Journal of Business Economics and Management
ISSN 1611-1699/eISSN 2029-4433
2023 Volume 24 Issue 1: 54–73
https://doi.org/10.3846/jbem.2023.17192

MECHANISM OF INNOVATION AND STANDARDIZATION DRIVING COMPANY COMPETITIVENESS IN THE DIGITAL ECONOMY

Jing YANG[1], Lijun ZHOU[1*], Yuyang QU[1], Xiang JIN[2], Shishi FANG[1]

[1]*College of Economics and Management, China Jiliang University, Hangzhou, China*
[2]*School of Marketing, UNSW Business School, University of New South Wales, Sydney, Australia*

Received 06 December 2021; accepted 23 May 2022

Abstract. Data have changed the characteristics of the global value chain in the context of digital economy. Standards and innovation are the key facilitators of digital economy. Considering the collaborative development of innovation and standardization, this paper constructs a theoretical model of the impact of innovation and standardization levels on company competitiveness. Furthermore, the moderating effect of the coupling coordination of innovation and standardization was analyzed for both factors. In total, 171 listed companies in the field of digital economy were selected as the research. The results indicated that a company's level of innovation and standardization influences company competitiveness. Moreover, the relationship between innovation and standardization was found to be a coordinating development relationship and not a conventional promotion or hindrance. This article also proposed some pertinent suggestions for companies involved in the global value chain competition.

Keywords: technological innovation, standardization, coupling coordination, digital economy, competitiveness, listed company.

JEL Classification: L15, L21, C12.

Introduction

Currently, the digital economy has been paid attention to promoting and strengthening the national economy in almost counties (Abendin & Duan, 2021; Jiao & Sun, 2021; Amuso et al., 2020). For example, the digital economy contributing to the country's GDP, Germany, the United Kingdom, and the United States are the top three, with 63.4%, 62.3%, and 61.0% contributions, respectively, followed by South Korea, Japan, Ireland, and France, with rank 4 to 7 and >40% contributions and then by Singapore, China, and Finland, with ranks 8 to 10 and >30% contributions (China Academy of Information and Communications Technology

*Corresponding author. E-mail: *zhlj0606@cjlu.edu.cn*

[CAICT], 2020). However, from the perspective of different economic development levels, a large gap exists in the proportion of national digital economy; in particular, the proportion of the digital economy in the GDP of developed countries is 1.9 times than that of developing countries. Digital economy has occupied a dominant position in the national economy of developed countries, accounting for 51.3% of the GDP, while the digital economy of developing countries accounts for only 26.8% (CAICT, 2020). The digital economy and digital technologies have been transforming national economies and lifestyles worldwide, and regardless of the economy or other related issues, both academia and the industry have emphasized digital transformation, such as enterprise digitalization and digital governance. However, a fixed definition of digital economy is yet to be arrived at, and this lack of consensus leads to inconsistent estimates of the size of a digital economy (Oostrom et al., 2016). Bukht and Heeks (2017) classified the following three layers of digital economy: core scope, narrow scope, and broad scope. The core layer concerns the digital (IT/ICT) sector's economic activities, including information services, telecommunications, hardware manufacture, software, and IT consulting. The narrow scope focuses on the digital economy, such as digital services and platform economy. The broad scope highlights digitalized economy, including e-businesses, Industry 4.0, sharing economy, and the gig economy (United Nations Conference on Trade and Development [UNCTAD], 2019).

"Data" is the most pertinent input factor that is significantly utilized by data-driven companies (Deng, 2020; Hanna, 2016), in turn changing the character of global value chains. Different factors influence the development of the digital economy differently. In particular, developed countries emphasize on the technology component, whereas developing countries consider the organizational factor more functional (Kartiwi & MacGregor, 2007; Szeles & Simionescu, 2020).

No organization can control the underlying technologies of the digital economy, nor is technology the only driver (Sturgeon, 2019). Because of its links with the industry and consumers, business models have assumed more importance, and such models include modularity, open innovation, and platforms (Sturgeon, 2019). Compared with technology related factors, organizational factors are the main barriers faced by developing countries (Kartiwi & MacGregor, 2007). From the perspective of the modularity level, proprietary standards can help companies increase flexibility and reduce costs in the intrafirm modular stage (Gawer & Cusumano, 2014). Furthermore, industry standards can decrease the friction stemming from organizational and geographic distance in the inter-firm modular stage (Sturgeon, 2019). Industries with lower industry-level standards fall short in terms of the modularity (Sturgeon et al., 2008). From the perspective of open innovation, digitization has considerably increased the value of innovation, which, in turn, emphasizes intellectual property protection (Chen, 2020). Moreover, higher patentability standards increase the value of innovation and reduce research and development (R&D) risks (Chen, 2020). In terms of diversity of platforms, the digital economy has evolved as a set of nested modules and platforms based on a mix of de jure and de facto standards (Sturgeon, 2019). Compared with the foundational level that highlights the role of technology platforms, the high level emphasizes the standardized hardware and software systems.

Although innovation and standardization are key factors driving company development, it is still a challenge for developing countries and noncore companies to conduct achieve the valuable technological innovation (Bourlès et al., 2013), which may result in the risk of dependency on technology and further isolation and exclusion from high-value digital chains due to technology monopoly or oligopoly by developed countries or core companies. Additionally, the digital economy provides opportunities through fine slicing and relocation of global value chains (Sturgeon, 2019; Deng, 2020). The introduction of rich digital tools, technical assistance, capital, and human resources provide developing countries and noncore companies with more possibilities for innovation, particularly platforms. Developing countries and noncore companies must seize the opportunities furnished by the digital economy. However, because the digital economy is a new domain undergoing rapid changes, research, particularly in the form of empirical studies, in this field has been scant. The current study targets companies in China and analyzes how company competitiveness (CC) can be enhanced through innovation and standardization. However, studies on the relationship between innovation and standardization have indicated that the positive and negative effects are concomitant (Narayanan & Chen, 2012; Zoo et al., 2017). Therefore, this study developed the coupling model of innovation and standardization and selected listed companies to verify the theoretical model.

The remainder of this paper is structured as follows. Section 1 presents a literature review of standardization and innovation using CiteSpace. Then the coupling model of standardization and innovation has been developed. Section 2 171 listed companies in the field of digital economy in China are selected as research objects and variables are measurement such as innovation input and output, coupling coordination, and so on. Next, in Section 3 theoretical model was subsequently verified through used coupling coordination analysis, correlation analysis, and regression analysis. Finally, some suggestions for promoting CC under digital economy are presented in the last Section.

