelt, 1974). These two types of diversification strategies may impact a firm's ability to acquire and leverage resources from diverse industries in different ways. Influenced by big data development, this study empirically examines how distinct diversification strategies influence firms' innovation performance in open economies.

3. Hypotheses and framework development

Innovation is a complicated process with intensive knowledge, information, and resources. In today's open economy, open resources in abundance at home and abroad provide greater opportunities for EMFs to tap into different markets using the composition-based philosophy to creatively assemble and integrate resources for innovation development (Jugend et al., 2020; Luo and Child, 2015). This section focuses on a firm's diversification strategy and organizational slack, elaborating on their direct and interactive effects on a firm's innovation performance.

3.1. Big data and diversification strategy for a firm's innovation in an open economy

3.1.1. Effects of international diversification

Big data development strengthens the connections between countries and promotes cross-border cooperation among firms. Studies on the role of internationalization in firms' innovation mostly support expansion into foreign countries, offer opportunities for firms to access new and diverse resources, and increase organizational knowledge by learning from others (Hitt et al., 1997). In addition, internationalization can also be a "springboard" for many EMFs to catch up with advanced economies rapidly by acquiring innovation resources (e.g., knowledge, technology, and other strategic assets) from foreign markets, especially in big data environments (Luo and Tung, 2018; Kumar et al., 2020). Specifically, the effects of international diversification on firms' innovation are embodied in the following aspects.

First, a firm that conducts international diversification can acquire abundant innovation resources from foreign markets that may not be available domestically (Hitt et al., 1997; Hsu et al., 2015). The firm can also learn the latest information and cutting-edge technological knowledge from a wider range of sources. Khan et al. (2018) pointed out that establishing a global network and cooperating with foreign suppliers, customers, and other organizations provides a strong basis for a firm's competitive advantages. Second, studies have also highlighted the learning-by-exporting process in which a firm with a high level of internationalization can borrow and explore new ideas by observing and imitating foreign companies, and integrating them into its management and innovation practices. Third, international diversification enables firms to access and hire better scientists and skilled technical experts globally (Kafouros et al., 2018). Having a wider variety of talent can increase efficiency in a firm's innovation and improve the quality of innovative goods and services.

Moreover, internationalizing firms that access different markets and partners around the globe can also buy R&D inputs from the cheapest sources and locate their departments in the most productive regions (Kafouros et al., 2008). The advancement of big data enables firms to utilize advanced technology to integrate and deal with external resources to improve innovation (Yaqoob et al., 2016). Since EMFs typically face resource constraints in a weak institutional framework (Wu et al., 2016), diversifying the business into a global market helps them combine advantageous resources overseas and enhance innovation performance in open economies. Taking these together, we propose the following:

Hypothesis 1: A firm's international diversification is positively associated with its innovation performance.

3.1.2. Effects of business diversification

Firms in big data environments are also inclined to develop their businesses in new and different product markets. From the CBV perspective, the growth of big data encourages EMFs to diversify their business, which the firm can use to leverage advantageous resources spread among diversified industries and achieve compositional innovation (Li et al., 2021). However, EMFs are characterized by weak competency in coping with more heterogeneous businesses and a lack of strategic resources (Kaufmann and Roesch, 2012). A firm with overall business diversification might find it challenging to integrate these diversified resources effectively, and diversification also crowds out the resources used for the firm's innovation activity. In addition, higher overall business diversification could pose more challenges for managers who are becoming familiar with all the businesses, which may further cause organizational and control inefficiencies in combining and utilizing heterogeneous resources for practicing innovation (Cincera and Ravet, 2014). Given the pressure from short-term "return-on-investment" objectives, division managers in big data environments tend to invest in projects with more immediate financial performance rather than in risky activities, such as R&D and innovation.

Conversely, although corporate managers may not pay the same amount of attention to many divisions, they can focus on a smaller number of divisions instead (Holzmayer et al., 2020). For firms conducting related business diversification, the resources and knowledge distributed among similar industries can easily be identified, assimilated, and combined into the firm's innovation practices. Moreover, related business diversification allows for reciprocal information to flow from corporate managers to divisional managers, where corporate managers are more likely to achieve strategic control than those in firms with a lot of unrelated business diversification. Additionally, in related business diversification, knowledge structure and resource characteristics are similar between the firm and the invested business; the firm can integrate and jointly use these resources to create a synergistic effect.

To this end, despite big data development providing more opportunities for firms to access innovation resources available in different fields, the results differ for divergent business diversification strategies. Compared to overall business diversification, a firm with a higher degree of related business diversification might effectively compose and absorb related resources, which is beneficial to the firm's innovation in an open economy (Purkayastha et al., 2012). Thus, we propose the following hypothesis:

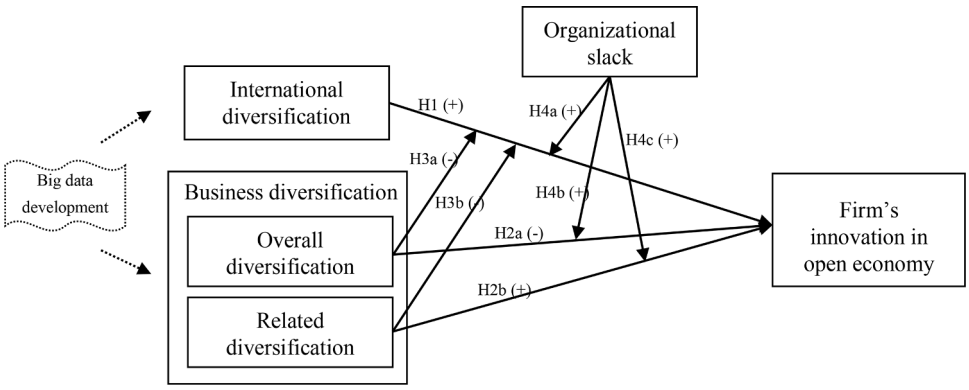

Fig. 1. Research framework.

Hypothesis 2a: A firm's overall business diversification is negatively associated with its innovation performance.

Hypothesis 2b: A firm's related business diversification is positively associated with its innovation performance.

3.1.3. *Interaction effects of international and business diversification*

International and business diversification strategies may influence a firm's innovation performance in an open economy. Prior studies on firm diversification strategies typically discuss their interaction effects on financial performance (Zúñiga-Vicente et al., 2019). However, a firm's innovation activity can become more complicated. For most EMFs that lack strong managerial and technical capabilities, a firm with a higher degree of business diversification might substitute the effect of international diversification on innovation development.

An international firm that diversifies its business into various product markets, whether related to business diversification or not, may find it challenging to integrate and control businesses effectively. On the one hand, business-diversified firms need to deal with a substantial number of transactions. If the firm expands internationally, information overload can reduce managers' efficiency in controlling the firm's businesses; thus, resources from diverse markets and industries cannot be better integrated and utilized to create advantages for innovation development. On the other hand, as a firm's business diversifies, managers need to adjust their internal governance structure and resource configuration to respond to environmental uncertainties. When a firm concurrently pursues international diversification, the different regulations and cultures across countries may further increase the workload and pressure for managers to deal with the mismatch between internal corporate settings and external contexts, which causes managers to divert their attention from the core business (Chang and Wang, 2007).

