R&D MANAGEMENT

Maneuvering the bumps in the New Silk Road: Open innovation, technological complexity, dominant design, and the international impact of Chinese innovation

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Chinese innovation is again flowing westwards, which is fomented by China's Belt and Road Initiative. In this context, we study the international impact of innovations from specific countries. Based on panel data of patents from 27 countries over 17 years, we find that levels of open innovation, technological complexity, and dominant design influence the international impact of innovations from a country. Contrary to earlier research, however, this influence is negative when open innovation activities are involved. This is particularly relevant in the context of Chinese innovation, in which the same innovation networks that promote efficient production may hinder the development of innovations. Due to the innate uncertainty and newness of innovation, partners beyond the common local and long-term networks must be included. Hence, to effectively create a New Silk Road of Innovation, innovation ecosystems may need to expand across national borders. This opens up fruitful avenues for future research, and individuals with multiple cultural identities can bridge the gaps between contexts.

1. Introduction

For many years, Asian companies have focused on adapting Western technologies and developing them further through local R&D activities using Western innovation processes (Brem and Wolfram, 2017). In this setup, Asian companies defined themselves as prolonged workbench for Western companies. This very successful strategy allowed Chinese companies to become global players based on the Chinese version of state capitalism (Schweinberger, 2014). This strategy meant many dominant designs were taken for granted, such as engine technologies or telecommunication standards. However, a new trend has recently emerged: companies from Eastern markets are developing products for Western markets. This development is related to frugal innovation, which focuses on products that are affordable and meet the needs of resource-constrained consumers (Agarwal et al., 2016). Due to cost pressure and scarcity tendencies in many Western markets, these products are gaining momentum which could be enhanced by the so-called 'New Silk Road'. This project, also called China's Belt and Road Initiative, aims to stimulate trade, especially to Northwest China and Central Asia, while also considering sustainability (Li et al., 2015). The idea is based on the established 'Silk Road', which has connected Asia and Europe for centuries (Liu, 2010; Hansen, 2012). The New Silk Road project focuses on bringing more products from the West to the East, and vice versa, based on the initial success in earlier centuries. Hence, it is one of the biggest economic projects of our time, creating many opportunities but also challenges in terms of innovation dynamics and the appropriation of R&D (Di Minin and Bianchi, 2011; Corsi et al., 2014).

Within this context, our research focuses on innovation mechanisms related to the increased international connectivity of innovation – i.e., open innovation, technological complexity, and dominant design – and their relationship with the international impact of Chinese innovation. In a broader sense, we investigate how the international impact of innovation can be measured. With this approach, we yield to foster our understanding of success factors for international innovation activity.

This article is structured as follows: First, a brief overview of related literature on the international impact of Chinese innovation and on the role of openness, technological complexity, and dominant designs is provided. Based on this background, hypotheses are derived and presented. Subsequently, the methodological approach is introduced, which is followed by a presentation and discussion of the results of this study. Finally, implications for theory and practice are described, as well as key limitations and potential avenues for future research on this emerging phenomenon.

2. Theoretical background

2.1. *The international impact of Chinese innovation*

Chinese companies are evolving from copying Western technology to developing innovations of their own (Xu et al., 2018). Chinese knowledge is, therefore, increasingly flowing westwards, and knowledge flows are becoming more and more reciprocal (Collinson and Liu, 2019). It is crucial to study the growing international impact of Chinese innovation since the use of technologies by external parties is an indicator of those technologies' quality and usefulness. Whereas international innovation impact can be achieved through, for example, export of business model innovations and practices, or of innovation culture or innovation talents, we here focus on the impact of technological innovations on subsequent technologies.

As countries develop innovation capabilities, they tend to produce more valuable technologies (Petralia et al., 2017). To understand China's technological progress, we must move beyond considering the level of specific innovations or firms and instead consider entire innovation ecosystems (Adner and Kapoor, 2016). Innovations evolve from prior technologies (Basalla, 1988) in a process that involves recombining existing knowledge to generate new ideas (Kogut and Zander, 1992).

China has a unique innovation ecosystem, which exists in a transition economy in which private property and risk-taking are gradually being introduced. Historically, China has been the home of many of humanity's most fundamental innovations, but private enterprises have only been officially registered in mainland China since 1989 (Jian et al., 2020). During the previous period without possible remuneration for investing in uncertain outcomes, individuals lacked incentives for innovation. The Chinese government now recognizes innovation as the main driving force of development (Chinese Minister of Science and Technology, 2016), and innovation is moving to the forefront of Chinese business. However, China's innovation ecosystem still differs greatly from those of emerging economies around the world since business in general, and innovation in particular, relies on government support (Zhang and Merchant, 2020). Whereas a more market-oriented approach was fomented in the early years of transition, government intervention has been a key characteristic of China's innovation policy since 2003 (Chen and Naughton, 2016). This means that instead of relying on individual entrepreneurs, innovation is largely government-funded, and thus, the government and not the market determines the type of innovation pursued (Jian et al., 2020). A prominent example is the solar industry, which has demonstrated the importance of contextual factors such as changing institutions and technology transfer (Huang et al., 2016). In the face of cultural obstacles, Chinese companies have acquired European entities to gain access to their innovation capabilities (Yakob et al., 2018). While Chinese telecom giant Huawei is now receiving royalties from Western companies such as Apple, and Chinese technology is advancing in the aerospace, aviation, nuclear energy, and high-speed rail industries, Chinese gains from intellectual property exports are still a mere one percent of those of the United States (Li et al., 2020). Connections by high-speed rail, in turn, contribute to innovation in the connected regions, further evidence of the complexity of China's innovation ecosystem (Gao and Zheng, 2020).

Since connectivity is imperative to Chinese innovation, President Xi Jinping launched the Belt and Road Initiative in 2013 to promote connectivity and partnerships among Asia, Europe, and Africa – effectively creating a New Silk Road of Innovation (National Development and Reform Commission, Ministry of Foreign Affairs and Ministry of Commerce of the People's Republic of China, 2015). The export of innovations from China to Europe will play a central role in the New Silk Road and, hence, this initiative will also lead to new R&D networks. These networks might emerge in an East-East context or in an East-West one, meaning science-technology–based innovation will also grow locally (Di Minin et al., 2012; Chen et al., 2012).

2.2. *Openness and the international impact of innovation*

As the world becomes increasingly interconnected, innovation is also growing (Castells, 2000). The innovation process increasingly takes place in 'purposively managed knowledge flows across organizational boundaries', that is, open innovation (Chesbrough and Bogers, 2014, p. 17). Whereas the term 'open source' refers to innovation outcomes that are open for access or use by others (West and O'Mahony, 2008), 'open innovation' refers to the innovation process and collaboration within this process, such as through alliances or licensing agreements. By opening up the innovation process, firms are able to access innovation capabilities without going through the costly process of building them (Chesbrough, 2006). This should reduce dependence on the local environment for innovation inputs.

The use of external knowledge not only improves firms' innovation performance (Ahuja, 2000; Bouncken et al., 2016), but can also impact society as a whole (Ahn et al., 2019). When firms can increase the value of innovation through openness (Chesbrough and Appleyard, 2007), the surrounding innovation ecosystem also benefits (Ferras-Hernandez and Nylund, 2019). As Chen et al. (2011) show, openness to external sources of innovation has become a key success factor for Chinese companies. Still, firms in this transition economy need to overcome open innovation capability gaps (Li et al., 2016). International open innovation requires overcoming cognitive impediments, such as favoring innovations that are in line with Chinese culture (Mei et al., 2019), and overcoming operating barriers, such as the use of unapproved suppliers (Lewin et al., 2017).

