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The Impact of Industry–University–Research Alliance Portfolio Diversity on Firm Innovation: Evidence from Chinese Manufacturing Firms

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Abstract: Innovation is a key factor for the sustainable development of firms. Although it has been a prevalent phenomenon that firms maintain multiple industry–university–research (I–U–R) alliances simultaneously to generate innovation, there is a lack of explorations in this phenomenon in extant literature. In this study, we introduce a new construct, I–U–R alliance portfolio, and investigate the impact of its diversity on a focal firm's innovation performance. Hypotheses are proposed and examined using datasets of 176 listed firms in the Chinese manufacturing industry. We find that I–U–R alliance portfolio diversity exerts a positive effect on a focal firm's innovation performance and a firm's absorptive capacity positively moderates this relationship. Furthermore, we contend that with increasing levels of government financial support, the positive relationship between I–U–R alliance portfolio diversity and firm innovation performance is strengthened. Finally, our findings provide several theoretical and practical implications for the I–U–R alliance portfolio and firm innovation.

Keywords: industry–university–research; alliance portfolio diversity; government financial support; innovation performance; sustainable development

1. Introduction

In the increasingly fierce competitive environment, continuous innovation has become crucial for the survival and sustainability of firms [1,2]. However, it is difficult for firms to innovate entirely on their own because of limited resources and capabilities [3] and thus firms need to follow the open innovation paradigm to interact with other organizations [4,5]. Knowledge from universities or research institutes is widely recognized as an essential driver of spurring firm innovation performance [6,7]. Therefore, firms are increasingly relying on collaborations with universities or research institutes to gain and leverage external knowledge [8], thereby forming different forms of I–U–R alliances including industry–university (I–U), industry–research institute (I–R), and industry–university–research institute (I–U–R) collaborations. Nowadays, that firms engage in multiple I–U–R alliances simultaneously has become a common phenomenon. For instance, Weichai, one of the most famous Chinese machinery industry firms, has established plenty of I–U–R alliances with some prominent universities and research institutes like MIT, University of Wisconsin and Tsinghua University at home and abroad in recent years. Moreover, the Weichai story is not unique, for many firms are depending on their portfolios of I–U–R alliances to enhance innovation performance. Following the definitions of the project portfolio [9] and the alliance portfolio [10], we introduce a new construct, I–U–R alliance portfolio, defined as the collection of I–U–R alliances in which a focal firm is involved.

Prior research has examined the influence of I–U–R collaborations on firm innovation performance. For example, Maietta [7] finds that in the university-industry R&D collaboration, geographical

proximity to a university positively influences firm product innovation whereas the amount of the codified knowledge production has the negative effect on firm product innovation. Kobarg, Stumpf-Wollersheim, and Welpe [11] indicate that university–industry collaboration is positively associated with both the incremental and radical innovation performance. However, extant studies only focus on the level of the single collaboration and thus lack the research from the portfolio perspective. Besides, a significant body of studies have investigated the association between alliance portfolio diversity and a focal firm's innovation performance, but they have generated inconclusive results. Specifically, some research provides results showing that alliance portfolio diversity has an inverted U-shaped association with firm innovation performance [12,13], others argue that alliance portfolio diversity exerts a positive [14,15] or U-shaped impact on firm innovation performance [16]. Previous literature only pays attention to the impact of common alliance portfolios on firm innovation, lacking the explorations in the association between I–U–R alliance portfolio diversity and firm innovation performance. In addition, the triple helix theory points out that the government, firms, and universities closely collaborate and interact with each other according to the needs of economic development, thus forming a three-helix relationship in which three forces cross each other and spiral upward [17]. Though the triple helix collaboration has been believed vital to the success of regional innovation development at the macro-level [18,19], previous research provides little understanding of how it affects firm innovation performance at the micro-level of the firm. In general, although firms' establishing I–U–R alliance portfolios to improve innovation performance has been a universal phenomenon, it remains unknown whether characteristics of I–U–R alliance portfolios influence a focal firm's' innovation performance.

Therefore, this study aims to fill the gaps in literature by answering the following two questions: First, to what extent does I–U–R alliance portfolio diversity impact a focal firm's innovation performance? Second, under what conditions does I–U–R alliance portfolio diversity influence a focal firm's innovation performance? We focus on the diversity of I–U–R alliance portfolios because diversity is a key descriptor of a portfolio.