1. Literature review and model construction

1.1. Standardization and innovation literature analysis

Standards, which plays a critical role in the industrialization of innovative achievements (Sanders, 1972; Brunsson et al., 2012), promote the transformation of innovation results by creating knowledge and technology transfer channels, in turn reducing production costs and technology lock-ins (Blind & Gauch, 2009). Owing to the in-depth research on the role of standards in technology, market, strategizing, and other related fields, studies have increasingly identified a complex relationship between standards and innovation. This study employed CiteSpace visualizing a blueprint for literature review (Chen, 2006; Yang et al., 2021, 2022) to understand the development process and trends of the relationship between the two factors. Literature from the core collection of Web of Science, namely SCI and SSCI databases, were selected, and the titles selected were limited to "standard" and innovation and standardization and innovation. The timeline of the studies selected is from 1986 to 2019; in total, 211 documents were selected. The top 20 keywords used for the cluster analysis have been presented in Table 1, and the time context is illustrated in Figure 1.

Table 1. Top 20 keywords by literature frequency

Sort	Time	Keywords	Frequency	Betweenness centrality
1	2008	Standardization	30	0.38
2	2008	Standard	29	0.28
3	2009	Innovation	41	0.23
4	2009	Diffusion	11	0.3
5	2009	Competition	8	0.12
6	2009	Compatibility	7	0.13
7	2009	China	7	0.08
8	2009	Technology standard	6	0.05
9	2009	3G	5	0.03
10	2010	Performance	16	0.19
11	2010	Knowledge	10	0.07
12	2010	Industry	7	0.04
13	2010	Impact	6	0.09
14	2011	Strategy	10	0.09
15	2011	Adoption	5	0.02
16	2011	Dominant design	4	0.02
17	2013	Standardization	5	0.04
18	2014	developing country	4	0.02
19	2016	Technology	9	0.03
20	2016	Management	6	0.09

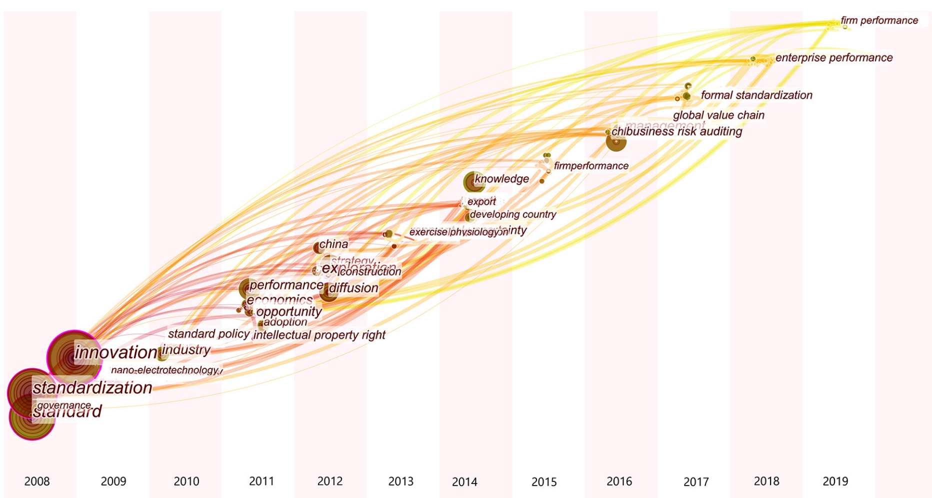

Figure 1. Keywords summary by the timeline view

Figure 1 shows that the research on the relationship between innovation and standardization has been gradually developing since 2008, and this research topic can be divided into three stages on the basis of the keywords selected by the current study.

The first stage was termed technology connection, which was associated with research on innovation and standardization that was connected with the core word technology. The research time interval was 2008–2010, and the high-frequency keywords were 3G, diffusion, and technology standard among others. Timeline view included the keywords "intellectual property", "nano-electrotechnology", and "industry". Research at that time reasonably reflected the characteristics of having "technology" as the focus.

The second stage was termed strategic integration, specifically in reference to the scope of the research on innovation and standardization that has rapidly extended into the spatial dimension. The research period of this stage was from 2011 to 2016. The high-frequency keyword "strategy" appeared in 2010 as the obvious node. Other keywords such as management and performance also appeared, in addition to strategy. The research on innovation and standardization has risen from a technical level to a strategic level, even to a national strategic level in certain instances. The keyword "China" appeared in 2012 and developing country appeared in 2014. In the communications field, the national disputes on 3G and 5G standards and those between large enterprises fully demonstrated that the keywords such as standard war and technical war had risen to a strategic level at the national level.

The third stage was denoted as global integration, and the research on innovation and standardization indicated a trend toward globalization and synergy. The time interval of this period was 2017 to present, with the emergence of the global value chain in 2017 as the obvious node. The development of digital economy has tremendously changed innovation and business models. Business models such as modularity, open innovation, and platforms need to integrate innovation and standardization. Another critical factor is the collaborative development of innovation and standardization. de Vries and Verhagen (2016) and Jiang et al. (2016) introduced the coupling system into the study of standardization and innovation and analyzed the interaction between the two factors at both the company level and the industrial level.

1.2. Model construction

On the basis of the literature review on innovation and standardization and the characteristic trends observed in recent research, this research focused on the keywords emerging industries and interactive development and selected companies in the field of digital economy as the research objects. When analyzing the effects of innovation and standardization on CC in digital economy, this research examined the synergy between innovation and standardization. Furthermore, the coupling coordination degree (CCD) was used to measure the matching level between the two. In addition, this article analyzed the moderating effect of CCD in the driving of development by "innovation + standardization" and explored its influence on CC enhancement from a collaborative perspective. Figure 2 illustrates the theoretical model of this research.