An international firm in an open economy that engages in different kinds of product markets may amplify the complexity of information processing and coordination tasks, exceeding managers' abilities. Under such conditions, the positive effect of international diversification on a firm's innovation is at risk of decreasing.

In particular, in a big data environment with increasing competition, a firm's innovation activity inevitably requires more investments and managers to spend much time and effort on it. If the firm adopts highly international and business diversification, resources for innovation will suffer from being squeezed. As such, international firms with dominant or single businesses could be more advantageous in promoting a firm's innovation improvements. For instance, the Chinese high-tech enterprise Huawei has a higher level of internationalization, but it always sticks to its core business instead of engaging in diversification.[1] As a result, Huawei's patent applications have been ranked number one in the world since 2017. In summary, we propose the following hypotheses:

Hypothesis 3a: A firm's overall business diversification negatively moderates the relationship between international diversification and a firm's innovation performance.

Hypothesis 3b: A firm's related business diversification negatively moderates the relationship between international diversification and a firm's innovation performance.

3.2. *Organizational slack in big data: a moderating role*

Organizational slack is thought of a bundle of resources within or available to an organization above the minimum needed to create a given output level (Geiger and Cashen, 2002; Marlin and Geiger, 2015). As documented in prior studies, organizational slack can benefit firms, as it serves as a buffer from shortages of funds and increases the potential for a firm to generate competitive advantages, especially in a competitive environment (Ju and Zhao, 2009). Big data development promotes the flow of knowledge, information, and resources across industries and regions; intensifies interorganizational competition; and pushes firms to diversify their business into different fields to capture resources in a global network. In addition, the rise of big data technology enhances firms' decision analysis and managerial capabilities, which the firm can use to integrate better and exploit external resources to improve innovation outcomes. Organizational slack in a big data environment is suggested to moderate the effects of diversification strategy on a firm's innovation performance.

As noted above, firms that engage in international diversification can obtain valuable knowledge and resources from the global market, which benefits the firm's innovation in an open economy. The firm with the highest organizational slack is most likely to facilitate the positive effect of international diversification for two reasons. First, organizational slack indicates a firm's potentially available resources that could greatly reduce the firms' anxiety and concern over foreign markets (Lin et al., 2009). Second, higher organizational slack increases a firm's adaptability to uncertain foreign environments (Carneiro et al., 2018). A firm can better connect with foreign companies and accelerate learning in global collaboration (Lin et al., 2009).

Organizational slack can also mitigate the adverse effects of overall business diversification on a firm's innovation. As a firm diversifies, greater organizational slack allows the firm to experiment with new strategies, such as introducing new products, entering new industries, and supporting new innovative activities that might not be approved in a more resource-constrained condition (Yang and Chen, 2017). Moreover, organizational slack enables the firm to absorb shocks to the organization and provides more opportunities to encourage a firm's innovation practice. Similarly, when a firm conducts related diversification, more organizational slack can support the firm's integration and leverage

[1] Ren Zhengfei was interviewed by "Shenzhen Business Daily" at Huawei headquarters in April 2018. https://www.sohu.com/a/227399268_161795

Table 1
Sample descriptive statistics.

Industry	All firms	% over total	Patent	Average Firm age	Firm size	International diversification (%)	Overall Business diversification	Related business diversification
Electronics, machinery, and equipment	2014	22.74	168217	17.05	22.11	17.672	0.322	0.045
Chemical and allied industries	1298	14.65	12887	16.96	22.01	12.022	0.443	0.107
Metals	746	8.42	32136	16.88	22.79	9.558	0.258	0.026
Transportation, communications, utilities	1376	15.53	7577	17.61	22.51	3.600	0.498	0.094
Mineral industries	291	3.28	5125	15.73	23.02	6.062	0.453	0.053
Agriculture, forestry, and related products	601	6.78	5669	17.29	21.88	8.131	0.483	0.063
Services	1952	22.04	2655	19.64	22.47	5.094	0.508	0.082
Others	579	6.54	10670	16.83	22.32	16.204	0.381	0.051

relevant knowledge and resources for innovative practice and achieve a synergistic effect. Taking these together, we propose the following:

Hypothesis 4a: Organizational slack positively moderates the relationship between international diversification and a firm's innovation performance.
Hypothesis 4b: Organizational slack positively moderates the relationship between overall business diversification and a firm's innovation performance.
Hypothesis 4c: Organizational slack positively moderates the relationship between related business diversification and a firm's innovation performance.

In summary, the theoretical framework and logic relationships of the proposed hypotheses are shown in Figure 1.

4. Methods

4.1. Sample design and data collection

We take Chinese publicly listed companies from 2009 to 2018 as the research samples. This period is appropriate for our research because Chinese companies increasingly engaged in international activities and expanded into different product markets during this time, thanks to economic development. Moreover, this period avoids the impact of the global financial crisis of 2008 and the severe influence of the COVID-19 pandemic on firms' international business and domestic operations.

We used a web-crawling algorithm to collect patent application data from the State Intellectual Property Office for each firm over ten consecutive years (Lin et al., 2020). In addition, we collected data on international and business diversification from the WIND economic database. The data on firms' finances, corporate governance, and ownership information were obtained from the China Stock Market & Accounting Research (CSMAR) database, which has been widely used in management studies in China (Greve and Man Zhang, 2017).

Here, we excluded cases with outliers and missing financial data. We also winsorized all variables at the 1% and 99% to reduce the potential influence of variables with extreme values. After data collection and data preprocessing, we obtained 8,857 observations from 1,076 listed Chinese companies. To analyze the data, we used STATA 12.0.

4.2. Sample description

Table 1 shows the sample distribution by industry. Industry classification is based on a two-digit code from the China Securities Regulatory Commission (CSRC). The results show that the electronics, machinery, and equipment industries have the largest patent applications, followed by the metals, chemicals, and allied industries, suggesting the importance of technological innovation in Chinese manufacturing. The highest level of international diversification is seen among the electronics, machinery, and equipment industries, reflecting the recent global expansion of Chinese high-tech firms and supporting that firms with the highest international diversification tend to perform better in innovation. Additionally, the industry with the highest overall business diversification is the services industry; as expected, it has a reverse relationship with innovation outcomes. Finally, the highest level of related business diversification is within the chemical and allied industries, followed by transportation, communications, and utilities.

4.3. Measures

4.3.1. Dependent variable

Innovation performance is represented by patent applications in a given year. This measurement is consistent with the method used in innovation research (Jia et al., 2019; Fisch et al., 2019). Some studies argue that patents have limitations as an indicator of innovation output; for example, not all firms' innovation activities lead to patents, and patents can represent only codified and explicit technological knowledge. However, there are still many benefits of using patent data for Chinese companies in this study. On the one hand, patent data constitute the most detailed and systematically compiled and managed data about innovation in China, including inventions, utility models, and industrial design. On the other hand, China has transitioned from an economy of imitation to innovation. Many policies implemented during the transition have encouraged patenting by indigenous firms, and the productivity of innovation, as measured by the number of patents, has increased rapidly in recent decades.