Drawing from the knowledge-based view (KBV) perspective, we examine the consequence of I–U–R alliance portfolio diversity on a focal firm's innovation performance. Using Chinese manufacturing industry as the research context, we reveal that I–U–R alliance portfolio diversity positively influences firm innovation performance. Further, we investigate the conditions under which I–U–R alliance portfolio diversity affects a focal firm's innovation performance. Absorptive capacity is often used as a firm-level construct that helps to explain why some firms are more able to learn from external partners than other firms [20], we therefore explore the role that absorptive capacity plays in the relationship. Our study reveals that absorptive capacity positively moderates the effect of I–U–R alliance portfolio diversity on firm innovation performance. In addition, governments can strongly influence business operations through policy-making and resource allocation [21], thus we examine the contingent effect of government financial support in the firm-led I–U–R collaborations. Our results show that increasing levels of government financial support will enhance the positive impact of I–U–R alliance portfolio diversity on firm innovation performance. Our results thus make three major contributions to the existing literature. First, we go beyond prior research that solely focuses on the level of single I–U–R alliance and develop a new construct, revealing how I–U–R alliance portfolio diversity influences a focal firm's innovation performance, thus contributing to the literature on I–U–R collaborations. Second, we examine the contingent effect of government financial support in firm-led I–U–R collaborations and investigate the effect of the triple helix of university–industry–government relations on innovation at the micro-level of the firm, thus adding to the triple helix theory. Third, by paying attention to I–U–R alliance portfolio phenomenon and studying the performance implications of its diversity for a focal firm, we extend previous alliance portfolio literature that examines the relationship between alliance portfolio diversity and firm innovation performance.

This research is structured as follows. Section 2 shows the hypotheses of this study, while Section 3 describes the sample, variables, and the research methods. The results and robustness checks are

shown in Section 4. Section 5 presents the discussion of the results, including theoretical implications, managerial implications, and limitations. Finally, Section 6 presents the conclusion.

2. Theory and Hypotheses

2.1. I–U–R Alliance Portfolio Diversity and Firm Innovation Performance

I–U–R alliance portfolio partners not only include universities and research institutes, but also may include other partners like firms, social associations, and governments. Different kinds of partners can serve different purposes [13], such as offering a focal firm knowledge, experiences, and expertise that are beneficial to improve innovation performance [22]. In line with previous alliance portfolio literature [13,23], this study defines I–U–R alliance portfolio diversity in terms of the variety of partners with which a focal firm directly collaborates in the I–U–R alliance portfolio.

First, allying with diverse partners provides a focal firm with a broader variety of knowledge access. Different kinds of partners in the I–U–R alliance portfolio possess diverse knowledge bases. For instance, universities can give access to fundamental knowledge and have the capacity to conduct high-level research [24], and public research institutes can provide a focal firm with knowledge like the industry key and commonality technical as a result of their functions and responsibilities. Therefore, with the increasing of the I–U–R alliance portfolio diversity, a focal firm can get access to broader knowledge bases from external partners [23] so that it can gain distinct and diverse knowledge assets and expand knowledge bases [25]. According to the KBV, the knowledge bases and elements that I–U–R alliance partners provide enable a focal firm to improve innovation performance [26].

Second, with the increasing of I–U–R alliance portfolio diversity, the potential for creative recombination and novel combinations increases. Innovation is a process of combining existing and new knowledge elements available to the firm in a novel way [27]. Combing supplementary and complementary knowledge elements from diverse types of partners with a focal firm's internal knowledge resources can prevent the firm from being locked into its prior knowledge [28], generate possible complementarities as well as synergies, and increase the opportunities for novel combinations [13,29]. Besides, collaborating with different types of external partners belongs to the coupled open innovation, which reduces costs and risks of innovation activities and increases the return from a firm internal R&D activities by leveraging partner's capacities [5,30]. Hence, it contributes to a focal firm's innovation performance.

Moreover, exposure to diverse ideas, experiences and other knowledge resources from external partners allows focal firms to think 'outside the box' [31], as well as provides more information and networking opportunities for solving problems and reducing uncertainty [32]. To sum up, combining our arguments above on the association between I–U–R alliance portfolio diversity and a focal firm's innovation performance, we hypothesize:

Hypothesis 1: *I–U–R alliance portfolio diversity has a positive effect on firm innovation performance.*

2.2. The Contingent Effect of a Firm's Absorptive Capacity

Absorptive capacity refers to a firm's ability to value, assimilate, and commercially apply new, external knowledge [28], which is recognized as a dynamic capability pertaining to knowledge creation and utilization that enhances a firm's ability to gain and sustain the competitive advantage [33]. Absorptive capacity is critical in determining the magnitude and range of knowledge flows [34], which is crucial for sustaining a firm's innovation performance [35]. In addition, absorptive capacity is conducive to reinforcing, complementing, or refocusing a firm's knowledge base, and helps the speed, frequency, and magnitude of firm innovation performance, thus developing and maintaining absorptive capacity is of great importance for a firm's long-term survival and sustainable development [36].