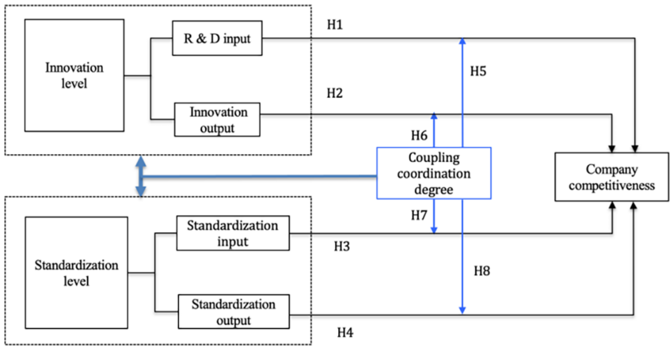

Figure 2. Theoretical model

1.2.1. Innovation and CC

The academia and the industry have arrived at a complete consensus on the significant impact of innovation on economic growth, social development, industrial upgradation, and enhancement of CC. The development of economic growth theory enabled Solow (1957) and Romer (1990) to highlight that technological progress, instead of capital accumulation clearly, is the decisive factor in economic growth. Moreover, Teece (1986) proposed a framework for innovation and profitability. Porter (1998) found that innovation creates new value and then proposed the concept of innovation-driven, in turn dividing a country's economic growth into four stages: factor-driven, investment-driven, innovation-driven, and wealth-driven.

Innovation is the basis of competitiveness, and the company competitiveness depends on their innovative ability and their orientation to technology and information (Doğan, 2016). Innovating with new technologies and capabilities has become the most critical component of competitiveness (Akis, 2015; Yang et al., 2020). Therefore, innovation has always been regarded as an important factor for enterprises to obtain company competitiveness (Chursin et al., 2016).

In economic development, innovation can achieve value appreciation through productivity improvement and market value increase (Teece, 1986, 2017; Furman & Hayes, 2004). The evaluation of innovation capability includes multiple perspectives, including innovation factors, input–output, and innovation process (Castellacci & Notera, 2013; Hashi & Stojčić, 2013; Dziallas & Blind, 2019). This study drew on validated research results to measure the level of innovation from the input–output perspective and proposed the following hypotheses:

H1: R&D input (RDI) significantly and positively influences CC.

H2: Innovation output (IO) significantly and positively influences CC.

1.2.2. Standardization and CC

Many scholars have studied the macroeconomic benefits and micro performance of standardization. At the macro level, numerous studies have supported the role standards play in promoting economic growth. Miotti (2009) analyzed the data of Germany, Austria, and Switzerland to discover that their average economic growth was 3.3%, of which 0.9% was attributable to technical standardization. Data from 1948–2002 in the United Kingdom highlighted that the contribution rate of standards to productivity growth had reached 13%. Moreover, the contribution rate of technical standards to GDP growth was estimated to be 0.79% from 1997 to 2007 in China (Yu, 2008).

At the microlevel, the benefits of companies adopting standards are mainly due to reducing production costs and transaction costs, increasing economies of scale, penetrating new markets, and obtaining monopoly rents (Blind, 2004). Therefore, enterprises can obtain a cost advantage (Swann, 2010). The consequences of standards-based competition will determine the success of enterprises to a large extent, particularly in today's technologically developed society. Enterprises work toward making their technology the standard in the market because this type of first-mover advantage will bring the possible profit in its initial stage (Shin et al., 2015). In addition, companies may encounter certain obstacles because of their involvement in standardization (Blind & Gauch, 2009).

Standardization has become an important strategic tool for enterprises (Blind & Rauber, 2016). Since technical standards are a kind of explicit knowledge, the knowledge acquired by enterprises in the process of standardization can improve their competition (Lavie, 2006). At the same time, enterprises participating in technical standardization can also use a certain technology to influence the content of the standard to gain a competitive advantage (Fernandez et al., 2000). Standards can increase the competitiveness of enterprises through economies of scale (Hussain & Khan, 2013), reducing costs (Swann, 2010), and avoiding information asymmetry (Baron & Spulber, 2018).

Meanwhile, a company's standardization level can be performed from different perspectives. Shin et al. (2015) divided research on standardization into the demand-side and supply-side of standardization. Wen and Zeng (2019) and Zou et al. (2020) analyzed standardization output (SO) by primarily measuring the number of standards formulated and revised by a company. Therefore, considering the relevant findings, this research drew on the input–output perspective of innovation research, measured the standardization level of companies from the two dimensions of standardization input (SI) and SO, and proposed the following hypotheses:

H3: SI significantly and positively influences CC.

H4: SO significantly and positively influences CC.

1.2.3. Moderating effect of the coupling degree of innovation and standardization

Literature on the relationship between standardization and innovation is abundant worldwide; however, the research conclusions are yet to reach a consensus. While standards facilitate innovation (Goluchowicz & Blind, 2011; Zoo et al., 2017), they also hinder technological innovation. Thus, a paradoxical relationship has always existed between the two. In particular, in developing countries, owing to increased participation in international business, the fields of politics and technology have begun paying renewed attention to their standards and innovations (Lee & Oh, 2006; Zoo et al., 2017).

In terms of innovative transformation, standards are a critical facilitator of the industrialization of innovation achievements. An understanding of whether new technologies can be transformed into standards is key to successful technological innovation (Katz & Safranski, 2003). However, the quality of the technology transformed into a standard will, itself, affect transformation. David (1985) highlighted that transforming optimal technology into the standard promotes technological progress, whereas transforming suboptimal technology into the standard hinders progress.

Shin et al. (2015) argued that a standard is an effective tool for diffusing innovation. Not only can standardization accelerate technology diffusion and application but also shorten the time between technological innovation and technology diffusion (Tassey, 2000; Blind, 2002). However, Hanseth et al. (1996) reported that implementing standardization reduces a company's choices for innovation strategy, thereby limiting their innovation ability. On the topic of benefits of innovation, Tassey (2000) proposed that standardization increases the benefits of technological innovation. Standard has been considered a governance tool (Arnold & Hasse, 2015), whereas standardization has always been viewed as an obstacle to innovation (Choi et al., 2011).

Previous literature has highlighted the paradoxical relationship between innovation and standards through generation, diffusion, and transformation of innovation. Therefore, the relationship between the two warrants examination from a collaborative perspective, with a deeper understanding of the "black box" of its role in enhancing CC.

Although ambivalent relationships between innovation and standardization are sometimes observed, they represent a virtuous circle, not a vicious circle (Shin et al., 2015). Zoo et al. (2017) demonstrated that innovation and standardization have become increasingly critical for the sustainable economic growth of developing countries, particularly in the context of global economic integration and competition. To extend this line of research, scholars such as de Vries and Verhagen (2016) and Jiang et al. (2016) analyzed the coordination and matching relationship between the two from the perspective of coupling. From the perspective of the collaborative development of innovation and standardization, this research examined the impact of the coupling coordination on the two. Furthermore, the CCD was incorporated into the model as a moderating variable, leading to the following hypotheses:

H5: The CCD of innovation and standardization positively moderates the impact of R&D investment on CC.