With increasing R&D intensity, Chinese manufacturing small- and medium-sized enterprises (SMEs) are beginning to implement strategies for protecting intellectual property (Mei et al., 2019). Varsakelis (2001) argues that a nation's culture, its patent protection, and its economy's openness are key measures of R&D intensity and subsequent innovations. While all Chinese innovations were government owned, protecting property rights was not an issue, but now adopting external practices appears to aid the international impact of Chinese innovation, and shift the open innovation environment away from only taking Western economies' view. The new Eastern economies provide environments where open innovation happens in different forms, including inbound and outbound setups with local academic institutions and companies (Fu and Xiong, 2011; Wang et al., 2012; Gawer and Cusumano, 2014; West et al., 2014; Cassiman and Valentini, 2016). Open innovation in the form of close collaboration between different firms is thus particularly important for achieving lasting results, and we define the degree of open innovation as the extent to which firms collaborate in specific innovations. Then, the degree to which a country's firms are engaged in open innovation should be positively related to that country's international impact, which is formalized below:

H 1 The degree of open innovation is positively related to the international impact of the innovation of a country.

2.3. *Technological complexity and the impact of innovation*

Technological complexity drives the economic growth of nations and is the result of interactions between activities (Hidalgo and Hausmann, 2009). Connectivity augments complexity since the latter increases when either the number of technological components or the amount of interactions between them rises (Fleming and Sorenson, 2001). Complex technologies tend to be more valuable than simple ones because developing complex technologies requires a more sophisticated set of innovation capabilities (Balland et al., 2019), and countries begin to develop more complex and valuable innovations as their innovation capabilities develop (Petralia et al., 2017). Complexity should, therefore, increase the international impact of a country's innovation since technology has an important role in economic growth. Hence, it is also important to understand the relevant science and technology policies to ensure longer term economic growth (Feldman et al., 2012).

H 2a The degree of technological complexity is positively related to the international impact of innovation of a country.

Complex innovations are more difficult to transfer than their simpler counterparts (Kogut and Zander, 1993), and technology transfer is generally risky (Bozeman, 2000). Managing organizational knowledge processes and their transfer can be seen as a key factor for new business development in general, especially in an emerging market context (De Boer et al., 1999). Since open innovation requires knowledge transfer between organizations (Simard and West, 2006), complex innovations should be less likely to be completely and successfully transferred. Thus, openness may reduce the positive effects of technological complexity on the international impact of innovation. Openness is not always positive for a company, as some companies profit more than others due to their resource configuration and organizational capabilities (Schuster and Brem, 2015). Prior research (e.g., Salge et al., 2013) argues that openness is curvilinearly related to new product success. Thus, complex technologies are expected to have less international innovation impact in the presence of open innovation.

H 2b Open innovation moderates the relationship between technological complexity and international innovation impact, so that more complex technologies have less impact when there is a high degree of open innovation.

2.4. *Dominant design and the impact of innovation*

Innovation is also highly dependent on the establishment of standards. The term 'dominant design' has been used to describe the emergence of a technological standard in an industry, and research has demonstrated that a dominant design is not necessarily the objectively 'best' technology. Such a design is set once it is accepted by the market. One of the most famous cases – among many examples – is Blu-ray, which won its dominant design battle with HD-DVD, which was a similar but incompatible format. Even though HD-DVD was first to the market, similar to the known term 'DVD', and perceived as the more advanced technology (Waller et al., 2008), Blu-ray had more supporters driving its acceptance in the market as the standard (Den Uijl and de Vries, 2013).

Hence, dominant design is an innovation that represents 'over 50 percent of the new implementations of the breakthrough technology' (Anderson and Tushman, 1990, p. 614). Dominant designs can also be a precondition for achieving a dominant market position (Utterback and Suárez, 1993; Suárez and Utterback, 1995), but they are often not the best available solution (Christensen, 2000), as Blu-ray demonstrates. When a dominant design is established, innovations at the technology level focus on other subsystems (Abernathy and Utterback, 1978). The rate of innovation decreases at this stage (Brem et al., 2016). Since the dominant design is adopted by the majority of the subsequent innovations on that technology (Murmann and Frenken, 2006), the impact of a country's innovation should increase if it produces a greater quantity of dominant designs.

H 3a The amount of dominant designs is positively related to the international impact of the innovation of a country.

Establishing a dominant design across several countries requires the interconnectivity of innovation systems across national borders (Breschi and Malerba, 1997), which is the apparent aim of the Belt and Road Initiative. Since the financial crisis of 2008, the role of globalization has become even more important in the context of dominant design emergence (Brem et al., 2020). Dominant designs can be generated through means such as market battles and standardization committees (Keil et al., 2000; Gallagher, 2007). Large firms with an existing, sustained international impact on innovation can sometimes achieve market dominance single-handedly, whereas most companies rely on other firms accepting and building on their innovation. Examples of such large firms in the business-to-consumer context include Apple with its iPhone and related ecosystem and Microsoft with its Office suite and related network; in business-to-business settings, many examples of sustained international dominant designs exist in industries such as building materials and production technologies. However, organizations are more likely to adopt an innovation if they have been involved in the development of innovations in an open innovation process (Ndou et al., 2011; Inauen and Schenker-Wicki, 2012), and SMEs in particular profit from a flexible and open structure that builds on their competitive advantage (Lee et al., 2010). Open innovation should, thus, decrease the international innovation impact of countries with low levels of dominant design but should increase the impact of countries with many dominant designs.

> *H 3b* Open innovation moderates the relationship between dominant design and international innovation impact, so that the relationship is stronger when there is a high degree of open innovation.

Our hypotheses can be summarized in a conceptual framework (see Figure 1). We developed this country-level conceptual model by examining salient contextual antecedents to the international impact of Chinese innovation that are related to increased connectivity, that is, open innovation processes, technological complexity, and the generation of dominant designs. We then test the model for countries in general and for China in particular.

3. Data and methods

We test the hypotheses with a patent citation analysis. Patent citations allow for tracing the impact of certain innovations on others, since a patent citation implies that the cited innovation has been used in the citing patent (Rosenkopf and Nerkar, 2001; Jaffe and de Rassenfosse, 2017). Patents are also useful for studying the relationship between connectivity and innovation, as patent data are particularly rich and includes information, that is, regarding the breadth and scope of technology as well as information about the authors including their location. Thus, patents have been used to study open innovation (Hitchen et al., 2017; Suh and Jeon, 2019), technological complexity (Fleming and Sorenson, 2001; Ivanova et al., 2017), and dominant design (Brem et al., 2016; Huenteler et al., 2016).

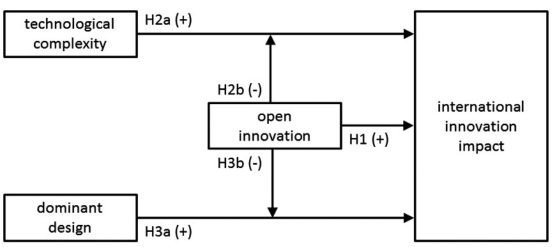

Figure 1. Conceptual model.

The data set has been extracted from the OECD Citations Database and the OECD REGPAT Database, July 2019 edition, which are based on data from the European Patent Office's Worldwide Statistical Patent Database (PATSTAT, Autumn 2019 edition). It only contains data from patent citations to patents applied for between 2000 and 2016 via the Patent Co-operation Treaty. The data set includes data for some countries from earlier years, but Chinese patents are only available from 2000 on, and thus, we used this year as our lower bound.

Since we study cross-country innovation, we only want to take into account direct knowledge flows from one country to another, and therefore, exclude citations of patents from the same country. In order to maintain the focus on those cross-country knowledge flows and not study external knowledge that has previously been integrated into a country's knowledge base, we only include citations introduced by the applicant, and omit citations introduced later, for example, by the patent examiner. Our sample includes the 27 countries that have observations in the OECD Citations Database for all 17 years of the study, that is, those countries that have had a patent cited during each of the 17 years, as listed in Table 1. We thereby include all countries for which patented innovations have consistently had an impact on the innovation of other countries during the period of the study. The sample thus consists of observations for 459 country years. The United States and Canada were included for completeness in spite of being located outside the New Silk Road, as their innovation has a considerable impact and is often used as a benchmark (Li et al., 2020).