First, a firm's absorptive capacity plays a leading role in enabling a firm to effectively acquire and utilize external knowledge [37]. As the I–U–R alliance portfolio diversity increases, a focal firm can get access to more diverse knowledge stock from external I–U–R alliance portfolio partners. Absorptive capacity is one of the most vital determinants of a firm to effectively acquire, assimilate, and apply new knowledge to improve innovation performance [38]. Therefore, a firm's absorptive capacity enhances the positive effect of I–U–R alliance portfolio diversity on firm innovation performance. Second, a firm's absorptive capacity can be beneficial to influence the effectiveness of innovation activities [39]. Firm innovation performance not only relies on knowledge stock, but also depends on acquiring useful knowledge and utilizing it effectively in a firm's internal innovation activities [40]. When a focal firm implements internal innovation activities to utilize knowledge from diverse I–U–R alliance portfolio partners, absorptive capacity can increase the effectiveness of innovation activities, thereby promoting the use of external knowledge. In addition, a firm's absorptive capacity contributes to improving the efficiency of organizational learning and innovative capability [28], thus helping the learning and transformation of the knowledge from I–U–R alliance portfolios.

Extant literature has also pointed out that absorptive capacity helps to make use of external knowledge within organizations, improving the ability to assimilate and utilize knowledge, and eventually enhancing firm innovation performance [41,42]. From the above, absorptive capacity is crucial for effectively acquiring, learning, assimilating and utilizing external knowledge from various I–U–R alliance portfolio partners, thereby enhancing the positive influence of I–U–R alliance portfolio diversity on firm innovation performance. That is, a firm's absorptive capacity positively moderates the association between I–U–R alliance portfolio diversity and a focal firm' innovation performance. According to these arguments above, we propose the following hypothesis:

Hypothesis 2: *With increasing levels of a firm's absorptive capacity, the positive effect of I–U–R alliance portfolio diversity on firm innovation performance is strengthened.*

2.3. The Contingent Effect of Government Financial Support

Innovation is a crucial driver of firms' productivity growth and sustainable competitive advantage and governments have been showing increasing interest in firms' open innovation [43]. Therefore, governments, especially those in emerging economies, have increasingly supported firms with funding, information, land, tax incentives, and so on, to promote firm innovation [44,45]. For instance, in order to realize the ambition of entering the ranks of innovative countries by 2020 and establish itself as the leading country in science and technology by 2050, the Chinese government has set a goal of increasing R&D investment to 2.5 percent of its GDP by 2020 and strengthening financial support in firms' R&D activities [45].

First, government financial support is conducive to a focal firm's internal R&D activities. In order to enhance innovation performance, a focal firm needs to assimilate and commercially apply knowledge from diverse alliance partners through internal R&D activities. In addition, government financial support contributes to a firm's R&D activities by reducing the costs, increasing R&D investment, and expanding the scale of R&D activities [46,47], indicating that government financial support can strengthen the benefits of increasing I–U–R alliance portfolio diversity to promoting firm innovation performance. Second, government financial support can make up for the costs resulting from acquiring knowledge from I–U–R alliance portfolio partners to a certain degree. Extant research indicates that increasing partner type diversity will generate searching and learning costs when a focal firm is exposed to diverse and complementary knowledge, as well as new learning methods from external partners [23,48]. However, with governmental financial support, a firm can offset these costs to some extent, which is beneficial to strengthening the positive impact of I–U–R alliance portfolio diversity on firm innovation performance. Third, financial resources are a critical ingredient for a firm to obtain external technology and information, which can turn into other kinds of resources [49]. For example,

with the government financial support, a firm can hire employees with strong knowledge and capacity, which is conductive to acquiring external knowledge. Hence, a focal firm can acquire knowledge from the I–U–R alliance portfolio better through government financial support. Besides, Greco, Grimaldi, and Cricelli [43] point out that public subsidies are conductive to activating some potentially fruitful collaborations and fostering the coordination of a focal firm with its partners, thus enhancing open innovation efficiency.