H6: The CCD of innovation and standardization positively moderates the impact of IO on CC.

H7: The CCD of innovation and standardization positively moderates the impact of SI on CC.

H8: The CCD of innovation and standardization positively moderates the impact of SO on CC.

2. Research design

2.1. Sample selection and data collection

According to the classification of digital economy from Bukht and Heeks (2017), this research selected 22 concepts related to the digital economy, with Royalflush (Flush) as the scope of the collection. Furthermore, 209 listed companies in the digital economy field of Shanghai and Shenzhen stock markets as of December 31, 2018, were selected. Relevant data were retrieved from the CSMAR series research database, the National Public Service Platform for Standards Information (SAC), the annual reports of the listed companies, and other financial websites such as Flush. To ensure the validity and accuracy of the data, this study manually cleaned and verified the data after collection, and the companies with incomplete data were eliminated. Thus, 171 valid samples were finally obtained.

Among these 171 sample companies, 93 had 1,000–5,000 employees, accounting for 54.39% of the study sample, and 169 companies had been in operation for over ten years. In terms of industry classification, the sample companies were classified into 32 diverse industries, of which 56 companies belonged to the software and information technology service industry, accounting for 32.75% of the study sample. Moreover, 31 companies were related to the computer, communications, and other electronic equipment manufacturing industry, accounting for 18.13% of the study sample. A total of 13 companies belong to the electrical machinery and equipment manufacturing industry, accounting for 7.60%. There are 9 companies in the chemical raw materials and chemical product manufacturing industry, accounting for 5.26%. In addition, other industries include telecommunications, broadcast television and satellite transmission services, general equipment manufacturing, business services, etc. The specific distribution of companies is presented in Table 2.

Table 2. Statistical analysis of sample characteristics

Sample Company	Category	Frequency	Percentage
Size (unit: employees)	Below 1000	23	13.45
	1000~5000	93	54.39
	5000~10 000	31	18.13
	Above 10 000	24	14.04
Established time (unit: years)	Below 10	2	1.17
	10~19	110	64.33
	20~29	56	32.75
	Above 30	3	1.75
Revenue (unit: USD)	Below 0.15 billion	31	18.13
	0.15~0.75 billion	93	54.39
	0.75~1.45 billion	23	13.45
	Above 1.45 billion	24	14.04
Industry	The software and information technology service industry	56	32.75
	Computer, communications and other electronic equipment manufacturing industry	31	18.13
	Electrical machinery and equipment manufacturing	13	7.60
	Chemical raw materials and chemical products manufacturing	9	5.26

End of Table 2

Sample Company	Category	Frequency	Percentage
	Textile and apparel industry	6	3.51
	Instrumentation Manufacturing	6	3.51
	Automotive Manufacturing	5	2.92
	Internet and related services	4	2.34
	Special equipment manufacturing	4	2.34
	Others	37	21.64

2.2. Variable measurement

This study analyzed the coordinated development of the three dimensions of innovation, standardization, and CC. From the perspective of input–output, the innovation and standardization levels were divided into input (innovation input and SI, respectively) and output (IO and SO, respectively). The degree of the coordinated development of innovation and standardization was measured through the degree of coupling coordination. The current study employed six variables: RDI, IO, SI, SO, CCD, and CC.

2.2.1. RDI

RDI mainly comprises two aspects: financial input and personnel input. RDI is measured by proportion to reduce the impact of enterprise size and improve the comparability between enterprises. In particular, the proportion of R&D financial input (investment in R&D expenditure/prime operating revenue) and R&D personnel input (number of R&D employees/number of overall employees) were considered.

2.2.2. IO

IO was mainly manifested in the number of patents held by companies. To maintain data consistency, this study obtained the data on patents from the CSMAR database.

2.2.3. SI

The measurement methods of SI are similar to RDI, which also includes two aspects: financial input and personnel input. However, standardization expenses were not listed separately in the budget and final accounts of a firm. Considering the availability of data, SI was measured through only personnel inputs. The decision to participate in a standard technical committee (TC) is strategically critical for an enterprise, and this decision can greatly influence the market (Riillo, 2013). The expert network comprising TC personnel is a carrier of technical knowledge and a valuable social resource. The SI is measured by the specific headcount of companies' TCs.

2.2.4. SO

SO is mainly measured by the number of standards primarily formulated and revised by a company. Because of the fierce international industrial competition in the industry, industry standards also play a pivotal role in the digital economy. Therefore, the number of standards comprises two components: the number of national standards and the number of industry standards.

2.2.5. CC

CC can usually be reflected in the company's performance, which is mainly determined through accounting-based performance indicators and stock market–based performance indicators. In this study, accounting-based operating revenue was employed as an indicator of CC.

2.2.6. CCD

Herein, CCD refers to the degree of coupling coordination between innovation level (comprising RDI and IO) and standardization level (SI and SO). Firstly, this study conducted the data normalization. The method of medium weight proposed by Li and Cui (2018) was referred to determine the weight of each indicator. According to the method, the indicators of each dimension of the evaluation system were considered equally critical and thus given equal weightage. Subsequently, the CCD was measured by the following formula:

$$D = \sqrt{C \times T} \quad (T = \alpha u_1 + \beta u_2), \tag{1}$$

where D represents the CCD, C presents the coupling degree (see formula (2)):

$$C = \left\{ \frac{z(x)h(y)}{\left[\frac{z(x)+h(y)}{2} \right]^2} \right\}^k, \tag{2}$$

where $z(x)$ and $h(y)$ are the contributions of the innovation level and the standardization level, respectively, and k is the adjustment coefficient.

T in formula (1) denotes the comprehensive coordination index reflecting innovation and standardization. This study considered innovation and standardization to be equally significant for the development of an industry, and α and β were set as 0.5. Coupling coordination levels can be categorized into 10 levels between 0 and 1, with an interval of 0.1 (Li & Cui, 2018). Furthermore, 0.5 is the boundary value between imbalances and coordination.

3. Empirical analysis of listed companies

3.1. Descriptive analysis

Significant correlation exists among RDI, IO, SI, SO, CC, and CCD, thereby providing the necessary premise for analyzing the relationship between the variables and testing the moderating effect. Table 3 demonstrates the result of descriptive analysis.