4.3.2. Independent variables

Multiple measures are used in previous studies for international diversification (inter_div), such as the number of foreign countries in which a firm has operated, the number of foreign subsidiaries, and the ratio of foreign sales to total sales (Zúñiga-Vicente et al., 2019; Wu et al., 2019). However, China is a latecomer in the global market and faces challenges in building foreign subsidiaries. In addition, we could not uniformly capture sales in each foreign country or region because of data limitations. Therefore, in this study, we measured international diversification using the ratio of foreign sales to total sales in our analysis. Overall, we captured business diversification (overall busi_div) using the entropy index, which is commonly utilized in diversification strategy studies (Zúñiga-Vicente et al., 2019). The measure of overall business diversification was calculated as

$$\text{Overall business diversification} = \sum P_i \times \ln(1/P_i), \quad (1)$$

$$\text{Overall business diversification} = \text{Related business diversification} + \text{Unrelated business diversification} \quad (2)$$

Here, P_i refers to the proportion of sales in business segment i, and $\ln(1/P_i)$ is the weight for each segment i. The entropy measure considers the number of segments in which a firm operates and the relative

Table 2
Variables and measures.

Type	Variable	Values	Method used to measure the variables
Dependent	Innovation performance	Discrete (N° of patents)	Number of patents applied by the firm in a year
Independent	International diversification	Continuous (%)	The ratio of a firm's foreign sales to its total sales in a year
	Overall business diversification	Continuous	Measured by entropy index with the calculation as $\sum P_i \times \ln(1/P_i)$, P_i refers to the proportion of sales in business segment i
	Related business diversification	Continuous	Measured by entropy index which the diversification resulting from businesses in 4-digit segments with a 2-digit industry group
Moderator	Organizational slack	Continuous	Measured by a firm's equity/debt ratio in a year
Control	Firm size	Continuous	Natural logarithm of a firm's total assets in a year
	Debt-to-asset ratios	Continuous	Measured by a firm's total debts to total assets in a year
	Cash Flow	Continuous	The ratio of net cash flow from a firm's operating activities to the total assets in a year
	Total employees	Continuous	Natural logarithm of a firm's total number of employees in a year
	Board size	Discrete (N° of board members)	Number of a firm's total board members in a year
	Board independence	Continuous	The ratio of a firm's independent directors to the total number of board directors
	Returnee directors	Continuous	The ratio of a firm's returnee directors to the total number of board directors
	Dynamic capability	Continuous	Average score of the items: (1) % increase in R&D investment = (1/2)*[(R&D$_{t-1}$ – R&D$_{t-2}$)/R&D$_{t-2}$]+[(R&D$_{t-2}$ – R&D$_{t-3}$)/R&D$_{t-3}$];(2) % increase in marketing development = (1/2)*[(MK$_{t-1}$ – MK$_{t-2}$)/MK$_{t-2}$]+[(MK$_{t-2}$ – MK$_{t-3}$)/MK$_{t-3}$] R&D was measured by the ratio of R&D expenditure; MK was measured by the ratio of a firm's sale expense
	State ownership	Dichotomous 0,1	The value of "1" if a firm was ultimately controlled by any level of the Chinese government and "0" otherwise
	Provincial Marketization	Continuous	The China Marketization Index developed by Wang et al. (2018).
	Manufacturing	Dichotomous 0,1	The value of "1" if a firm was in the manufacturing industry according to the Industry Classification Guideline by China Securities Regulatory Commission (CSRC), and "0" otherwise

Note: all the independent variables, moderator and control variables are lag one year in the regression analyses.

importance of each segment in a firm's total sales. Business diversification is formed by adding two components, related business diversification and unrelated business diversification, as shown in Equation 2. Related business diversification (related busi_div) is defined as diversification resulting from businesses in four-digit segments with a two-digit industry group, whereas unrelated business diversification arises from businesses in different two-digit groups (Ramaswamy et al., 2017).

Business diversification was measured using Python software. First, we identified specific business types for each firm based on the industry classification guidelines established by the CSRC. Then, we used Python's "split" function and conducted some interactions to acquire the list of industry codes and the proportion of their sales for all sample firms. Finally, we used the log function in the "math" library and the built-in sum function to calculate the entropy for each firm's business diversification.

4.3.3. Moderating variable

Organizational slack (Org_slack) has been broadly conceptualized into different dimensions, such as available slack, recoverable slack, and potential slack (Marlin and Geiger, 2015). Here, we focus on potential slack, emphasizing the extent of the unused borrowing capacity available to a firm. A higher potential slack indicates a firm's ability to raise cash resources quickly, if required. We measured this variable using the debt-to-equity ratio, consistent with Duan et al. (2020).

4.3.4. Control variables

We controlled for firm size to consider the effect on a firm's risk-taking and innovation behavior (Knott and Vieregger, 2020). We measured this variable using the logarithm of a firm's total assets. We also controlled for debt-to-asset ratios to capture the effect (if any) of a firm's financial leverage on innovation investments. To control the possibility that a firm's cash flow affects its ability to engage in innovation activity, we measured the net cash flow from a firm's operating activities, scaled by its total assets. We used the logarithm of total employees to control the effect of the number of employees on a firm's innovation. In addition, to consider the effects of board structure on innovation behavior, we controlled board size (the number of board members) and board independence (the ratio of independent directors to the total number of board members). We also controlled the returnee directors' effects on a firm's innovation strategy and performance (Lin et al., 2014); we measured this variable using the ratio of board returnees to total board members.

Moreover, dynamic capability has been found to influence a firm's innovation performance (Wu et al., 2016). Following Hsu and Wang (2012), we controlled for this by measuring the percentage of R&D investment and marketing development over the past three years, and we used the average value of these two items to capture the effect of a firm's dynamics.

To control the influence of state ownership on a firm's innovation, we created a dummy variable equal to "1" if a firm was controlled by the state or government and "0" otherwise. We also controlled the degree of provincial marketization in the province where the company is located. It is argued that places with high levels of marketization have more resources available for firm innovation activity. We measured this variable using data from the China Marketization Index developed by Wang et al. (2018). In addition, we controlled for manufacturing using a dummy variable coded "1" if a firm is in the manufacturing industry and "0" otherwise.

Finally, we controlled for the effect of time using the year dummy. To alleviate the potential endogeneity problem, we lagged all explanatory variables by one year. Table 2 summarizes the variables and their measures.