To summarize, we can conclude that government financial support plays a moderating role in the association between I–U–R alliance portfolio diversity and a firm's innovation performance. Specifically speaking, government financial support strengthens the impact of I–U–R alliance portfolio diversity on firm innovation performance. Hence, we propose the following hypothesis:

Hypothesis 3: *With increasing levels of government financial support, the positive effect of I–U–R alliance portfolio diversity on firm innovation performance is strengthened.*

Based on all of the above considerations, we develop an integrated theoretical model (Figure 1) which illustrates the three hypothesized relationships to be tested.
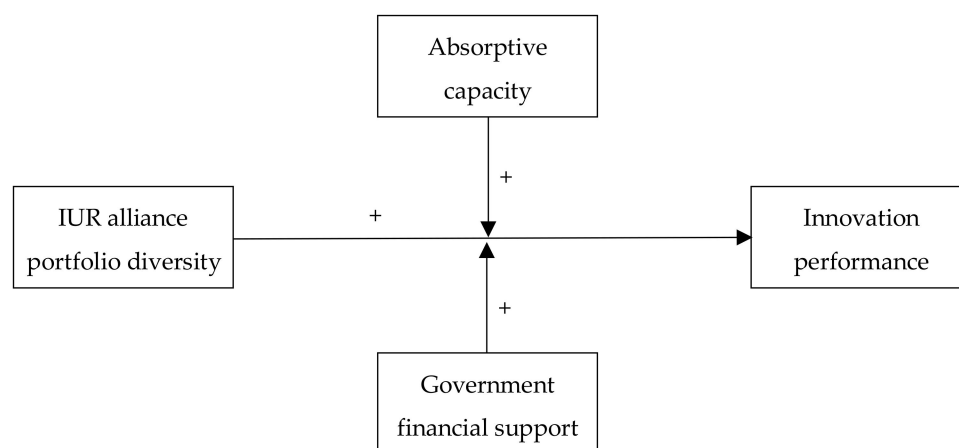

Figure 1. Theoretical model.

3. Data and Methods

3.1. Sample

The manufacturing industry is a particularly suitable empirical context for testing the hypotheses we proposed for these reasons: First, the phenomenon that firms participate in multiple I–U–R alliances simultaneously is very prevalent in the manufacturing industry. Second, the manufacturing industry is characterized by a high level of uncertainty surrounding fabrication, and innovation is a relevant performance metric for manufacturing activities [26]. Third, the manufacturing industry covers a wide range of segment sectors, which is conducive to improving the application scope of our research conclusions. As a result, we select firms in the manufacturing industry as the research sample.

Since I–U–R alliances typically often last for 5 years and termination dates are rarely reported, we follow previous research in applying a 5-year window to construct a focal firm's I–U–R alliance portfolio [20,50]. For example, the I–U–R alliance portfolio of year t is computed as the collection of I–U–R alliances established from the year t-5 to the year t-1. Specifically, we search I–U–R alliance data from the manufacturing firms listed on the Chinese main board and rule out firms that do not meet the requirement of possessing at least two I–U–R alliances or the firms that have been listed less than five years by the observation year. Moreover, we gather the I–U–R alliance data starting from 2009 to 2015, for plenty of relevant data before 2008 is missing and we need to set a few years to observe the results. Thus, we get I–U–R alliance portfolios from 2014 (include all the I–U–R alliances entered by a

focal firm from 2009 to 2013) and I–U–R alliance portfolios from 2016 (include all the I–U–R alliances entered by a focal firm from 2011 to 2015).

Data on I–U–R alliance activities are mainly collected from the WIND database, which is a popular and authoritative database in China and has reasonably consistent and complete coverage on firm alliance activities [51]. Similar to the SDC Platinum database, the WIND database has been widely recognized and used in prior literature [51,52]. Besides, we collect the I–U–R alliance information on each firm's official website and Badu News, a popular news search engine in China, to supplement and revise our collected data. Other data, like firms' basic information, are mainly drawn on from the CSMAR database, which is a leading provider of information on Chinese listed companies and widely used in extant literature [53]. Moreover, patent information is collected from the Chinese National Intellectual Property Administration and firms' annual reports. Following these rules, we collect the sample of 187 firms representing 20 manufacturing sectors. After matching data and removing various missing values, we finally get 350 firm-year observations from 176 firms.

3.2. Measures

3.2.1. Dependent Variable

Innovation performance. Patents are directly related to innovation performance and represent an externally validated measure of technological novelty [54], which are characterized by consistency and objectiveness [55]. Thus, patents have been extensively used as an indicator of innovation performance in prior studies. In addition, since the application date represents the earliest point when new firm capabilities can be identified [12] and is a more accurate representation of the date of firm innovation [14], we use the patent applications to measure innovation performance. Therefore, in this study, firm innovation performance is measured as the annual number of successful patent applications by a firm [56,57]. Besides, we also adopt an alternative measurement for innovation performance when performing robustness checks.