3.1. Dependent variable

The dependent variable *impact* is defined as the importance of the innovation of a country for future inventions. It is measured as the number of forward

Table 1. Countries in the sample

Austria	Ireland	Spain
Australia	Israel	Sweden
Belgium	Italy	Switzerland
Canada	Japan	United Kingdom
China	Luxembourg	United States
Denmark	Netherlands	Virgin Islands
Finland	Norway	
France	Republic of Korea	
Germany	Russia	
India	Singapore	

citations to the patents applied for by organizations from a country in a given year. A forward citation implies the use of the cited invention in another invention, and the variable *impact* thus measures the number of times a country's innovations have been used in other inventions in the sample period. For example, Chinese inventions patented in 2010 where cited 441 times by other inventions, and the impact for China in 2010 is therefore 441. The technological impact of innovations has frequently been measured by citation counts at the level of individual patents (Rosenkopf and Nerkar, 2001; Jaffe and de Rassenfosse, 2017). This measure has been compared to expert evaluations of technological impact and importance with no significant differences found between the two measures (Albert et al., 1991).

3.2. Independent variables

Open is the average degree of open innovation for a country's patents in a year. Open innovation denotes purposive interorganizational collaboration (Chesbrough, 2003), and such collaboration has been quantified with patent data since patent records indicate which organizations collaborated on each patent application (Hitchen et al., 2017; Suh and Jeon, 2019). Hence, we use the average number of applicants, for example, firms, universities, or public laboratories (Guellec and van Pottelsberghe de la Potterie, 2001) for each country year. Such a measure avoids issues associated with binary measures of open innovation (Barge-Gil, 2010).

Complexity is measured as the average number of eight-digit International Patent Classification (IPC) classes assigned to the patent of a country during each year. Complexity is generated by the interaction between activities (Hidalgo and Hausmann, 2009) or technological components (Fleming and Sorenson, 2001). Technological complexity can then be measured as the number of patent classes employed by the innovators in a country (Ivanova et al., 2017). Patents are, therefore, useful to measure complexity (Fleming and Sorenson, 2001).

Dominant design is measured as the average number of dominant designs created in a country in one year. A dominant design is an innovation used by the majority of subsequent innovations in one technology (Murmann and Frenken, 2006). Since patent citations imply the use of an innovation by another, these citations have been previously employed to measure dominant designs (Brem et al., 2016; Huenteler et al., 2016). We measure dominant designs for technologies using the eight-digit IPC class. Thus, at the patent level, *dominant* is a binary variable that takes the value of 1 if the patent has received more than 50% of citations in one eight-digit IPC class during any year; to conduct analysis on the country-year level, we take the average of this variable for patents applied for in each year. For example, if *dominant* has a value of .01 in a certain country year, one percent of the innovations patented by that country in that year have become dominant designs.

3.3. Control variables

We control for the potential differences among the types of technologies on the first level of the IPC scheme. We create control variables for the three largest categories, namely human *necessities* (e.g., agriculture, food, and medicine), *chemistry* and metallurgy, and *physics*. A patent can pertain to several different categories in the scheme, and including all categories, therefore, induces collinearity of the control variables representing certain categories. We hence do not create separate variables for the remaining five smaller categories; performing operations and transporting; textiles and paper; fixed constructions; mechanical engineering, lighting, heating, weapons and blasting; and electricity. The control variables indicate the share of patents belonging to each category for each country year.

We control for time-variant effects through the estimation method employed. *Year* is the priority year, that is, the year of the first patent application. We also control for the specific characteristics of each country by including county effects in the estimation method. We thus implicitly consider the heterogeneity of countries in terms of factors such as patenting systems and innovation culture.

3.4. Estimation method

Our dependent variable *impact* is derived from count data, and Poisson regressions are, therefore, likely to be appropriate. We carry out a series of Poisson panel regressions. The basic Poisson model can be expressed as follows:

$$Pr\left(Y_{it}=y_{it}\right)=\frac{\exp(-\lambda_t)\,\lambda_{it}^{\lambda_{it}}}{y_{it}\,!}$$

where λ_{it} is the mean and the variance of the dependent variable and y_{it} is the observed variable. In Model 1, we included country-specific random effects as follows:

$$\lambda_{it}=\beta' X_{it}+\alpha+u_{it}+\varepsilon_{it}$$

where u_{it} is a random effect for the *i*th country and ε_{it} is the within-class error. In Model 2, we included fixed effects for each country:

$$\lambda_{it} = \beta' X_{it} + \alpha_i + u_{it}$$

where u_{it} is a fixed effect for the *i*th country. In Model 3, we included the interaction effects among the independent variables in the random-effects model, and in Model 4, we include the interaction effects in the fixed-effects model. In Model 5, we fit the model to the data for a single country, China. Since this requires a pooled regression, we include the time variable *year* among the control variables:

$$\lambda_{it} = \beta' X_t + \alpha + \varepsilon_{it}$$

where X_t is a vector of the independent and control variables and ε_{it} denotes the error term. In Model 6, we include the interaction effects in this specification.

4. Results

Figure 2 depicts Chinese-patent citations from the three countries that cited Chinese innovations most, with a marked increase in citations in recent years. The countries that used Chinese innovations the most are not geographically or culturally close to China. Rather, a pronounced recent increase is present in European countries such as Germany and the United Kingdom. The international impact of Chinese innovation is, thus, not only rising in quantity, but also in geographical reach.

Table 2 lists the Chinese innovations with the greatest impact, as well as their degree of openness, complexity, and dominant design. Notably, all of these innovations constitute dominant designs. Most are chemical compounds, mainly pesticides, and Sinochem appears to play a major role.

Table 3 reports the descriptive statistics and correlations for the entire data set. We assess the absence of multicollinearity by calculating the variance inflation factors, which are all under 1.30, with a mean of 1.20 and a tolerance above 0.76 for all variables (Kutner et al., 2004).

Table 4 contains the results of the Poisson regressions for the entire data set. Model 1 is a panel regression with the independent and control variables and random country effects for all 27 countries in the sample, whereas Model 2 is a fixed-effects regression with the same variables. Although the coefficients and diagnostics for both models are quite similar, a Hausman (1978) test rules out the random-effects specification. Model 2 rejects H1 regarding the positive relationship between open and impact, but lends support to H2a and H3a regarding the positive relations of complexity and dominant with impact.

Model 3 adds the interactions of *open* with *complexity* and *dominant* to the random-effects regression, and Model 4 is the corresponding fixed-effects regression. Again, a Hausman test yields preference for the fixed-effects specification. Both interactions have significant effects and were graphed in Figure 3a,b (Aiken and West, 1991). In Figure 3a, we see that *open* moderates the relationship between *complexity* and *impact*, with more complex technologies having less impact when there is a high degree of open innovation; this supports H2a. Figure 3b shows that *open* moderates the relationship between *dominant* and *impact*, so that the relationship is stronger when there is a high degree of open innovation. This lends support to H2b. Open innovation does decrease the international innovation impact for low levels of dominant design but increases the impact of countries with many dominant designs.