Table 3
Descriptive statistics, correlation coefficients, and VIFs

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Mean	26.66	10.09	0.41	0.06	1.80	22.32	0.50	0.04	7.77	8.87	0.37	0.09	2.11	0.55	7.58
Std.Dev.	192.22	18.75	0.42	0.22	3.48	1.36	0.38	0.09	1.36	1.89	0.05	0.13	18.88	0.49	1.86
VIF	—	1.11	1.31	1.26	1.17	2.11	1.13	1.03	2.14	1.26	1.15	1.10	1.01	1.15	1.10
1 Innovation performance	1														
2 Inter_div	0.06***	1													
3 Overall busi_div	-0.05***	-0.06***	1												
4 Related busi_div	0.02**	-0.03***	0.44***	1											
5 Org_slack	-0.02**	0.01	-0.04***	-0.02***	1										
6 Firm size	0.14***	-0.03***	0.06***	0.04***	-0.21***	1									
7 Debt-to-asset ratios	0.01*	-0.04***	-0.01	0.00	-0.31***	0.10***	1								
8 Cash Flow	0.01*	0.01	-0.03***	-0.01*	0.04***	0.04***	-0.02***	1							
9 Total employees	0.16***	0.11***	0.03***	0.01	-0.18***	0.57***	0.02***	0.13***	1						
10 Board size	0.04***	-0.02***	-0.00	-0.01	-0.09***	0.26***	0.06***	0.06***	0.25***	1					
11 Board independence	0.01	0.00	0.02**	0.01*	0.01	0.03***	-0.00	-0.04***	-0.00	-0.31***	1				
12 Returnee directors	0.04***	0.10***	-0.01	0.03***	0.00	0.15***	-0.03***	0.04***	0.12***	-0.00	0.09***	1			
13 Dynamic capability	0.00	-0.00	-0.01	-0.01	-0.00	0.09***	-0.00	0.00	0.07***	0.00	0.00	0.06***	1		
14 State ownership	0.01	-0.07***	0.03***	0.04***	-0.09***	0.20***	0.07***	0.00	0.15***	0.19***	-0.05***	-0.14***	0.02**	1	
15 Provincial marketization	0.03***	0.14***	0.07***	0.01	0.02**	0.07***	-0.06***	0.01	-0.02***	-0.04***	-0.01	0.15***	0.01	-0.14***	1
16 Manufacturing	0.08***	0.22***	-0.16***	-0.05***	0.06***	-0.12***	-0.08***	0.01*	0.16***	-0.06***	-0.02**	0.01	0.01	-0.14***	-0.03***

Note: N=8,857.
* $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$

4.4. *Modeling*

Our dependent variable is a highly right-skewed count variable that takes on nonnegative integer values. We adopted the random-effects negative binomial model to test the proposed hypotheses. The Poisson model can also test hypotheses where the dependent variable is a count. However, in patent-based studies, this condition is seldom met because of the data exhibiting overdispersion. As such, scholars often resort to using a negative binomial model to analyze panel count data to control for heterogeneity (Wang et al., 2016). A year dummy is also included to control for factors that are the same for all cross-sectional units but vary over time. Models (3) to Model (5) examine the individual effects of different diversification strategies on a firm's innovation performance.

$$\text{Innovation Performance}_{i,t} = \beta_1\text{Inter\_div}_{i,t} + \beta_2\text{Controls}_{i,t} + \varepsilon \quad (3)$$

$$\text{Innovation Performance}_{i,t} = \beta_1\text{Overall Busi\_div}_{i,t} + \beta_2\text{Controls}_{i,t} + \varepsilon \quad (4)$$

$$\text{Innovation Performance}_{i,t} = \beta_1\text{Related busi\_div}_{i,t} + \beta_2\text{Controls}_{i,t} + \varepsilon \quad (5)$$

To test the interaction effect of international and business diversification, we set Models (6) and (7), where the negative value of the coefficient in both interaction variables shows that business diversification has a substitution effect on a firm's international diversification to innovation performance. Similarly, Models (8) to Model (10) examine the moderating effect of a firm's organizational slack on the diversification-innovation relationship.

$$\begin{aligned}\text{Innovation Performance}_{i,t} = {} & \beta_1\text{Inter\_div}_{i,t} + \beta_2\text{Overall busi\_div}_{i,t} \\ & + \beta_3\text{Inter\_div} \times \text{Overall busi\_div}_{i,t} \\ & + \beta_4\text{Controls}_{i,t} + \varepsilon \end{aligned} \quad (6)$$

$$\begin{aligned}\text{Innovation Performance}_{i,t} = {} & \beta_1\text{Inter\_div}_{i,t} + \beta_2\text{Related busi\_div}_{i,t} \\ & + \beta_3\text{Inter\_div}_{i,t} \times \text{Related busi\_div}_{i,t} \\ & + \beta_4\text{Controls}_{i,t} + \varepsilon \end{aligned} \quad (7)$$

$$\begin{aligned}\text{Innovation Performance}_{i,t} = {} & \beta_1\text{Inter\_div}_{i,t} + \beta_2\text{Org\_slack}_{i,t} + \beta_3\text{Inter\_div} \\ & \times \text{Org\_slack}_{i,t} + \beta_4\text{Controls}_{i,t} + \varepsilon \end{aligned} \quad (8)$$

$$\begin{aligned}\text{Innovation Performance}_{i,t} = {} & \beta_1\text{Overall busi\_div}_{i,t} + \beta_2\text{Org\_slack}_{i,t} \\ & + \beta_3\text{Overall busi}_{\text{div}} \times \text{Org}_{\text{slack}\,i,t} + \beta_4\text{Controls}_{i,t} \\ & + \varepsilon \end{aligned} \quad (9)$$

$$\begin{aligned}\text{Innovation Performance}_{i,t} = {} & \beta_1\text{Related busi\_div}_{i,t} + \beta_2\text{Org\_slack}_{i,t} \\ & + \beta_3\text{Related busi\_div} \times \text{Org\_slack}_{i,t} \\ & + \beta_4\text{Controls}_{i,t} + \varepsilon \end{aligned} \quad (10)$$

5. Results

Table 3 presents the descriptive statistics and correlation coefficients for the variables. The average number of patent applications for the companies in the sample is 26.66, and more than 10% of their sales come from foreign markets. The averages for overall business diversification and related business diversification are 0.41 and 0.06, respectively. We examine the variance inflation factor for the variables. Values below ten are generally accepted as an indication that there is no significant multicollinearity; the results show that the variables have values ranging from 1.01 to 2.14. We also perform the correlation coefficient test, and each of the variables has a value under 0.6. Therefore, multicollinearity is not a problem in our research model.

Table 4
Results of the mean difference test

	International diversification		
Average Innovation performance	Higher	Lower	T-value
	50.473	13.281	5.7165***
	Overall business diversification		
	Higher	Lower	T-value
	9.417	33.734	−7.4387***

5.1. Mean difference test

We calculate the difference in innovation performance across groups by splitting the sample into two groups (high vs. low) according to the average values for international diversification and overall business diversification. As presented in Table 4, companies with higher international diversification have more innovation output (50.473) than those with lower international diversification (13.281); in contrast, companies with lower overall business diversification have more innovation output (33.734) than their higher diversification counterparts (9.417). These results initially support our argument that firms generate different levels of innovation performance with different approaches to international and overall business diversification.

5.2. Regression results

The regression results are presented in Table 5. Column 1 is the baseline model with all control variables. Firms with a higher level of cash flow and many employees and board members are more likely to perform better in innovation activities. In addition, a firm's higher dynamic capability positively promotes innovation outcomes. The results also show that high innovation performance is more likely to occur in a firm located where there is a high level of marketization or in manufacturing firms. However, if a firm with a larger size or higher financial leverage tends to have a low level of innovation performance, this also occurs among firms owned by the state.