3.2.2. Explanatory Variables

I–U–R alliance portfolio diversity (I–U–R APD). I–U–R alliance portfolio diversity refers to the diversity of direct I–U–R alliance partner types that a focal firm is engaged with. I–U–R alliance partners not only include different kinds of universities and research institutes, but also include partners like other firms, social associations, and governments. Specifically, eight types can distinguish I–U–R alliance partners: (1) national universities, (2) local public universities, (3) private universities, (4) public research institutes, (5) enterprise research institutes, (6) companies, (7) governments, and (8) social associations. In line with extant research [58,59], we calculate I–U–R alliance portfolio diversity as one minus the sum of squared proportions of each type's number of partners in the I–U–R alliance portfolio through the formula $1 - \sum \left(\frac{n_i}{N}\right)^2$, where n_i represents the cumulative number of partners belonging to type i and N represents the aggregate amount of all partners.

Absorptive capacity. R&D is regarded as the central to the conceptualization of absorptive capacity, which is the method of improving a firm's ability to learn [28]. R&D expenditure broadly reflects the quality and quantity of a firm's human capital that helps to enhance a firm's ability to recognize, assimilate, and utilize external knowledge [60]. In addition, R&D expenditure is considered as the reflection of a firm's willingness to invest in absorptive capacity [28], and the appropriate measure of firm acquisition ability [33]. Given that the use of R&D expenditure as the proxy for absorptive capacity is well established in the prior literature [61,62], we measure absorptive capacity by using a logarithm transformation of a firm's annual R&D expenditure.

Government financial support (GFS). Governments often offer different kinds of financial support for firms to promote their growth and sustainable developments, especially to enhance their innovation capacity and performance [63]. Despite the variety of its forms, government financial support has focused on firm innovation and R&D activities. To measure government financial support, we calculate

the sum of various financial subsidies that a firm received from governments of all levels in a given year. Since the distribution of the sum of financial subsidies is highly skewed, we adopt a logarithm transformation.

3.2.3. Control Variables

At the firm level, we include six control variables. First, we control for firm size since it is related to a firm's resource and innovation capability [61], and we measure it as the logarithm transformation of a firm's total assets in a given year [64]. We also control for firm age, calculated as the number of years since a firm's founding, because it captures a firm's experience that may influence innovation performance [65]. Furthermore, state ownership is associated with a firm's innovation [45], thus we use the dummy variable SOE to indicate whether a firm is a state-owned enterprise. Besides, a firm's internal innovation efforts (IIE) are considered as a factor that affects firm innovation performance, thus we control for the variable and measure it as the share of R&D employees in the total number of employees [66]. The asset–liability ratio measures the firm's ability to use creditor funds for business activities, which may have an impact on a firm's innovation activities [67]. Therefore, we also control for the asset–liability ratio, which is calculated as total debt divided by total assets. In addition, we control for past firm performance because a firm's past performance is related to firm innovation performance [68]. Following previous research, we measure past firm performance as the return on assets of the year t-1 [64].

To ensure data availability, we construct I–U–R alliance portfolios from two different years, the year 2014 and the year 2016. To control for yearly fluctuations and unobservable factors that change over time [69], we control for the dummy variable year, which takes values of 1 if the I–U–R alliance portfolio from the year 2016 and 0 otherwise. Moreover, since different industries represent various environmental dimensions such as technological opportunity [70], we control for industry dummies. Our data include 20 manufacturing sub-industries, such as pharmaceutical manufacturing, equipment manufacturing, metal manufacturing, automotive manufacturing, food manufacturing, and so forth; thereby, 19 industry dummies should have been added to control for industry effects. However, to reduce the multicollinearity problem, we have to delete four industry dummies. In addition, different regions are various in economic development levels, institutional environments, and market environments, which may be related to firm innovation performance [71], we control for region dummies. According to economic and social development in different regions, China is officially divided into four parts, the eastern, central, western, and northeastern areas. Hence, we use three region dummies to control for region effects.

3.3. Methods

The dependent variable, measured as the number of successful patent applications, is a count variable. In the circumstances, the negative binomial model and the Poisson model are more appropriate because both of the two models take into account the non-negativity and discreteness of dependent variables [12]. The test of the assumption of the Poisson model rejects the null hypothesis that the dispersion parameter alpha is equal to zero, which violates the basic assumption of the Poisson model that the variance of the count variable equals its conditional mean holds [72]. Therefore, we finally adopt a negative binomial regression model, which can better deal with the over-dispersion issue than a Poisson regression model [73].