Table 3. Correlation analysis results

	RDI	IO	SI	SO	CCD	CC
RDI	1					
IO	0.733***	1				
SI	0.340***	0.388***	1			
SO	0.546***	0.727***	0.404***	1		
CCD	0.720***	0.660***	0.541***	0.642***	1	
CC	0.682***	0.771***	0.453***	0.511***	0.633***	1

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

3.2. Model analysis

Model analysis in the current paper primarily used the multiple linear regression analysis (Table 4) achieved by the SPSS (version 24.0). Model 1 demonstrates that both RDI ($\beta = 0.253$, $p < 0.01$) and IO ($\beta = 0.585$, $p < 0.01$) had a significant positive impact on the improvement of CC, in turn validating H1 and H2. From the perspective of path coefficients, IO exerted a greater impact than RDI did. Meanwhile, Model 2 highlighted that SI ($\beta = 0.295$, $p < 0.01$) and SO ($\beta = 0.392$, $p < 0.01$) both had a significant positive impact on the improvement of CC, thereby supporting H3 and H4. In particular, SO had a greater effect than SI did on the basis of path coefficients.

Model 3 indicates that the main effect of the coupling coordination level of innovation and standardization on CC exists. Based on Model 1, CCD was included in Model 4 and Model 5, and the results are both positively significant. Model 6 – Model 9 were a test of the moderating effect of CCD. The results of Model 6 highlighted that the interaction coefficient of RDI and CCD was positively significant, in turn indicating that CCD positively moderated the impact of RDI on the CC. Therefore, H5 was supported. The results of Model 7 demonstrate that the interaction coefficient of IO and CCD was negative significantly, indicating that with the increase in coordination degree, the impact of IO and CC weakens. Therefore, H6 was not supported. In Model 8, the interaction terms of SI and CCD were introduced into the equation. CCD was found to regulate the impact of SI on CC positively; therefore, H7 was assumed to be supported. The results of Model 9 shows that after adding the interaction term of SO and CCD, the SO was found to be not significant; however, the positive moderating effect was significant. H8 was thus supported.

Table 4. Regression model

Independent Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
RDI	0.253***			0.179**		0.250***			
IO	0.585***			0.544***			1.854***		
SI		0.295***			0.143**			0.148**	
SO		0.392***			0.164**				–0.043
CCD			0.633***	0.146**	0.451***	0.169**	0.148***	0.264***	0.509***
RDI*CCD						0.409***			
IO*CCD							–1.220***		
SI*CCD								0.415***	
SO*CCD									0.275***
Constant	1.054E-16	1.759E-16	1.258E-16	1.118E–16	1.452E-16	–0.068	0.131	–0.098	–0.032
R^2	0.624	0.334	0.401	0.633	0.434	0.570	0.712	0.507	0.444
Adjusted R^2	0.624	0.326	0.398	0.627	0.424	0.563	0.707	0.498	0.434
F value	139.346	42.115	113.212	96.162	42.693	73.881	137.876	57.278	44.407

Note: Dependent variable: CC. * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

3.3. Moderating effect analysis

This study employed the process plug-in in SPSS to verify the moderating effect of CCD. Model 1 was selected in the process program to test the moderating effect. The number of inspection samples was 5000. The moderating effects of CCD on RDI, IO, SI, and SO are illustrated in Figures 3, 4, 5, and 6, respectively.

In summary, CCD played a positive role in regulating the relationship between RDI and CC. At the same time, obvious differences existed between companies with high CCD and low CCD (Figure 3). For companies with high CCD, the RDI exerted a significant effect on CC ($b_{simple} = 0.4235$; SE = 0.0950; $p < 0.01$); for companies with low CCD, the effect of IO on CC was nonsignificant ($b_{simple} = 0.1912$; SE = 0.1189; $p = 0.1098$). At the same level of RDI, the CC of companies with high CCD was found to be far greater than that of companies with low CCD. In particular, with the increase in RDI, the gap between companies with high and low CCD was more obvious.

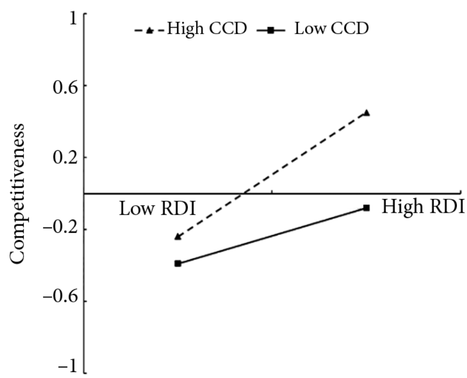

Figure 3. Moderating effect of the coupling degree on the relationship between RDI and CC

CCD played a positive role in moderating the relationship between IO and CC (Figure 4). For companies with high CCD, IO exerted a significant impact on CC ($b_{simple} = 1.6544$; SE = 0.1522; $p < 0.01$); for companies with low CCD, IO still had a significant impact on CC ($b_{simple} = 2.0546$; SE = 0.2046; $p < 0.01$).

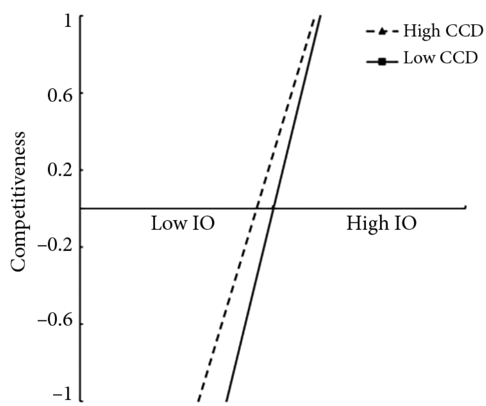

Figure 4. Moderating effect of the coupling degree on the relationship between IO and CC

Overall, CCD was found to play a positive role in moderating SI and CC. In particular, obvious differences can be found between companies with high and low CCD (Figure 5). For companies with a high CCD, SI exerted a significant impact on CC (b_{simple} = 0.3305; SE = 0.0720; $p < 0.01$); for companies with a low CCD, the role of SI on CC was found to be insignificant (b_{simple} = –0.0339; SE = 0.0733; p = 0.6440). Meanwhile, at the same level of standardization, the CC of companies with high CCD was observed to be far greater than that of companies with low CCD. In particular, the gap became more gaping with increase in SI. For companies with low CCD, the trend of CC declining with increasing SI was observed, which indicated that failure to closely integrate SI with technological innovation might lead to wastage of resources and result in an invalid investment.