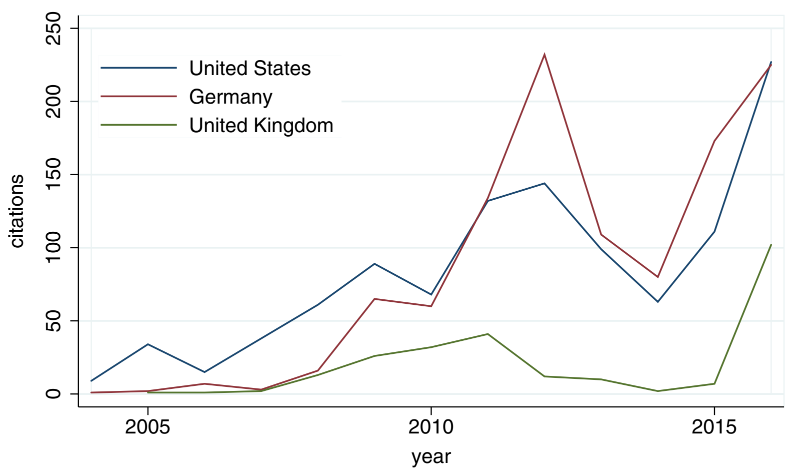

Figure 2. Citations of Chinese patents from other countries.

Table 2. Chinese innovations with greatest impact

Patent	Applicant(s)	Impact	Open	Complexity	Dominant
Preparation method and use of compounds having high biocidal activities	East China University of Science and Technology	93	1	2	1
Fluoromethoxypyrazole anthranilamide compounds, synthesization methods and uses thereof	Sinochem Lantian, Zhejiang Research Institute of Chemical Industry	82	2	8	1
Ortho-heterocyclyl formanilide compounds, their synthesis methods and use	Jiangsu Pesticide Research Institute	82	1	5	1
Benzamide compounds and applications thereof	Sinochem Corporation, Shenyang Research Institute of Chemical Industry	80	2	6	1
An apparatus using recyclable resource	Li Haiquan	68	1	1	1
Heterocyclic nitrogenous or oxygenous compounds with insecticidal activity formed from dialdehydes and their preparation and uses thereof	East China University of Science and Technology, Shanghai Shengnong Pesticide	48	2	12	1
Condensed amino nitroguanidine compounds, synthesis and use as botanical insecticides thereof	Qin Zhaohai	44	1	4	1
Cyano benzenedicarboxamide compounds, preparing methods and as agricultural insecticides uses thereof	Sinochem Lantian, Zhejiang Research Institute of Chemical Industry	44	2	12	1
Compound of 2,5-disubstituted-3-nitroimino-1,2,4-triazoline and preparation method and use as pesticide thereof	China Agricultural University	43	1	3	1
Ether compounds with nitrogen-containing 5-member heterocycle and the uses thereof	Sinochem Corporation, Shenyang Research Institute of Chemical Industry	43	2	9	1

Table 3. Descriptive statistics and correlations

	Variable	Mean	SD	1	2	3	4	5	6	7
1.	Impact	653.49	1,472.38							
2.	Open	1.08	0.15	−0.09*						
3.	Complexity	2.60	0.84	0.08*	−0.03					
4.	Dominant	0.44	0.14	−0.05	0.15**	0.01				
5.	Year	2008	4.90	−0.23**	0.01	−0.14**	−0.14**			
6.	Necessities	0.38	0.17	0.05	−0.21**	0.22**	−0.35**	0.04		
7.	Chemistry	0.36	0.15	0.12**	−0.05	0.31**	−0.14**	0.09**	0.11**	
8.	Physics	0.13	0.09	−0.02	0.17**	0.09*	0.11**	−0.03	−0.19**	−0.27**

n = 459.
**Significant at the 5% level.
*Significant at the 10% level.

Table 4. Poisson regression results

Variable	Model 1	Model 2	Model 3	Model 4
	RE	FE	RE	FE
Open	−7.59**	−7.59**	−9.11**	−9.10**
Complexity	0.04**	0.04**	4.03**	4.02**
Dominant	1.77**	1.77**	−23.06**	−23.07**
Open × complexity			−3.85**	−3.85**
Open × dominant			24.30**	24.31**
Necessities	0.11**	0.11**	0.37**	0.38**
Chemistry	−1.15**	−1.15**	−0.91**	−0.91**
Physics	−1.76**	−1.76**	−2.12**	−2.12**
Year				
Constant	14.32**		15.66**	
Diagnostics				
Log likelihood	−55,545	−55,266	−51,747	−51,468**
Wald χ^2 (df)	25,443**	25,449**	29,217**	29,224**

n = 459.
**Significant at the 5% level.

Table 5 reports the model's fit to the observations in order to understand to which extent the impact of Chinese innovation follows the general model. Model 5 is, hence, a Poisson regression that includes the independent and control variables for China only. It does not support H1 regarding the positive relationship between *open* and *impact*, and it depicts a negative relationship between *complexity* and *impact*, thus, rejecting H2a. H3a is supported by a significant positive relation of dominant with impact. Model 6 includes the interactions of open with the other independent variables. They are significant and, therefore, plotted in Figure 4a,b. In Figure 4a, the negative slope of *complexity* is steeper for higher degrees of *open* innovation, so H2b is only supported for high degrees of complexity in China. In Figure 4b, the positive slope of *dominant* is slighter for more *open* innovation, which rejects H3b for China.

5. Discussion and conclusion

Barring H1, all hypotheses were supported for the full sample (see Table 6). Regarding China specifically, a different picture emerges: H1 is not supported, but also H2a and H3b are rejected and H2b is only partially supported by the data. This section discusses the implications of the results.

We find that the levels of open innovation, technological complexity, and dominant design influence the international impact of innovations from a country. Contrary to theory, however, this impact decreases when open innovation activities are involved. One explanation could be that too much openness might be harmful for innovation in general, particularly in a competitive international environment. This finding contributes to the scarce body of literature on the negative effects of open innovation: For example, Su et al. (2009) find that partnerships with suppliers, customers, and competitors do not contribute to innovativeness. This is in line with Stefan and Bengtsson (2017), who associate negative open innovation outcomes with supplier and customer collaborations; thus, when firms innovate through collaboration within the networks in which they are deeply embedded, the results tend to not travel well.

This is particularly relevant in the context of Chinese innovation, in which the same innovation networks that promote efficient production may hinder the impact of innovation. An explanation might be that innovation requires different types of promoters (Hauschildt and Kirchmann, 2001). Such promoters are ideally found in communities supporting the creation, sharing, and dissemination of innovations (Fichter, 2009). Due to the innate uncertainty and newness of innovation, partners beyond the common local and long-term networks must be included. To effectively create a New Silk Road of Innovation, innovation ecosystems may need to expand across national borders. This opens up fruitful avenues for innovation research, and individuals with multiple cultural identities can bridge the gaps between contexts (Lee et al., 2018).

Lee et al. (2009) and Kim and Park (2010) further identify SMEs as negatively affected by open innovation. Brem et al. (2017) demonstrate that these negative effects relate partly to the choice of strategy for intellectual property (IP) protection. These results are also interesting in the context of Chen et al. (2011), who found that openness is a success factor for companies from China. While this might sound contradictory, it could be explained by the Chinese cultural norms regarding cognitive impediments (Mei et al., 2019) or by operating barriers, such as in terms of bureaucracy. Future research could study the relationship between connectivity and innovation impact under different regimes of IP protection, specifically in the context of improvements in Chinese IP rights that may be required in light of the increased connectivity created by the Belt and Road Initiative.