A selection bias may exist in our sample, because forming alliance portfolios is a firm's strategic choice based on some firm characteristics [50]. Thus, we take a Heckman two-stage analysis to deal with the potential selection bias [74]. In the first stage, we ran a Probit model to regress the possibility of firms establishing I–U–R alliance portfolios on firms' characteristics like firm age, firm size, state-owned enterprise, financial performance, and growth rate. We generate the inverse Mills ratio from the estimation and then include it as a control variable in the second stage. Then, we perform negative binomial regressions to estimate the parameters. In addition, since multiplicative interaction terms

in regression models may cause the multicollinearity problem, the independent variable and the moderator variable have been mean centered before creating the interaction term.

4. Results

Table 1 presents descriptive statistics and pairwise correlations among variables of this study. All the correlations values are generally not high, indicating that there is a low risk of facing the multicollinearity problem. Moreover, we also test for multicollinearity by examining variance inflation factors (VIF). In the full model, the maximum VIF value is 4.61 and is well below the critical threshold of 10 [75], and the mean VIF value is 1.65, which again suggest that our results are not harmed by the multicollinearity problem.

Table 1. Descriptive statistics and correlation matrix.

	Variables	1	2	3	4	5	6	7	8	9	10	11
1	Innovation performance	1										
2	Firm size	0.39	1									
3	Firm age	0.02	−0.05	1								
4	SOE	0.01	0.10	−0.06	1							
5	IIE (in %)	0.05	0.01	−0.02	−0.02	1						
6	Asset–liability ratio	0.18	0.39	0.00	0.25	0.05	1					
7	Past firm performance	0.07	0.17	−0.03	−0.19	−0.03	−0.39	1				
8	Year	0.03	0.08	0.22	−0.00	−0.24	−0.04	−0.12	1			
9	GFS	0.44	0.69	0.01	0.09	0.10	0.35	0.05	0.08	1		
10	Absorptive capacity	0.45	0.76	−0.10	0.03	0.10	0.25	0.23	0.07	0.64	1	
11	I–U–R APD	0.16	0.19	−0.03	0.07	−0.01	0.10	0.03	0.14	0.18	0.18	1
	Mean	311.72	23.11	18.83	0.63	14.44	0.50	0.04	0.50	17.54	0.46	0.52
	S. D.	1061.5	1.25	4.14	0.48	9.64	0.18	0.06	0.50	1.67	1.66	0.22
	Minimum	0	20.24	6	0	0.45	0.09	−0.28	0	10.50	−7.95	0
	Maximum	10881	27.10	31	1	60	0.98	0.29	1	22.11	4.85	0.82

Note: N = 350. Correlations with an absolute value > 0.10 are significant at 5% level.

Table 2 displays the regression results of negative binomial models, which is based on two-tailed tests. Model 1 only includes control variables, serving as the point of comparison for the following models, and the independent variable, moderator variables, and their interaction terms are subsequently added in the following models. Results of Model 1 indicate the significant impacts of firm size, internal innovation efforts, and past firm performance on firm innovation performance, which are consistent with findings in Models 2 to 5. The estimated results show that all the coefficients for the inverse Mill's ratio is not significant, suggesting that there is no selection bias exist in our equations. Besides, Hypothesis 1 proposes that I–U–R alliance portfolio diversity positively affects a focal firm's innovation performance. The coefficient for I–U–R alliance portfolio diversity is positive and significant in Model 2 (β = 0.947, *p* < 0.01), which is in line with the results of the following three models. According to likelihood ratio tests, the model fit is improved compared with Model 1, indicating that Hypothesis 1 is supported.

Hypothesis 2 states the moderating effect of a firm's absorptive capacity on the association between I–U–R alliance portfolio diversity and firm innovation performance. The regression results of Model 3 show a positive and highly significant effect of the interaction term between I–U–R alliance portfolio diversity and absorptive capacity on firm innovation performance (β = 0.936, *p* < 0.001). Moreover, the coefficient for the interaction term between I–U–R alliance portfolio diversity and absorptive capacity remains significant in Model 5 (β = 0.482, *p* < 0.1), the full model. Figure 2 shows the moderating role of absorptive capacity in the association. The low level of absorptive capacity is capacity at the mean minus one standard deviation and the high level of absorptive capacity is capacity at the mean plus one standard deviation. The figure indicates that absorptive capacity enhances the positive impact of I–U–R alliance portfolio diversity on firm innovation performance. From the above, these results indicate that the effect of I–U–R alliance portfolio diversity on firm innovation performance is positively moderated by a firm's absorptive capacity, so that Hypothesis 2 is supported.