Models 1-4 report the results of the relationship between firms' diversification strategies and innovation performance. The results for Model 1 indicate that international diversification has a positive and significant effect (0.002, $p < 0.05$) on a firm's innovation, indicating that in open economies, firms that engage in international activities can obtain knowledge and resources from foreign markets, which benefits the firm's innovation performance. Thus, H1 is supported. Model 2 shows that the coefficient for overall business diversification is -0.181 ($p < 0.01$); the coefficient for related business diversification in Model 3 is 0.19 ($p < 0.05$). The results also support H2a and H2b, which states that firms with higher overall business diversification may create inefficiencies in management and control when integrating different external resources, while conducting related business diversification enables a firm to combine similar resources to achieve a synergy effect, which is positive for a firm's innovation. Model 4 includes all the variables, and the results are consistent with these findings.

Models 5 and 6 report the results of the interaction between international and business diversification. We can see that overall and related diversification negatively affect the relationship between international diversification and a firm's innovation performance, suggesting that

Table 5
Regression results of diversification strategies on innovation performance

VARIABLES	Baseline	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Inter_div		0.002**			0.002*	0.004***	0.002**
		(0.001)			(0.001)	(0.001)	(0.001)
Overall busi_div			-0.181***		-0.265***	-0.067	
			(0.053)		(0.058)	(0.066)	
Related busi_div				0.190**	0.391***		0.370***
				(0.092)	(0.104)		(0.113)
Inter_div × Overall busi_div						-0.007***	
						(0.002)	
Inter_div × Related busi_div							-0.012**
							(0.004)
Firm size	-0.092***	-0.084***	-0.089***	-0.095***	-0.087***	-0.081***	-0.084***
	(0.030)	(0.030)	(0.030)	(0.030)	(0.030)	(0.030)	(0.030)
Debt-to-asset ratios	-0.432***	-0.442***	-0.420***	-0.445***	-0.450***	-0.428***	-0.455***
	(0.120)	(0.120)	(0.120)	(0.120)	(0.120)	(0.120)	(0.120)
Cash Flow	0.667***	0.663***	0.634***	0.678***	0.638***	0.663***	0.668***
	(0.230)	(0.230)	(0.230)	(0.231)	(0.230)	(0.231)	(0.230)
Total employees	0.256***	0.245***	0.253***	0.259***	0.249***	0.244***	0.246***
	(0.031)	(0.031)	(0.031)	(0.031)	(0.031)	(0.031)	(0.031)
Board size	0.030**	0.030**	0.028**	0.0310***	0.028**	0.026**	0.030***
	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
Board independence	-0.816**	-0.814**	-0.800**	-0.809**	-0.778**	-0.765**	-0.791**
	(0.322)	(0.322)	(0.323)	(0.320)	(0.320)	(0.322)	(0.318)
Returnee directors	-0.285*	-0.319**	-0.268*	-0.302**	-0.327**	-0.287*	-0.319**
	(0.150)	(0.151)	(0.151)	(0.151)	(0.152)	(0.152)	(0.152)
Dynamic capability	0.001**	0.001**	0.001**	0.001**	0.002**	0.001**	0.001**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
State ownership	-0.110**	-0.106**	-0.105**	-0.113**	-0.106**	-0.096*	-0.103*
	(0.0525)	(0.052)	(0.052)	(0.052)	(0.052)	(0.052)	(0.052)
Provincial marketization	0.063***	0.060***	0.066***	0.063***	0.064***	0.065***	0.061***
	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)
Manufacturing	0.879***	0.869***	0.859***	0.877***	0.838***	0.859***	0.872***
	(0.069)	(0.069)	(0.069)	(0.069)	(0.069)	(0.069)	(0.069)
Year Dummy	Control	Control	Control	Control	Control	Control	Control
Constant	-1.441***	-1.516***	-1.427***	-1.398***	-1.409***	-1.574***	-1.563***
	(0.509)	(0.509)	(0.508)	(0.510)	(0.508)	(0.508)	(0.510)
Observations	8,857	8,857	8,857	8,857	8,857	8,857	8,857
Log likelihood	-18851.48	-18849.28	-18845.67	-18849.40	-18836.78	-18839.96	-18843.83
Wald chi2	969.93***	975.45***	981.96***	974.07***	1000.62***	996.38***	988.23

Note: Numbers in parentheses are standard errors. * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$.

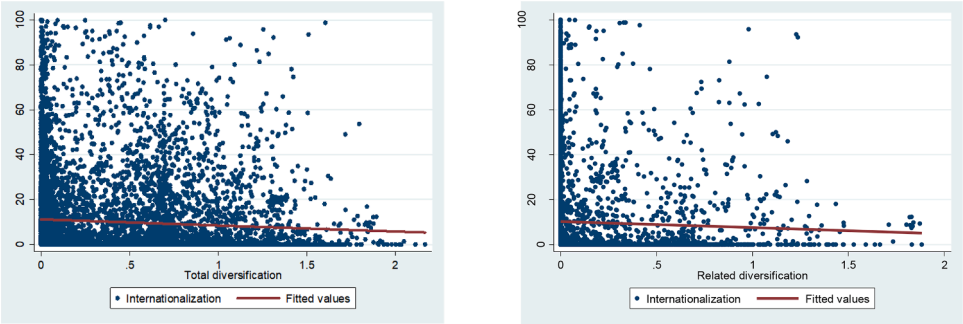

Fig. 2. Relationship between international and business diversification.

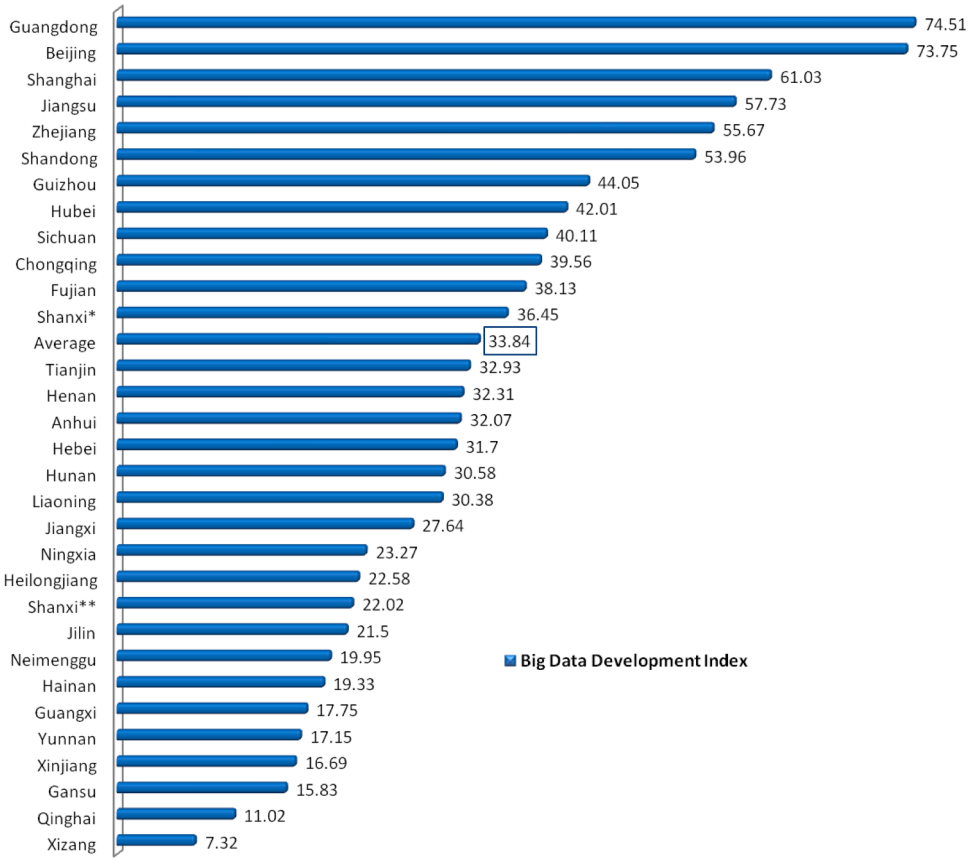

Fig. 3. Big Data Development Index in China's provinces (2018). Note: Shanxi* refers to the province with the capital of Xi'an; Shanxi** refers to the province with the capital of Taiyuan.