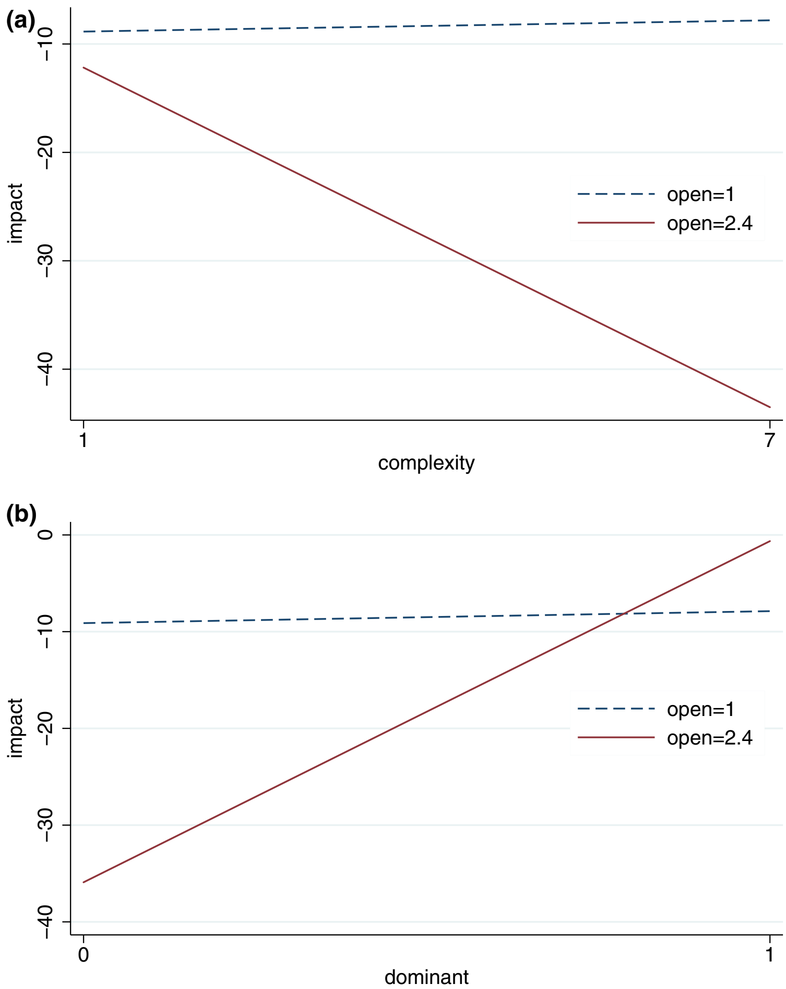

Figure 3. (a) Interaction of complexity and open for the full sample. (b) Interaction of dominant and open for the full sample.

Complementary explanations for the difficulty of translating open innovation into innovation impact provide fruitful avenues for further study. In a dynamic approach to open innovation, firms create the dynamic capabilities necessary to virtuously use their innovation ecosystems (Enkel et al., 2020). The ability to recognize opportunity and the ability to capitalize on it have been highlighted as driving innovation performance in internationalized Chinese manufacturers (Wu et al., 2016). The capabilities that foment open innovation must be simultaneously dynamic and deeply embedded in the Chinese context. The creation of embedded dynamic capabilities that enable firms to exploit the connectivity of the New Silk Road of Innovation is, therefore, a particularly intriguing avenue for research.

Open innovation further reduces international innovation impact by moderating the positive effects of complexity and dominant design for countries in general. This is not yet the case for China; however,

Table 5. Poisson regression results for Chinese data

Variable	Model 5	Model 6
Open	−0.22	29.72**
Complexity	−0.91**	5.20**
Dominant	8.82**	51.04**
Open × complexity		−5.56**
Open × dominant		−38.05**
Necessities	1.15**	0.15
Chemistry	6.45**	7.41**
Physics	−11.18**	−9.99**
Year	0.13**	0.13**
Constant	−266.58**	−290.42**
Diagnostics		
Log likelihood	−211	−194
LR χ^2 (df)	1,129**	1,165**

n = 17.
**Significant at the 5% level.

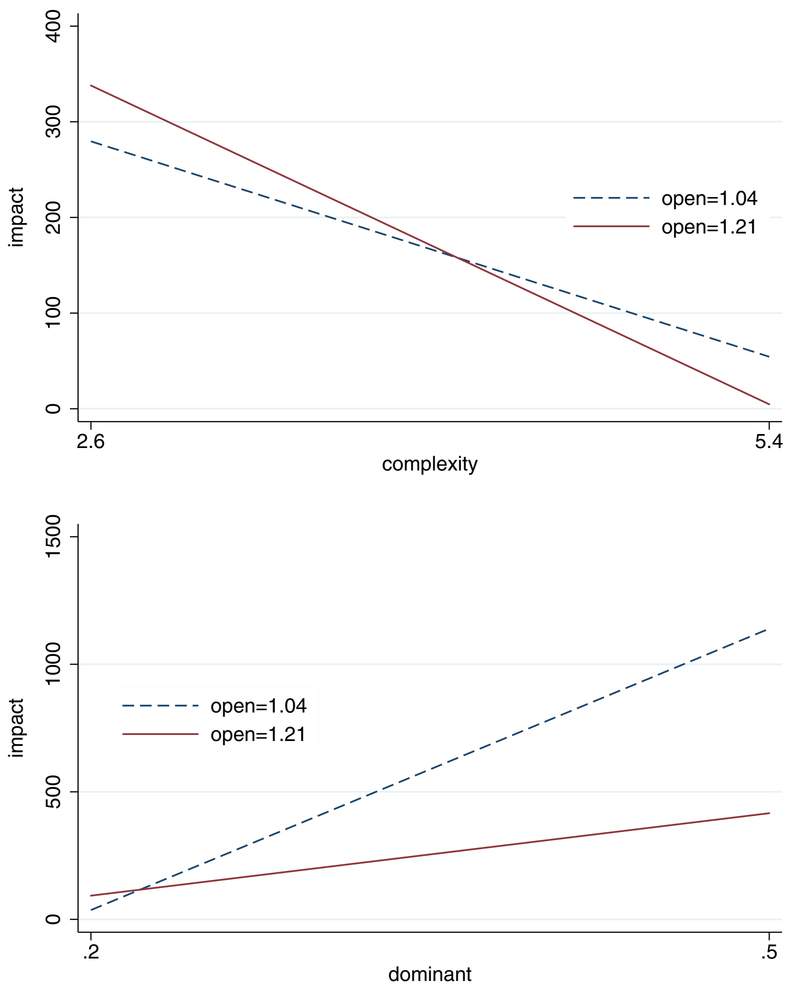

Figure 4. (a) Interaction of complexity and open for China. (b) Interaction of dominant and open for China.

Table 6. Overview of results

	Hypothesis	Full sample	China
H1.	The degree of open innovation is positively related to the international impact of the innovation of a country	Rejected	Not supported
H2a.	The degree of technological complexity is positively related to the international impact of the innovation of a country	Supported	Rejected
H2b.	Open innovation moderates the relationship between technological complexity and international innovation impact, so that more complex technologies have less impact when there is a high degree of open innovation	Supported	Partially supported
H3a.	The amount of dominant designs is positively related to the international impact of the innovation of a country	Supported	Supported
H3b.	Open innovation moderates the relationship between dominant design and international innovation impact, so that the relationship is stronger when there is a high degree of open innovation	Supported	Rejected

as connectivity increases along the New Silk Road of Innovation, the degree of connectivity-related factors is likely to increase, and the joint dynamics of open innovation, technological complexity, and dominant design are likely to approach those of other countries. In this new, more complex landscape, the embeddedness of innovation at different ecosystemic levels is crucial to achieving international impact. We find that when a country produces dominant designs, the international impact of its innovations grows. We identified pesticides as an area in which China has established a number of dominant designs and in which Chinese innovation has the greatest international impact (see Table 1). This area is important for Chinese agriculture in the light of recent regulatory bans of high-toxicity and high-residue compounds, since China uses twice the world average amount of pesticides per hectare of land OECD, 2018).