Furthermore, Hypothesis 3 posits that higher levels of government financial support will increase the role of I–U–R alliance portfolio diversity in enhancing a focal firm's innovation performance. The coefficient for the interaction term between I–U–R alliance portfolio diversity and government financial support in Model 4 is positive and significant ($\beta = 0.842$, $p < 0.001$). In addition, in line with the results of Model 4, the results of Model 5 also indicate that the interaction term between the independent variable and government financial support has a significant and positive effect on our dependent variable ($\beta = 0.475$, $p < 0.05$), which is qualitatively the same with the former ones. Hence, these results provide support for Hypothesis 4. Figure 3 visually illustrates the impact of I–U–R alliance portfolio diversity on a firm's absorptive capacity. The low level of government financial support is the mean minus one standard deviation and the high level of government financial support is the mean plus one standard deviation, and the two lines present that with the increasing levels of government financial support, the positive influence of I–U–R alliance portfolio diversity on firm innovation performance is strengthened.

Table 2. Negative binominal regression results for firm innovation performance.

	Model 1	Model 2	Model 3	Model 4	Model 5
Industry dummies	Included	Included	Included	Included	Included
Region dummies	Included	Included	Included	Included	Included
Intercept	−12.642 ***	−13.190 ***	−4.487 *	−12.761 ***	−4.608 *
	(2.167)	(2.136)	(2.069)	(1.780)	(1.888)
Firm size	0.729 ***	0.729 ***	0.319 ***	0.337 ***	0.016
	(0.091)	(0.091)	(0.091)	(0.088)	(0.089)
Firm age	−0.014	−0.006	0.026†	0.013	0.023†
	(0.020)	(0.019)	(0.015)	(0.015)	(0.014)
SOE	0.163	0.099	0.235†	0.079	0.067
	(0.177)	(0.184)	(0.137)	(0.146)	(0.129)
IIE	0.017 †	0.018 *	0.017 *	0.021 **	0.016 *
	(0.009)	(0.008)	(0.006)	(0.008)	(0.006)
Asset-liability ratio	1.360 *	1.156 †	0.266	0.078	−0.103
	(0.670)	(0.640)	(0.496)	(0.436)	(0.403)
Past firm performance	7.844 ***	7.260 ***	3.437 *	5.448 ***	3.086 *
	(2.156)	(2.025)	(1.394)	(1.256)	(1.224)
Year	0.172	0.085	−0.043	−0.080	−0.130
	(0.168)	(0.159)	(0.124)	(0.124)	(0.113)
Inverse Mills ratio	−1.091	−0.868	−0.298	0.269	0.563
	(0.857)	(0.885)	(0.855)	(0.857)	(0.857)
I–U–R APD		0.947 **	1.072 ***	1.151 ***	0.985 ***
		(0.349)	(0.303)	(0.311)	(0.296)
Absorptive capacity			0.451 ***		0.421 ***
			(0.058)		(0.049)
I–U–R APD × Absorptive capacity			0.936 ***		0.482 †
			(0.238)		(0.272)
GFS				0.477 ***	0.421 ***
				(0.057)	(0.053)
I–U–R APD × GFS				0.842 ***	0.475 *
				(0.166)	(0.224)
Observations	350	350	350	350	350
Wald Chi-square	720.04	708.65	825.54	931.77	1171.14
Log likelihood	−1935.884	−1932.064	−1885.451	−1886.401	−1858.107

Note: † $p < 0.10$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$, two-tailed tests. All models include 15 industry dummies and three region dummies. Robust standard errors are in parentheses.

Robustness Checks

To confirm the robustness of our results, we perform some additional tests. First of all, we lag our explanatory variables with respect to the dependent variable by one year to reduce reverse causality [50,59]. The regression results are proven to be qualitatively the same as the former ones. The results indicate that the coefficient for I–U–R alliance portfolio diversity is positive and significant ($\beta = 0.886$, $p < 0.01$), which further supports Hypothesis 1. Besides, the results reveal a positive and significant effect of the interaction term between I–U–R alliance portfolio diversity and absorptive capacity on firm innovation performance ($\beta = 1.200$, $p < 0.001$) and the interaction term between I–U–R