there is a substitution effect between international and business diversification strategies. Therefore, H3a and H3b are supported. The results presented in Figures 2 and 3 show that most Chinese companies tend to conduct either business diversification strategies with a low level of internationalization or international strategies with a more focused business. This finding also reflects how Chinese companies configure their resources in different regions and product markets to promote innovation in an open economy.

Table 6 presents the results of testing the moderating effect of organizational slack. As shown in the results for Models 7-9, organizational slack positively moderates the effect of international diversification (0.001, $p < 0.1$), overall business diversification (0.024, $p < 0.1$), and related business diversification (0.137, $p < 0.01$). These results support our argument that as big data development encourages firms to engage in diversification strategies, a firm with more organizational slack could be capable of dealing with and integrating those diversified resources for its innovation practice, thus increasing a firm's adaptability to external environmental uncertainties. Thus, H4a-H4c are supported. Models 10 and 11 include all the variables for organizational slack, international diversification, two business diversification variables, and their interactions. The results remain robust and reveal that organizational slack positively influences the relationship between firms' diversification strategies and innovation performance in open economies.

5.3. *Further analysis in different big data development environments*

Big data development varies across regions in China. As discussed earlier, big data technology provides more opportunities and potential for EMFs to make connections and invest in different markets around the globe. For firms in a region with more big data development, the market will likely be open, transparent, and full of innovative dynamism,

Table 6
The moderating effect of organizational slack

VARIABLES	Model 7	Model 8	Model 9	Model 10	Model 11
Inter_div	0.002			0.001	0.001
	(0.001)			(0.001)	(0.001)
Overall busi_div		−0.225***		−0.214***	
		(0.059)		(0.057)	
Related busi_div			0.001		−0.014
			(0.117)		(0.119)
Org_slack	−0.021*	−0.009	−0.005	−0.026**	−0.023**
	(0.011)	(0.008)	(0.006)	(0.012)	(0.012)
Inter_div × Org_slack	0.001*			0.001*	0.001*
	(0.000)			(0.000)	(0.000)
Overall busi_div × Org_slack		0.024*		0.020*	
		(0.014)		(0.011)	
Related busi_div × Org_slack			0.137***		0.150***
			(0.051)		(0.052)
Firm size	−0.080***	−0.087***	−0.095***	−0.077**	−0.084***
	(0.030)	(0.030)	(0.030)	(0.030)	(0.030)
Debt-to-asset ratios	−0.578***	−0.446***	−0.453***	−0.555***	−0.560***
	(0.144)	(0.133)	(0.134)	(0.144)	(0.144)
Cash Flow	0.671***	0.641***	0.682***	0.643***	0.684***
	(0.231)	(0.231)	(0.230)	(0.231)	(0.231)
Total employees	0.241***	0.252***	0.259***	0.239***	0.245***
	(0.031)	(0.031)	(0.031)	(0.031)	(0.031)
Board size	0.029**	0.027**	0.030***	0.027**	0.030***
	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
Board independence	−0.834***	−0.809**	−0.806**	−0.822**	−0.818**
	(0.322)	(0.323)	(0.321)	(0.323)	(0.321)
Returnee directors	−0.324**	−0.270*	−0.295*	−0.306**	−0.334**
	(0.151)	(0.151)	(0.151)	(0.152)	(0.151)
Dynamic capability	0.002**	0.002**	0.002**	0.001**	0.001**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
State ownership	−0.108**	−0.106**	−0.113**	−0.104**	−0.111**
	(0.052)	(0.052)	(0.052)	(0.052)	(0.052)
Provincial marketization	0.060***	0.066***	0.063***	0.063***	0.059***
	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)
Manufacturing	0.874***	0.862***	0.881***	0.857***	0.874***
	(0.069)	(0.069)	(0.069)	(0.069)	(0.069)
Year Dummy	Control	Control	Control	Control	Control
Constant	−1.473***	−1.410***	−1.398***	−1.451***	−1.443***
	(0.510)	(0.508)	(0.510)	(0.508)	(0.510)
Observations	8,857	8,857	8,857	8,857	8,857
Log likelihood	−18847.41	−18843.94	−18845.97	−18840.24	−18841.80
Wald chi2	978.23***	984.68***	983.26***	994.40***	991.95***

Note: Numbers in parentheses are standard errors. * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$.

making the firms more motivated to pursue diversification strategies and external resources to create competitive advantages. However, in a region with less big data development, where the market is relatively closed and has a limited flow of information, knowledge, and resources, firms may be somewhat restricted from acquiring necessary resources by diversifying the business into different industries or foreign markets.

To further examine the effects of diversification strategies on firms' innovation performance in different big data development environments, we classify the data into two subsamples according to the 2018 Big Data Development Index (BDDI) issued by the China Center for Information Industry Development. This index is measured using five aspects of development: environment, big data industry, big data application, data sharing, and technological innovation. Specifically, the higher big data development environment includes firms located in provinces with larger than average BDDI values; all other firms are classified as belonging to the lower big data development environment. As shown in Figure 3, Guangdong has the highest BDDI value, followed by Beijing and Shanghai. Twelve provinces have a BDDI value over the average of 33.84.

Table 7 presents the classification regression results. As expected, the effect of international diversification is stronger among companies in higher-development environments, with the coefficient in Model 1 (0.011, $p < 0.01$) being larger than that of Model 6 (0.008. $p < 0.05$). This result suggests that the development of big data could encourage firms to go abroad for obtaining innovation resources. In addition, overall business diversification harms firms' innovation in higher-development environments, whereas the positive role of related business diversification is stronger in lower-development environments. Furthermore, the results show that the interaction effect of international and business diversification only appears in higher-development settings. This supports the idea that as big data facilitating firms engage in business diversification, overdiversified businesses, especially those involved in many unrelated business diversifications, may create inefficiencies in management and divert attention and resources from innovation activities. These findings are largely consistent with our arguments.