While technological complexity is positively related to the international impact of innovation for countries in general, this relationship is negative for China. Possibly, China has not yet developed the dynamic capabilities that are required to manage complex innovations. Instead, Chinese capabilities will be better developed in the second generation of process and production innovation (Breznitz and Murphree, 2011), meaning the effects of increased connectivity associated with the Belt and Road Initiative have not yet manifested in terms of managing complexity. Since the complexity of innovation tends to increase as countries develop (Petralia et al., 2017), the Chinese innovation ecosystem is busy building the required capabilities for more complex innovation. The Chinese strategy for enhancing innovation capacity also includes establishing national agricultural high-development zones and promoting public-private partnerships (OECD, 2018), and China ranked 14th in the 2019 Global Innovation Index after a steep rise over the previous few years (Dutta et al., 2019). We find that Chinese innovation has a rapidly increasing impact on Western innovation (see Figure 2). This is in line with recent developments in fields such as frugal innovations, and this emerging-markets phenomenon is becoming increasingly present also in Western economies (Agarwal and Brem, 2017). The New Silk Road will help diffuse the ‘do more with less’ thinking in Europe and beyond with the generation of reverse innovation dynamics (Govindarajan and Ramamurti, 2011; Corsi et al., 2014).

Our research is concerned with innovation on the national level. Caution must thus be taken when interpreting the results at the firm level. Managers may not be able to affect the international impact of their national innovation system. Still, understanding the innovation ecosystem in which the firm is embedded is crucial for strategy creation (Autio and Thomas, 2014), and managers may play a role in activating this ecosystem (Nylund et al., 2019). In firms that aim for international business, it is clear that open innovation, technological complexity, and dominant designs play a role that can further clarify future research.

As with any research, several limitations need to be noted for this study. We only study the impact of technological innovations on subsequent technologies. This study could thus be complemented by explorations of different ways to achieve international innovation impact, that is, through business model innovation, innovation culture or innovation talent. For example, the international impact of technological innovation could be related to the impact generated by the social network resources of Chinese emigrants to other countries (Chung et al., 2020).

The use of patent data also carries certain limitations in addition to those associated with the exclusive study of technological innovations. Not all innovations are patented, but firms may rely on other protective mechanisms such as secrecy or speed-to-market (Leiponen and Byma, 2009). Future studies may evaluate the use of such mechanisms in the context of international innovation ecosystems. Moreover, although patent data allow for measuring the number of open innovation partners, it does not specify, for example, the mode of collaboration or the processes employed. This quantitative study could thus be complemented with qualitative research to gain further insights. This study also did not consider industry-specific dynamics, which could also play a role in the understanding of Chinese innovation. This might offer potential for future studies, as would further studies into the knowledge flows between countries in geographical proximity along the New Silk Road, including the China-Pakistan, Bangladesh-China-India-Myanmar, China-Mongolia-Russia, China-Central Asia-West Asia, and China-Indochina Peninsula economic corridors (National Development and Reform Commission, Ministry of Foreign Affairs and Ministry of Commerce of the People's Republic of China, 2015). In addition, the after-effects of the COVID-19 pandemic will likely impact the Belt and Road initiative. Since it depends on economic benefits and debt-financing along the road, modifications may be required due to the crisis (Buckley, 2020).Finally, the general development toward more sustainability might also have an effect on the project, especially since the launch of the United Nations Sustainability Goals. As mostly multinational companies are involved in the Belt and Road initiative, they have the opportunity to introduce responsible research and innovation along the Silk Road (Nylund et al., 2021).

References

Abernathy, W.J. and Utterback, J.M. (1978) Patterns of industrial innovation. *Technology Review*, **80**, 7, 40–47.

Adner, R. and Kapoor, R. (2016) Innovation ecosystems and the pace of substitution: re-examining technology S-curves. *Strategic Management Journal*, **37**, 4, 625–648.

Agarwal, N. and Brem, A. (2017) Frugal innovation-past, present, and future. *IEEE Engineering Management Review*, **45**, 3, 37–41.

Agarwal, N., Grottke, M., Mishra, S., and Brem, A. (2016) A systematic literature review of constraint-based innovations: state of the art and future perspectives. *IEEE Transactions on Engineering Management*, **64**, 1, 3–15.

Ahn, J.M., Roijakkers, N., Fini, R., and Mortara, L. (2019) Leveraging open innovation to improve society: past achievements and future trajectories. *R&D Management*, **49**, 3, 267–278.

Ahuja, G. (2000) Collaboration networks, structural holes, and innovation: a longitudinal study. *Administrative Science Quarterly*, **45**, 425–455.

Aiken, L.S. and West, S.G. (1991) *Multiple Regression: Testing and Interpreting Interactions*. Newbury Park, CA: Sage.

Albert, M.B., Avery, D., Narin, F., and McAllister, P. (1991) Direct validation of citation counts as indicators of industrially important patents. *Research Policy*, **20**, 3, 251–259.

Anderson, P. and Tushman, M.L. (1990) Technological discontinuities and dominant designs: a cyclical model of technological change. *Administrative Science Quarterly*, **35**, 604–633.

Autio, E. and Thomas, L.D.W. (2014) Innovation ecosystems: implications for innovation management. In: Dodgson, M., Gann, D.M., and Phillips, N. (eds.), *The Oxford Handbook of Innovation Management*. Oxford: Oxford University Press, pp. 204–228.

Balland, P.A., Boschma, R., Crespo, J., and Rigby, D.L. (2019) Smart specialization policy in the European Union: relatedness, knowledge complexity and regional diversification. *Regional Studies*, **53**, 9, 1252–1268.

Barge-Gil, A. (2010) Open, semi-open and closed innovators: towards an explanation of degree of openness. *Industry and Innovation*, **17**, 577–607.

Basalla, G. (1988) *The Evolution of Technology*. Cambridge: Cambridge University Press.

Bouncken, R.B., Plüschke, B.D., Pesch, R., and Kraus, S. (2016) Entrepreneurial orientation in vertical alliances: joint product innovation and learning from allies. *Review of Managerial Science*, **10**, 2, 381–409.

Bozeman, B. (2000) Technology transfer and public policy: a review of research and theory. *Research Policy*, **29**, 4–5, 627–655.

Brem, A., Nylund, P.A., and Hitchen, E.L. (2017) Open innovation and intellectual property rights: how do SMEs benefit from patents, industrial designs, trademarks and copyrights? *Management Decision*, **55**, 6, 1285–1306.

Brem, A., Nylund, P.A., and Schuster, G. (2016) Innovation and de facto standardization: the influence of dominant design on innovative performance, radical innovation, and process innovation. *Technovation*, **50**, 79–88.

Brem, A., Nylund, P., and Viardot, E. (2020) The impact of the 2008 financial crisis on innovation: a dominant design perspective. *Journal of Business Research*, **110**, 360–369.

Brem, A. and Wolfram, P. (2017) Organisation of new product development in Asia and Europe: results from