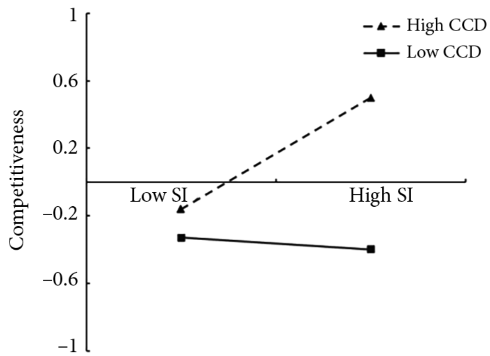

Figure 5. Moderating effect of the coupling degree on the relationship between SI and CC

CCD had no significant moderating effect between SO and CC. Irrespective of whether a company has high CCD (b_{simple} = 0.0076; SE = 0.1078; p = 0.9442) or low CCD (b_{simple} = –0.1013; SE = 0.1375; p = 0.4623), the impact of SO on CC was insignificant (Figure 6). Moreover, regardless of the level of SO, the CC of companies with high CCD was much higher than that of companies with low CCD. Hence, standards that are not integrated with innovation cannot improve CC and increasing the number of standards alone produces invalid results. Firms' pursuit of the number of standards has to shift to improving the quality of standards combined with innovation.

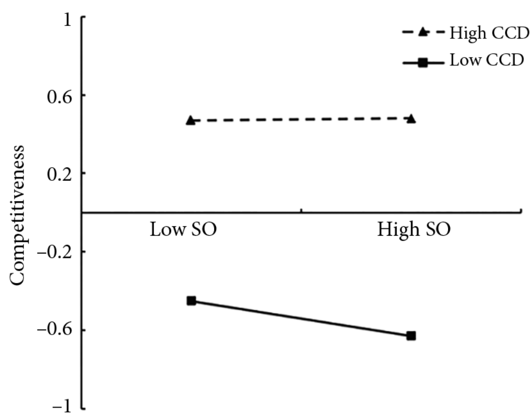

Figure 6. Moderating effect of the coupling degree on the relationship between SO and CC

Conclusions

The paradigm of technological innovation is undergoing tremendous changes in the context of the digital economy. This study takes listed companies in digital economy as the research object and explores how standardization and innovation can improve CC. Through coupling coordination analysis, correlation analysis, and regression analysis of the data obtained on innovation, standardization, and CC of China's 171 listed companies, the current article presents the following conclusions and implications:

First, the study results verify that innovation and standardization are the two key factors that drive these listed companies' development in the digital economy domain. In particular, RDI ($\beta = 0.253$, $p < 0.01$), IO ($\beta = 0.585$, $p < 0.01$), SI ($\beta = 0.295$, $p < 0.01$), and SO ($\beta = 0.392$, $p < 0.01$) exert a significant positive impact on the improvement of CC. Meanwhile, the CCD ($\beta = 0.633$, $p < 0.01$) of innovation and standardization has a greater effect on competitiveness, indicating that it is an effective means for companies to pay more attention to the coordinated development of innovation and standardization in the context of the digital economy.

Second, the demand for innovation capabilities is lacking in the standardization of the development level of companies in the field of the digital economy in China. In particular, the organizational factor is inevitable in developing countries. However, the current study's result demonstrates that among the 171 listed companies, only Zhongxing Telecommunication Equipment Corporation (ZTE) and Boe Technology Group Co., Ltd. (BOE) have achieved the coordination level of innovation and standardization ($D > 0.5$). This indicates that the current standardization level is far from keeping up with the pace of innovation development. To improve the position of Chinese companies in global value chains, the level of standardization must be improved quickly to address the issues concerning low innovation value in developing countries and non-core companies. At the same time, the development of standards must be driven by quality. The study's analysis results revealed that increasing the number of standards exerted a limited effect on the improvement of CC. For companies with low CCD, a negative impact may be observed. Moreover, the conversion efficiency of standards is negative, which is influenced by the current development status of standardization in developing countries. In the past five years, 60.78% of the newly established TCs established by the International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC) have been undertaken by developed countries, particularly in the fierce competition for standards in emerging fields. Therefore, in the field of the digital economy, an increase in standards that are not integrated with technological innovation may result in invalid investments by companies and even low-quality standards that will restrict industrial progress.

Third, improving CC in digital economy requires a two-wheel drive from "innovation + standardization", and standardization must develop in coordination with innovation. Regardless of whether the SI or SO is being considered, the competitiveness of a high-CCD company is much higher than that of low-CCD company. Moreover, low-CCD companies may run the risk of invalid input and output of standardization. The impact of standardization on company competitiveness is inseparable from the development of innovation; in other words, standards promote the development of innovation to facilitate the development of CC.

This study considers listed companies in China's digital economy as the research object, thereby enriching the empirical research on innovation and standardization in the digital economies of developing countries. In addition, the study explores the coordinated development of innovation and standardization from the theoretical perspective.

However, there are also some limitations in this research. Firstly, this study selected the samples from the digital economic industries, restricting the results applied to the other sectors. Secondly, the data from listed companies are collected only, leading to selection bias. Finally, the degree of coupling coordination is explored based on the macro level – standardization and innovation, which can be further refined to the micro-level, namely standard input and output, research input, and innovation output. Future research is recommended to draw from the core, narrow scope, and broad scope to conduct further comparative analysis to strengthen the pertinence and application of the practical guidance.

Funding

This research was funded by The Project of the National Social Science Fund of China under Grant 20BGL016.

Author contributions

Conceptualization and methodology, J.Y. and L. ZH; Collected data, Y. Q; Data analysis, Y. Q, X. J. and Sh. F; Writing, J.Y., Y. Q and X. J.; Revised advice, L. ZH. All authors have read and agreed to the published version of the manuscript.

Disclosure statement

The authors declare no conflict of interest.