5.4. Robustness check

We conduct robustness tests, and the results are presented in Table 8. We begin by examining the effect of overall business diversification using different measures (Cincera and Ravet, 2014). First, we measure diversification using the Herfindahl-Hirschman Index (HHI) based on sales for segments in the firm. The HHI is calculated as $HHI = 1 - \sum_{i=1}^{n} p_i^2$, where p_i represents the proportion of sales in segment i to the total sales. A higher HHI value suggests that the firm conducts a more diversified business. Model 1 shows that business diversification based on the HHI measure has a negative and significant effect on a firm's innovation performance. Second, we measure diversification using the number of market segments in which the firm operates. The results in

Table 7
Regression results in high and low big data development environments

VARIABLES	Higher big data development environment					Lower big data development environment				
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
Inter_div	0.011***			0.003**	0.001	0.008**			0.004	0.008***
	(0.001)			(0.001)	(0.001)	(0.002)			(0.003)	(0.002)
Overall busi_div		-0.241***		-0.046			-0.074*		-0.201	
		(0.062)		(0.079)			(0.106)		(0.125)	
Related busi_div			0.084		0.343**			0.392***		0.414**
			(0.120)		(0.153)			(0.148)		(0.176)
Inter_div × Overall busi_div				-0.012***					-0.017	
				(0.003)					(0.006)	
Inter_div × Related busi_div					-0.015**					-0.001
					(0.006)					(0.010)
Firm size	0.139***	-0.149***	-0.151***	-0.149***	-0.143***	0.102*	0.089	0.066	0.089	0.085
	(0.043)	(0.038)	(0.038)	(0.038)	(0.038)	(0.055)	(0.056)	(0.056)	(0.056)	(0.056)
Debt-to-asset ratios	-0.872***	-0.439***	-0.456***	-0.434***	-0.461***	-0.295	-0.283	-0.319	-0.300	-0.321
	(0.207)	(0.146)	(0.147)	(0.146)	(0.147)	(0.209)	(0.211)	(0.211)	(0.209)	(0.210)
Cash Flow	-0.674	0.303	0.375	0.389	0.370	1.030***	1.046***	1.084***	1.064***	1.064***
	(0.459)	(0.284)	(0.285)	(0.286)	(0.285)	(0.393)	(0.391)	(0.390)	(0.394)	(0.393)
Total employees	0.903***	0.279***	0.276***	0.278***	0.267***	0.122*	0.140**	0.170***	0.126*	0.144**
	(0.041)	(0.037)	(0.037)	(0.037)	(0.037)	(0.064)	(0.065)	(0.065)	(0.065)	(0.065)
Board size	-0.040**	0.048***	0.053***	0.045***	0.054***	-0.013	-0.019	-0.020	-0.011	-0.014
	(0.018)	(0.015)	(0.015)	(0.015)	(0.015)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)
Board independence	-1.315**	-1.422***	-1.376***	-1.358***	-1.346***	0.615	0.699	0.593	0.521	0.540
	(0.621)	(0.404)	(0.399)	(0.400)	(0.394)	(0.552)	(0.554)	(0.554)	(0.556)	(0.553)
Returnee directors	0.907***	-0.162	-0.201	-0.139	-0.191	-0.870***	-0.739**	-0.784**	-0.813***	-0.911***
	(0.275)	(0.172)	(0.172)	(0.173)	(0.173)	(0.314)	(0.313)	(0.312)	(0.314)	(0.313)
Dynamic capability	-0.002	0.001	0.001	0.001	0.001	0.002**	0.0021**	0.002**	0.002**	0.002**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
State ownership	-0.275***	-0.229***	-0.244***	-0.222***	-0.239***	0.336***	0.307***	0.315***	0.320***	0.343***
	(0.077)	(0.065)	(0.065)	(0.065)	(0.065)	(0.096)	(0.096)	(0.097)	(0.097)	(0.097)
Provincial marketization	0.023	0.039*	0.037	0.044*	0.037	0.066**	0.050	0.053	0.063*	0.067**
	(0.030)	(0.023)	(0.023)	(0.023)	(0.023)	(0.033)	(0.033)	(0.033)	(0.033)	(0.033)
Manufacturing	1.865***	0.883***	0.909***	0.899***	0.910***	0.778***	0.739***	0.748***	0.791***	0.776***
	(0.071)	(0.089)	(0.089)	(0.090)	(0.089)	(0.116)	(0.117)	(0.116)	(0.117)	(0.116)
Year Dummy	Control	Control	Control	Control	Control	Control	Control	Control	Control	Control
Constant	-7.947***	0.104	0.014	-0.007	-0.120	-5.304***	-4.927***	-4.685***	-4.966***	-5.102***
	(0.733)	(0.662)	(0.664)	(0.664)	(0.666)	(0.894)	(0.892)	(0.897)	(0.905)	(0.902)
Observations	5,895	5,895	5,895	5,895	5,895	2,962	2,962	2,962	2,962	2,962
Log likelihood	-18824.64	-18845.67	-18849.40	-18839.96	-18843.82	-18849.27	-18845.67	-18849.40	-18839.96	-18843.82
Wald chi2	979.23***	981.96***	974.07***	996.38***	988.23***	975.45***	981.96***	974.07***	996.38***	988.23***

Note: Numbers in parentheses are standard errors. * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$.

Model 2 show that this measure of diversification negatively affects a firm's innovation outcomes. Third, in addition to following Rumelt's (1974) categorizations of diversification strategies, we alternatively measure overall business diversification using the proportion of a firm's sales contributed by its largest single business; an increase in the sales proportion of the largest single business implies that more focused or dominant businesses are operated in the firm. Thus, we chose to reverse this variable. As predicted, the maximum measure (reverse-coded) of diversification is related to a decrease in a firm's innovation performance. These findings support our argument that overall business diversification undermines firms' innovation improvements.

Additionally, to eliminate the potential endogeneity between overall business diversification and innovation, we create an instrumental variable, diversityc, measured as the average business diversification of each firm from 2009 to 2018, which is constant for a given firm but it takes different values among firms. This is done to correct for the potential endogeneity of contemporaneous values (Garcia-Vega, 2006). Similarly, we also create an instrumental variable, related diversity, measured as each firm's average related business diversification. As shown in Model 5, diversityc (-0.348, $p < 0.01$) and related diversityc (0.674, $p < 0.01$) have the expected influence on a firm's innovation performance. Finally, considering that firms in manufacturing are more likely to produce innovation than those in other industries, we test the effects of international and business diversification (including overall and related business diversification) in a subsample that contains only manufacturing firms. The results are shown in Model 6 and remain robust.

6. Conclusion and discussion

The development of big data and open economies encourages EMFs to pursue diversification strategies to integrate external resources to create competitive advantages. In this paper, we draw on the CBV and examine how Chinese firms combine and leverage resources through international and business diversifications to enhance innovation performance. This study reveals that a firm's international diversification significantly improves its innovation performance, firms that conduct related business diversification can better absorb and leverage similar resources and apply them to innovation practices, whereas overall business diversification may lead to difficulties in coping with highly heterogeneous resources and can be detrimental to a firm's innovation.

Additionally, there is a substitution effect of a firm's international and business diversification; the positive influence of international diversification on a firm's innovation is at risk of being diminished if the firm also has a high level of business diversification (including related diversification). These results could be more significant if the firm is located in a region with higher big data development. Further study revealed that organizational slack, which serves as a firm-specific resource, can positively moderate the effect of diversification strategies on a firm's innovation performance.