Western multinationals R&D sites in Germany, India, and China. *Review of Managerial Science*, **11**, 1, 159–190.
Breschi, S. and Malerba, F (1997) Sectoral innovation systems: technological regimes, Schumpeterian dynamics, and spatial boundaries. In: Edquist, C. (ed.), *Systems of Innovation: Technologies, Institutions and Organizations*. London: Routledge, pp. 130–156.
Breznitz, D. and Murphree, M. (2011) *Run of the Red Queen: Government, Innovation, Globalization, and Economic Growth in China*. New Haven, CT: Yale University Press.
Buckley, P.J. (2020) China's belt and road initiative and the COVID-19 crisis. *Journal of International Business Policy*, **3**, 3, 311–314.
Cassiman, B. and Valentini, G. (2016) Open innovation: are inbound and outbound knowledge flows really complementary? *Strategic Management Journal*, **37**, 6, 1034–1046.
Castells, M. (2000) *The Rise of the Network Society*, 2nd edn. Oxford, UK: Blackwell.
Chen, J., Chen, Y., and Vanhaverbeke, W. (2011) The influence of scope, depth, and orientation of external technology sources on the innovative performance of Chinese firms. *Technovation*, **31**, 8, 362–373.
Chen, J., Guo, Y., and Zhu, H. (2012) Can me-too products prevail? Performance of new product development and sources of idea generation in China–an emerging market. *R&D Management*, **42**, 3, 273–288.
Chen, L. and Naughton, B. (2016) An institutionalized policy-making mechanism: China's return to techno-industrial policy. *Research Policy*, **45**, 10, 2138–2152.
Chesbrough, H.W. (2003) *Open Innovation: The New Imperative for Creating and Profiting from Technology*. Boston, MA: Harvard Business Press.
Chesbrough, H. (2006) Open innovation: a new paradigm for understanding industrial innovation. In: Chesbrough, H., Vanhaverbeke, W., and West, J. (eds.), *Open Innovation: Researching a New Paradigm*. Oxford: Oxford University Press, pp. 1–12.
Chesbrough, H.W. and Appleyard, M.M. (2007) Open innovation and strategy. *California Management Review*, **50**, 1, 57–76.
Chesbrough, H. and Bogers, M. (2014) Explicating open innovation: clarifying an emerging paradigm for understanding innovation. In: Chesbrough, H., Vanhaverbeke, W., and West, J. (eds.), *New Frontiers in Open Innovation*. Oxford: Oxford University Press, pp. 3–28.
Chinese Minister of Science and Technology. (2016) *Outline of the National Strategy of Innovation-Driven Development Background Briefing*. Available at http://www.china.com.cn/zhibo/zhuanti/ch-xinwen/2016-05/23/content_38515829.htm.
Christensen, C.M. (2000) The evolution of innovation. In: Dorf, R.C. (ed.), *The Technology Management Handbook*. Boca Raton, FL: CRC Press.120–129.
Chung, H.F., Yen, D.A., and Wang, C.L. (2020) The contingent effect of social networking ties on Asian immigrant enterprises' innovation. *Industrial Marketing Management*, **88**, 414–425.
Collinson, S. and Liu, Y. (2019) Recombination for innovation: performance outcomes from international partnerships in China. *R&D Management*, **49**, 1, 46–63.
Corsi, S., Di Minin, A., and Piccaluga, A. (2014) Reverse innovation at Speres: a case study in China. *Research-Technology Management*, **57**, 4, 28–34.
De Boer, M., Van Den Bosch, F.A., and Volberda, H.W. (1999) Managing organizational knowledge integration in the emerging multimedia complex. *Journal of Management Studies*, **36**, 3, 379–398.
Den Uijl, S. and de Vries, H.J. (2013) Pushing technological progress by strategic manoeuvring: the triumph of Blu-ray over HD-DVD. *Business History*, **55**, 8, 1361–1384.
Di Minin, A. and Bianchi, M. (2011) Safe nests in global nets: internalization and appropriability of R&D in wireless telecom. *Journal of International Business Studies*, **42**, 7, 910–934.
Di Minin, A., Zhang, J., and Gammeltoft, P. (2012) Chinese foreign direct investment in R&D in Europe: a new model of R&D internationalization? *European Management Journal*, **30**, 3, 189–203.
Dutta, S., Lanvin, B., and Wunsch-Vincent, S. (2019) *The Global Innovation Index 2019: Creating Healthy Lives—The Future of Medical Innovation*. Ithaca, NY: Cornell University, INSEAD and World Intellectual Property Organization.
Enkel, E., Bogers, M., and Chesbrough, H. (2020) Exploring open innovation in the digital age: a maturity model and future research directions. *R&D Management*, **50**, 1, 161–168.
Feldman, M.P., Link, A.N., and Siegel, D.S. (2012) *The Economics of Science and Technology: An Overview of Initiatives to Foster Innovation, Entrepreneurship, and Economic Growth*. Berlin: Springer Science & Business Media.
Ferras-Hernandez, X. and Nylund, P.A. (2019) Clusters as innovation engines: the accelerating strengths of proximity. *European Management Review*, **16**, 1, 37–53.
Fichter, K. (2009) Innovation communities: the role of networks of promotors in Open Innovation. *R&D Management*, **39**, 4, 357–371.
Fleming, L. and Sorenson, O. (2001) Technology as a complex adaptive system: evidence from patent data. *Research Policy*, **30**, 7, 1019–1039.
Fu, X. and Xiong, H. (2011) Open innovation in China: policies and practices. *Journal of Science and Technology Policy in China*, **2**, 3, 196–218.
Gallagher, S. (2007) The complementary role of dominant designs and industry standards. *IEEE Transactions on Engineering Management*, **54**, 2, 371–379.
Gao, Y. and Zheng, J. (2020) The impact of high-speed rail on innovation: an empirical test of the companion innovation hypothesis of transportation improvement with China's manufacturing firms. *World Development*, **127**, 1–16.
Gawer, A. and Cusumano, M.A. (2014) Industry platforms and ecosystem innovation. *Journal of Product Innovation Management*, **31**, 3, 417–433.

Govindarajan, V. and Ramamurti, R. (2011) Reverse innovation, emerging markets, and global strategy. *Global Strategy Journal*, **1**, 3–4, 191–205.

Guellec, D. and van Pottelsberghe de la Potterie, B. (2001) The internationalization of technology analysed with patent data. *Research Policy*, **30**, 1253–1266.

Hansen, V. (2012) *The Silk Road: A New History*. Oxford: Oxford University Press.

Hauschildt, J. and Kirchmann, E. (2001) Teamwork for innovation the 'troika' of promotors. *R&D Management*, **31**, 1, 41–49.

Hausman, J.A. (1978) Specification tests in econometrics. *Econometrica*, **46**, 6, 1251–1271.

Hidalgo, C.A. and Hausmann, R. (2009) The building blocks of economic complexity. *Proceedings of the National Academy of Sciences of the United States of America*, **106**, 26, 10570–10575.

Hitchen, E.L., Nylund, P.A., and Viardot, E. (2017) The effectiveness of open innovation: do size and performance of open innovation groups matter? *International Journal of Innovation Management*, **21**, 3, 1–24.

Huang, P., Negro, S.O., Hekkert, M.P., and Bi, K. (2016) How China became a leader in solar PV: an innovation system analysis. *Renewable and Sustainable Energy Reviews*, **64**, 777–789.

Huenteler, J., Ossenbrink, J., Schmidt, T.S., and Hoffmann, V.H. (2016) How a product's design hierarchy shapes the evolution of technological knowledge – evidence from patent-citation networks in wind power. *Research Policy*, **45**, 6, 1195–1217.

Inauen, M. and Schenker-Wicki, A. (2012) Fostering radical innovations with open innovation. *European Journal of Innovation Management*, **15**, 2, 212–231.

Ivanova, I., Strand, Ø., Kushnir, D., and Leydesdorff, L. (2017) Economic and technological complexity: a model study of indicators of knowledge-based innovation systems. *Technological Forecasting and Social Change*, **120**, 77–89.

Jaffe, A.B. and De Rassenfosse, G. (2017) Patent citation data in social science research: overview and best practices. *Journal of the Association for Information Science and Technology*, **68**, 6, 1360–1374.

Jian, J., Fan, X., Zhao, S., and Zhou, D. (2020) Business creation, innovation, and economic growth: evidence from China's economic transition, 1978–2017. *Economic Modelling*. https://doi.org/10.1016/j.econmod.2020.03.019.

Keil, T., Fomin, V., and Hens, T. (2000) Standardization: bridging the gap between economic and social theory. International Conference on Information Systems, Brisbane, pp. 206–217.

Kim, H. and Park, Y. (2010) The effects of open innovation activity on performance of SMEs: the case of Korea. *International Journal of Technology Management*, **52**, 3/4, 236–256.