References

Abendin, S., & Duan, P. (2021). International trade and economic growth in Africa: The role of the digital economy. *Cogent Economics & Finance*, *9*(1), 1911767. https://doi.org/10.1080/23322039.2021.1911767

Akis, E. (2015). Innovation and competitive power. *Procedia-Social and Behavioral Sciences*, *195*, 1311–1320. https://doi.org/10.1016/j.sbspro.2015.06.304

Amuso, V., Poletti, G., & Montibello, D. (2020). The digital economy: Opportunities and challenges. *Global Policy*, *11*(1), 124–127. https://doi.org/10.1111/1758-5899.12745

Arnold, N., & Hasse, R. (2015). Escalation of governance: Effects of voluntary standardization on organizations, markets and standards in Swiss fair trade. *Sociological Research Online*, *20*(3), 94–109. https://doi.org/10.5153/sro.3734

Baron, J., & Spulber, D. F. (2018). Technology standards and standard setting organizations: Introduction to the Searle Center database. *Journal of Economics & Management Strategy*, *27*(3), 462–503. https://doi.org/10.1111/jems.12257

Blind, K. (2002). Driving forces for standardization at standardization development organizations. *Applied Economics*, *34*(16), 1985–1998. https://doi.org/10.1080/00036840110111158

Blind, K. (2004). *The economics of standards: Theory, evidence, policy*. Edward Elgar Publishing.

Blind, K., & Gauch, S. (2009). Research and standardisation in nanotechnology: Evidence from Germany. *The Journal of Technology Transfer*, *34*(3), 320–342. https://doi.org/10.1007/s10961-008-9089-8

Blind, K., & Rauber, J. (2016). *Drivers for companies' entry into standardization*. https://wwws.law.northwestern.edu/research-faculty/clbe/events/innovation/documents/blind_rauber_entry_searle2016_final.pdf

Bourlès, R., Cette, G., Lopez, J., Mairesse, J., & Nicoletti, G. (2013). Do product market regulations in upstream sectors curb productivity growth? Panel data evidence for OECD countries. *The Review of Economics and Statistics*, *95*(5), 1750–1768. https://doi.org/10.1162/REST_a_00338

Brunsson, N., Rasche, A., & Seidl, D. (2012). The dynamics of standardization: Three perspectives on standards in organization studies. *Organization Studies*, *33*(5–6), 613–632. https://doi.org/10.1177/0170840612450120

Bukht, R., & Heeks, R. (2017). *Defining, conceptualising and measuring the digital economy* (Development Informatics Working Paper No. 68). https://doi.org/10.2139/ssrn.3431732

Castellacci, F., & Natera, J. M. (2013). The dynamics of national innovation systems: A panel cointegration analysis of the coevolution between innovative capability and absorptive capacity. *Research Policy*, *42*(3), 579–594. https://doi.org/10.1016/j.respol.2012.10.006

Chen, C. (2006). CiteSpace II: Detecting and visualizing emerging trends and transient patterns in scientific literature. *Journal of the American Society for Information Science and Technology*, *57*(3), 359–377. https://doi.org/10.1002/asi.20317

Chen, Y. (2020). Improving market performance in the digital economy. *China Economic Review*, *62*, 101482. https://doi.org/10.1016/j.chieco.2020.101482

China Academy of Information and Communications Technology. (2020). *A new vision of the Global Digital Economy (2020) – New driver of sustainable development under great changes*. CAICT.

Choi, D. G., Lee, H., & Sung, T. (2011). Research profiling for "standardization and innovation". *Scientometrics*, *88*(1), 259–278. https://doi.org/10.1007/s11192-011-0344-7

Chursin, A., Vlasov, Y., & Makarov, Y. (2016). *Innovation as a basis for competitiveness. Theory and practice*. Springer Cham. https://doi.org/10.1007/978-3-319-40600-8

David, P. A. (1985). Clio and the economics of QWERTY. *The American Economic Review*, *75*(2), 332–337.

de Vries, H. J., & Verhagen, W. P. (2016). Impact of changes in regulatory performance standards on innovation: A case of energy performance standards for newly-built houses. *Technovation*, *48–49*, 56–68. https://doi.org/10.1016/j.technovation.2016.01.008

Deng, Z. (2020). Analysis of the advantages and disadvantages of China digital economy development based on the industrial division of labor. *Economic Review Journal*, *4*, 67–76.

Doğan, E. (2016). The effect of innovation on competitiveness. *Istanbul University Econometrics and Statistics e-Journal*, *24*, 60–81. https://dergipark.org.tr/en/download/article-file/268727

Dziallas, M., & Blind, K. (2019). Innovation indicators throughout the innovation process: An extensive literature analysis. *Technovation*, *80–81*, 3–29. https://doi.org/10.1016/j.technovation.2018.05.005

Fernandez, E., Montes, J. M., & Vázquez, C. J. (2000). Typology and strategic analysis of intangible resources: A resource-based approach. *Technovation*, *20*(2), 81–92. https://doi.org/10.1016/S0166-4972(99)00115-7

Furman, J. L., & Hayes, R. (2004). Catching up or standing still?: National innovative productivity among "follower" countries, 1978–1999. *Research Policy*, *33*(9), 1329–1354. https://doi.org/10.1016/j.respol.2004.09.006

Gawer, A., & Cusumano, M. A. (2014). Industry platforms and ecosystem innovation: Platforms and innovation. *Journal of Product Innovation Management*, *31*(3), 417–433. https://doi.org/10.1111/jpim.12105

Goluchowicz, K., & Blind, K. (2011). Identification of future fields of standardisation: An explorative application of the Delphi methodology. *Technological Forecasting and Social Change*, *78*(9), 1526–1541. https://doi.org/10.1016/j.techfore.2011.04.014

Hanna, N. K. (2016). *Mastering digital transformation: Towards a smarter society, economy, city and nation*. Emerald Group Publishing. https://doi.org/10.1108/978-1-78560-465-220151009

Hanseth, O., Monteiro, E., & Hatling, M. (1996). Developing information infrastructure: The tension between standardization and flexibility. *Science, Technology, & Human Values*, *21*(4), 407–426. https://doi.org/10.1177/016224399602100402

Hashi, I., & Stojčić, N. (2013). The impact of innovation activities on firm performance using a multi-stage model: Evidence from the Community Innovation Survey 4. *Research Policy*, *42*(2), 353–366. https://doi.org/10.1016/j.respol.2012.09.011

Hussain, A., & Khan, S. (2013). International marketing strategy: Standardization versus adaptation. *Management and Administrative Sciences Review*, *2*(4), 353–359.