Table 8
Robustness test

VARIABLES	Diversification HHI-measure Model 1	Diversification number-measure Model 2	Diversification maximum-measure Model 3	Endogeneity test Model 5	Manufacturing only Model 6
Diversification HHI-measure	-0.415***				
	(0.092)				
Diversification number-measure		-0.048***			
		(0.014)			
Diversification max-measure (reversely coded)			-0.517***		
			(0.123)		
Diversityc (instrumental)				-0.348***	
				(0.079)	
Related diversityc (instrumental)				0.674***	
				(0.176)	
Inter_div					0.004**
					(0.001)
Overall busi_div					-0.801***
					(0.085)
Related busi_div					0.520***
					(0.157)
Firm size	-0.090***	-0.086***	-0.099***	-0.097***	0.434***
	(0.030)	(0.030)	(0.033)	(0.030)	(0.052)
Debt-to-asset ratios	-0.412***	-0.408***	-0.352***	-0.458***	-0.544***
	(0.120)	(0.119)	(0.131)	(0.120)	(0.197)
Cash Flow	0.616***	0.653***	0.741***	0.663***	-0.245
	(0.231)	(0.231)	(0.258)	(0.230)	(0.443)
Total employees	0.255***	0.253***	0.283***	0.260***	0.533***
	(0.031)	(0.031)	(0.035)	(0.031)	(0.052)
Board size	0.027**	0.0291**	0.023*	0.030***	-0.016
	(0.011)	(0.011)	(0.013)	(0.011)	(0.016)
Board independence	-0.791**	-0.808**	-0.954***	-0.799**	-0.504
	(0.323)	(0.322)	(0.365)	(0.318)	(0.539)
Returnee directors	-0.272*	-0.271*	-0.269*	-0.303**	1.402***
	(0.151)	(0.151)	(0.162)	(0.151)	(0.265)
Dynamic capability	0.002**	0.002**	0.001**	0.002**	-0.004**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
State ownership	-0.104**	-0.104**	-0.055	-0.116**	0.268***
	(0.052)	(0.052)	(0.056)	(0.052)	(0.070)
Marketization	0.065***	0.066***	0.063***	0.069***	0.197***
	(0.014)	(0.015)	(0.015)	(0.015)	(0.020)
Manufacturing	0.858***	0.856***	0.889***	0.826***	—
	(0.069)	(0.069)	(0.076)	(0.070)	—
Year Dummy	Control	Control	Control	Control	Control
Constant	-1.363***	-1.461***	-1.317**	-1.246**	-11.82***
	(0.508)	(0.507)	(0.560)	(0.508)	(0.832)
Observations	8,857	8,857	8857	8,857	4,862
Log likelihood	-18841.29	-18845.39	-16517.95	-18839.94	-16190.31
Wald chi2	990.33***	983.21***	922.92***	995.09***	931.43***

Note: Numbers in parentheses are standard errors. * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$.

6.1. Implications for research

This study makes three main contributions. First, we provide new insights for EMFs' innovation development by investigating how a firm's diversification strategy helps it obtain and integrate external resources. EMFs have made great achievements in innovation and have attracted increasing scholarly attention over the past few years. Although prior studies have demonstrated the importance of resources (e.g., social ties and government support) in EMFs' innovation, few have paid attention to the idea that as big data development grows, many EMFs adopt diversification behavior to accelerate resource accumulation and to combine the resources embedded in different markets to promote innovation practice. Taking the CBV perspective, we examine the effects of international and business diversification on Chinese firms' innovation performance, contributing to innovative research on EMFs.

Moreover, our findings can be extended to other emerging market contexts, such as India (Kale and Little, 2007; Dutta and Snehvrat, 2020), where companies often face constraints, including a lack of advanced technology, and tend to achieve leapfrog innovations by looking outward to gain necessary innovation resources. Our study complements the existing literature by highlighting that firms engage in international business or tap into related product markets to promote innovation performance.

Second, this study deepens our understanding of the substitution effect of international and overall business diversification on EMF innovation. Since EMFs are latecomers in a "catch-up game" globally, many companies still have disadvantages in resources and capabilities to support their high-quality innovation in open economies. An internationalizing firm with a high level of overall business diversification may cause low efficiency in resource integration and lead to high costs in controlling diversified businesses. Third, we contribute to existing innovation research by emphasizing the integration of external and internal resources, especially organizational slack. We highlight that organizational slack, which acts as an important potential resource, can support a firm's ability to do business overseas and encourage the firm to experiment with new strategies, such as entering new industries, which might not be approved under more resource-constrained conditions. Our findings advance innovative research in open economies by explicating that organizational slack (internal resource) has positive effects on EMFs that conduct diversification activities (gaining external resources).

6.2. Implications for practice

The findings of this study also have important practical implications for EMF managers. On the one hand, when conducting innovation activities, managers should value the role of international diversification. An EMF that connects foreign markets can obtain valuable resources and accelerate learning, which is beneficial for its innovation practice. However, this may not be advantageous for EMFs that concurrently engage in international and business diversifications. In light of Chinese innovation cases, such as Huawei and Alibaba, practicing an international diversification strategy with a narrower business or implementing a business diversification strategy with a lower level of internationalization would benefit a firm's innovation development in open economies.

On the other hand, EMF managers should carefully adopt business diversification strategies in big data environments with higher competition. Overall, business diversification, especially when much of it is unrelated business diversification, may negatively impact innovation development to some extent because EMFs still lack strong managerial and technological capabilities. Additionally, organizational slack can be a resource that helps a company adapt to inner adjustments and external changes. EMFs that aim to carry out innovation investments should focus on the effect of organizational slack, optimize their resource configuration, and achieve sustainable innovation development.

6.3. Limitations and future research directions

This study has several limitations that offer opportunities for future research. For example, we only investigate the diversification strategies of Chinese firms; further research can advance the CBV to examine the effects of other external resource strategies, such as network partnership and strategic acquisition, on firms' innovation performance (Christofi et al., 2019). In addition, our study finds that international and business diversification can be ways of acquiring outward resources that linearly influence a firm's innovation. However, prior studies also show that the effects of these two diversification behaviors on firms' performance are far from linear (Antretter et al. 2020; Garrido-Prada et al., 2019). Further research can analyze other possible relationships, such as "U"- and "S"-shaped relationships, and their combinative effect.

Moreover, our research only explores data from Chinese listed companies. Given that many unlisted companies, such as Huawei, have also achieved great innovations, the inclusion of more unlisted companies could extend our theory development and empirical design. Further studies could consider other EMFs and conduct a fine-grained exploration of how these firms compose and exploit their resources to achieve rapid innovation growth in an open economy.

Finally, the development of big data has promoted(Holzmayer and Sascha, 2020) the emergence of a variety of computer algorithms. In addition to the crawling algorithm and Python, some artificial intelligence and machine learning algorithms can help us process the data and conduct analyses. For example, cluster analysis is an unsupervised learning process that can classify data into clusters. In further research, we can use cluster analysis algorithms, such as k-means, to classify the sample into different categories and examine how diversification strategies in different subsamples influence firms' innovation in open economies.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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