Kogut, B. and Zander, U. (1992) Knowledge of the firm, combinative capabilities, and the replication of technology. *Organization Science*, **3**, 3, 383–397.

Kogut, B. and Zander, U. (1993) Knowledge of the firm and the evolutionary theory of the multinational corporation. *Journal of International Business Studies*, **24**, 4, 625–645.

Kutner, M.H., Nachtsheim, C.J., and Neter, J. (2004) *Applied Linear Regression Models*. New York: McGraw-Hill.

Lee, S., Park, G., Yoon, B., and Park, J. (2010) Open innovation in SMEs – an intermediated network model. *Research Policy*, **39**, 2, 290–300.

Lee, Y.T., Masuda, A.D., Fu, X., and Reiche, B.S. (2018) Navigating between home, host, and global: consequences of multicultural team members' identity configurations. *Academy of Management Discoveries*, **4**, 2, 180–201.

Lee, Y.G., Park, S.H., and Song, Y.I. (2009) Which is better for a firm's financial performance: an externally oriented or inwardly oriented innovation strategy? An empirical study on Korean SMEs. *Asian Journal of Technology*, **17**, 1, 57–73.

Leiponen, A. and Byma, J. (2009) If you cannot block, you better run: small firms, cooperative innovation, and appropriation strategies. *Research Policy*, **38**, 9, 1478–1488.

Lewin, A.Y., Välikangas, L., and Chen, J. (2017) Enabling open innovation: lessons from Haier. *International Journal of Innovation Studies*, **1**, 1, 5–19.

Li, P., Qian, H., Howard, K.W., and Wu, J. (2015) Building a new and sustainable "Silk Road economic belt". *Environmental Earth Sciences*, **74**, 10, 7267–7270.

Li, X., Zhou, Y., Xue, L., and Huang, L. (2016) Roadmapping for industrial emergence and innovation gaps to catch-up: a patent-based analysis of OLED industry in China. *International Journal of Technology Management*, **72**, 1/2/3, 105–143.

Li, Y., Ji, Q., and Zhang, D. (2020) Technological catching up and innovation policies in China: what is behind this largely successful story? *Technological Forecasting and Social Change*, **153**, 1–12.

Liu, X. (2010) *The Silk Road in World History*. Oxford: Oxford University Press.

Mei, L., Zhang, T., and Chen, J. (2019) Exploring the effects of inter-firm linkages on SMEs' open innovation from an ecosystem perspective: an empirical study of Chinese manufacturing SMEs. *Technological Forecasting and Social Change*, **144**, 118–128.

Murmann, J.P. and Frenken, K. (2006) Toward a systematic framework for research on dominant designs, technological innovations, and industrial change. *Research Policy*, **35**, 7, 925–952.

National Development and Reform Commission, Ministry of Foreign Affairs and Ministry of Commerce of the People's Republic of China. (2015) *Vision and Proposed Actions Outlined on Jointly Building Silk Road Economic Belt and 21st-Century Maritime Silk Road*. Available at https://language.chinadaily.com.cn/2015-03/30/content_19950951.htm.

Ndou, V., Vecchio, P.D., and Schina, L. (2011) Open innovation networks: the role of innovative marketplaces for small and medium enterprises' value creation. *International Journal of Innovation and Technology Management*, **8**, 3, 437–453.

Nylund, P.A., Brem, A., and Agarwal, N. (2021) Innovation ecosystems for meeting sustainable development goals: the evolving roles of multinational enterprises. *Journal of Cleaner Production*, **281**, 125329.

Nylund, P.A., Ferras-Hernandez, X., and Brem, A. (2019) Strategies for activating innovation ecosystems: introduction of a taxonomy. *IEEE Engineering Management Review*, **47**, 3, 12–19.

OECD. (2018) *Innovation, agricultural productivity and sustainability in China*. Paris: OECD Food and Agricultural Reviews, OECD Publishing.

Petralia, S., Balland, P.A., and Morrison, A. (2017) Climbing the ladder of technological development. *Research Policy*, **46**, 5, 956–969.

Rosenkopf, L. and Nerkar, A. (2001) Beyond local search: boundary-spanning, exploration, and impact in the optical disk industry. *Strategic Management Journal*, **22**, 4, 287–306.

Salge, T.O., Farchi, T., Barrett, M.I., and Dopson, S. (2013) When does search openness really matter? A contingency study of health-care innovation projects. *Journal of Product Innovation Management*, **30**, 4, 659–676.

Schuster, G. and Brem, A. (2015) How to benefit from open innovation? An empirical investigation of open innovation, external partnerships and firm capabilities in the automotive industry. *International Journal of Technology Management*, **69**, 1, 54–76.

Schweinberger, A. (2014) State capitalism, entrepreneurship, and networks: China's rise to a superpower. *Journal of Economic Issues*, **48**, 1, 169–180.

Simard, C. and West, J. (2006) Knowledge networks and the geographic locus of innovation. In: Chesbrough, H., Vanhaverbeke, W., and West, J. (Eds.) *Open Innovation: Researching a New Paradigm*. Oxford: Oxford University Press, pp. 220–240.

Stefan, I. and Bengtsson, L. (2017) Unravelling appropriability mechanisms and openness depth effects on firm performance across stages in the innovation process. *Technological Forecasting and Social Change*, **120**, 252–260.

Su, Y.S., Tsang, E.W., and Peng, M.W. (2009) How do internal capabilities and external partnerships affect innovativeness? *Asia Pacific Journal of Management*, **26**, 2, 309–331.

Suárez, F.F. and Utterback, J.M. (1995) Dominant designs and the survival of firms. *Strategic Management Journal*, **16**, 6, 415–430.

Suh, Y. and Jeon, J. (2019) Monitoring patterns of open innovation using the patent-based brokerage analysis. *Technological Forecasting and Social Change*, **146**, 595–605.

Utterback, J.M. and Suárez, F. (1993) Innovation, competition, and industry structure. *Research Policy*, **22**, 1, 1–21.

Varsakelis, N.C. (2001) The impact of patent protection, economy openness and national culture on R&D investment: a cross-country empirical investigation. *Research Policy*, **30**, 7, 1059–1068.

Waller, D.S., Wang, P.Z., Oppewal, H., and Morrison, M.D. (2008) *Brand Awareness of New Technology in the Introduction Stage: A Study of Blu-Ray vs HD-DVD Format*. Adelaide: Australian and New Zealand Marketing Academy Conference.

Wang, Y., Roijakkers, N.., Vanhaverbeke, W., and Chen, J. (2012) How Chinese firms employ open innovation to strengthen their innovative performance. *International Journal of Technology Management*, **59**, 3/4, 235–254.

West, J. and O'Mahony, S. (2008) The role of participation architecture in growing sponsored open source communities. *Industry and Innovation*, **15**, 145–168.

West, J., Salter, A., Vanhaverbeke, W., and Chesbrough, H. (2014) Open innovation: the next decade. *Research Policy*, **43**, 5, 805–811.

Wu, H., Chen, J., and Jiao, H. (2016) Dynamic capabilities as a mediator linking international diversification and innovation performance of firms in an emerging economy. *Journal of Business Research*, **69**, 8, 2678–2686.

Xu, G., Wu, Y., Minshall, T., and Zhou, Y. (2018) Exploring innovation ecosystems across science, technology, and business: a case of 3D printing in China. *Technological Forecasting and Social Change*, **136**, 208–221.

Yakob, R., Nakamura, H.R., and Ström, P. (2018) Chinese foreign acquisitions aimed for strategic asset-creation and innovation upgrading: the case of Geely and Volvo Cars. *Technovation*, **70**, 59–72.

Zhang, M. and Merchant, H. (2020) A causal analysis of the role of institutions and organizational proficiencies on the innovation capability of Chinese SMEs. *International Business Review*, **29**, 2, 1–13.

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