Jiang, H., Zhao, S., Li, Z., & Chen, Y. (2016). Interaction between technology standardization and technology development: A coupling effect study. *Information Technology and Management*, *17*(3), 229–243. https://doi.org/10.1007/s10799-015-0215-7

Jiao, S., & Sun, Q. (2021). Digital economic development and its impact on econimic growth in China: Research based on the prespective of sustainability. *Sustainability*, *13*(18), 10245. https://doi.org/10.3390/su131810245

Kartiwi, M., & MacGregor, R. C. (2007). Electronic commerce adoption barriers in Small to Medium-Sized Enterprises (SMEs) in developed and developing countries: A cross-country comparison. *Journal of Electronic Commerce in Organizations*, *5*(3), 35–51. https://doi.org/10.4018/jeco.2007070103

Katz, J. A., & Safranski, S. (2003). Standardization in the midst of innovation: Structural implications of the Internet for SMEs. *Futures*, *35*(4), 323–340. https://doi.org/10.1016/S0016-3287(02)00084-8

Lavie, D. (2006). The competitive advantage of interconnected firms: An extension of the resource-based view. *Academy of Management Review*, *31*(3), 638–658. https://doi.org/10.5465/amr.2006.21318922

Lee, H., & Oh, S. (2006). A standards war waged by a developing country: Understanding international standard setting from the actor-network perspective. *The Journal of Strategic Information Systems*, *15*(3), 177–195. https://doi.org/10.1016/j.jsis.2005.10.002

Li, E., & Cui, Z. (2018). Coupling coordination between China's regional innovation capability and economic development. *Scientia Geographica Sinica*, *38*(09), 1412–1421. https://doi.org/10.13249/j.cnki.sgs.2018.09.003

Miotti, H. (2009). *The economic impact of standardization. Technological change, standards growth in France*. https://normalisation.afnor.org/wp-content/uploads/2016/06/Etude-ImpactEcoNorm-GB2009.pdf

Narayanan, V. K., & Chen, T. (2012). Research on technology standards: Accomplishment and challenges. *Research Policy*, *41*(8), 1375–1406. https://doi.org/10.1016/j.respol.2012.02.006

Oostrom, L., Walker, A. N., Staats, B., Slootbeek-Van Laar, M., Ortega Azurduy, S., & Rooijakkers, B. (2016). *Measuring the internet economy in the Netherlands: A big data analysis*. CBS. Statistics Netherlands.

Porter, M. E. (1998). Clusters and the new economics of competition. In *Harvard Business Review* (pp. 77–90). https://hbr.org/1998/11/clusters-and-the-new-economics-of-competition

Riillo, C. A. (2013). Profiles and motivations of standardization players. *International Journal of IT Standards and Standardization Research (IJITSR)*, *11*(2), 17–33. https://doi.org/10.4018/jitsr.2013070102

Romer, P. M. (1990). Endogenous technological change. *Journal of Political Economy*, *98*(5, Part 2), S71–S102. https://doi.org/10.1086/261725

Sanders, T. R. B. (1972). *The aims and principles of standardization*. International Organization for Standardization.

Shin, D.-H., Kim, H., & Hwang, J. (2015). Standardization revisited: A critical literature review on standards and innovation. *Computer Standards & Interfaces*, *38*, 152–157. https://doi.org/10.1016/j.csi.2014.09.002

Solow, R. M. (1957). Technical change and the aggregate production function. *The Review of Economics and Statistics*, *39*(3), 312–320. https://doi.org/10.2307/1926047

Sturgeon, T. J. (2019). Upgrading strategies for the digital economy. *Global Strategy Journal*, 1364. https://doi.org/10.1002/gsj.1364

Sturgeon, T., Van Biesebroeck, J., & Gereffi, G. (2008). Value chains, networks and clusters: Reframing the global automotive industry. *Journal of Economic Geography*, *8*(3), 297–321. https://doi.org/10.1093/jeg/lbn007

Swann, G. M. P. (2010). *The economics of standardization: An update*. Innovative Economics Limited.

Szeles, M. R., & Simionescu, M. (2020). Regional patterns and drivers of the EU digital economy. *Social Indicators Research*, *150*(1), 95–119. https://doi.org/10.1007/s11205-020-02287-x

Tassey, G. (2000). Standardization in technology-based markets. *Research Policy*, *29*(4), 587–602. https://doi.org/10.1016/S0048-7333(99)00091-8

Teece, D. J. (1986). Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. *Research Policy*, *15*(6), 285–305. https://doi.org/10.1016/0048-7333(86)90027-2

Teece, D. J. (2017). Towards a capability theory of (innovating) firms: Implications for management and policy. *Cambridge Journal of Economics*, *41*(3), 693–720. https://doi.org/10.1093/cje/bew063

United Nations Conference on Trade and Development. (2019). *Digital economy report 2019. Value creation and capture: Implications for developing countries*. UNCTAD. United Nations publication.

Wen, J., & Zeng, D. (2019). Alliance portfolio configuration and firm's technology standardization capability. *Studies in Science of Science*, *37*(07), 1277–1285. https://doi.org/10.16192/j.cnki.1003-2053.2019.07.014

Yang, J., Jin, X., Le, W., & Sheng, F. (2021). Exploring service quality model from the perspective of sensory perception. *Total Quality Management and Business Excellence*, *32*(13–14), 1548–1568. https://doi.org/10.1080/14783363.2020.1747425

Yang, J., Shao, L., Jin, X., & Zhou, L. (2022). Impact of coupling of technological innovation and standardisation on industrial development: An empirical study of high-tech industry. *International Journal of Emerging Markets*. https://doi.org/10.1108/IJOEM-05-2021-0758

Yang, J., Vargas, L. G., Jin, X., & Zhou, L. (2020). Quality credit evaluation in the internet company: A system based on the analytic hierarchy process. *Journal of Business Economics and Management*, *21*(2), 344–372. https://doi.org/10.3846/jbem.2020.11409

Yu, X. (2008). *Standardization and economic growth – Theory, demonstration and case*. China Standards Press.

Zoo, H., de Vries, H. J., & Lee, H. (2017). Interplay of innovation and standardization: Exploring the relevance in developing countries. *Technological Forecasting and Social Change*, *118*, 334–348. https://doi.org/10.1016/j.techfore.2017.02.033

Zou, S., Zou, Z., & Zeng, D. (2020). Impact of competition-complementarity of collaborative R&D network on enterprise's technology standardization capability. *Studies in Science of Science*, *38*(1), 97–104.