alliance portfolio diversity and government financial support is also positive and significant ($\beta = 0.678$, $p < 0.001$). Thus, the results are in support of Hypotheses 2 and 3.
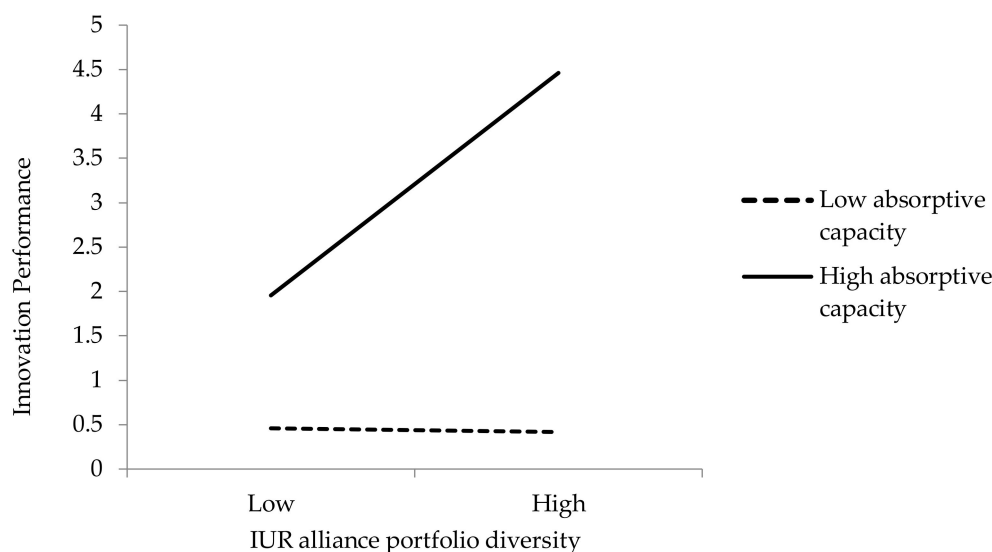

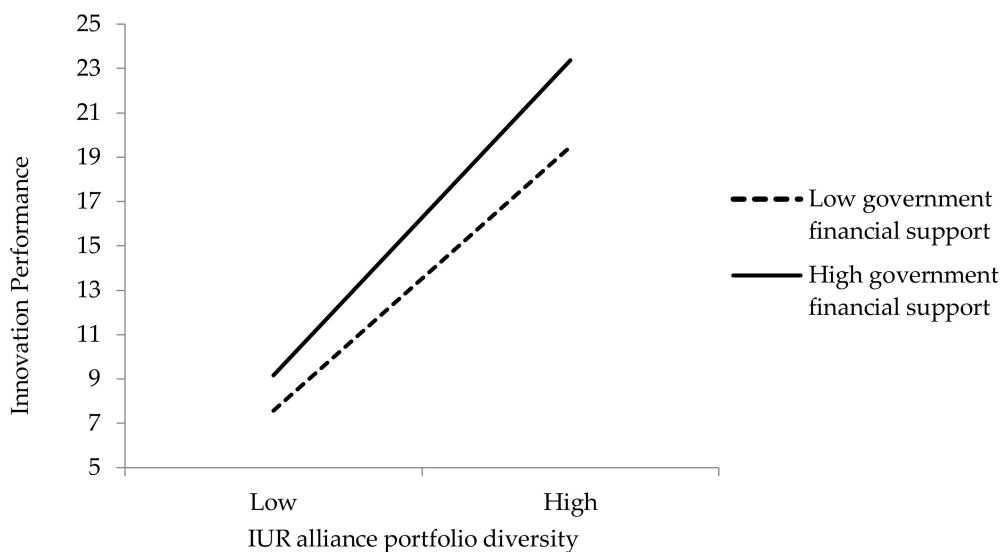**Figure 2.** Moderating effect of absorptive capacity.

Figure 3. Moderating effect of government financial support.

Second, we also test the robustness of our dependent variable, firm innovation performance. We use the count of invention patents as an alternative proxy for innovation performance because they represent higher levels of technological advancement [45]. The results are consistent with our formal results. Results show a positive and significant effect of the independent variable on the innovation performance ($\beta = 1.284$, $p < 0.01$), which supports Hypothesis 1. Besides, the coefficient for the interaction term between the independent variable and absorptive capacity is highly significant and positive ($\beta = 0.942$, $p < 0.001$) and the coefficient for the interaction term between I–U–R alliance portfolio diversity and government financial support is positive and significant ($\beta = 0.835$, $p < 0.001$), indicating that Hypothesis 2 and Hypothesis 3 are both supported.

Third, to enhance the robustness of the moderator variable and reduce bias, we adopt an alternative measurement for absorptive capacity. Consistent with previous studies, absorptive capacity can also be measured as the number of R&D employees [76,77]. The results remain consistent with previous

estimates. The coefficient for the interaction term of I–U–R alliance portfolio diversity and absorptive capacity is positive and significant ($\beta = 0.467$, $p < 0.1$), which further supports Hypothesis 2.

Finally, we test the robustness of our independent variable by adopting an alternative measure, calculated by dividing the number of different partner types that an I–U–R alliance portfolio has by the maximum possible number of partner types and then squaring the result [13,78]. We find that the estimated results are similar with former ones. For instance, the main effect agrees well with previous results ($\beta = 1.538$, $p < 0.05$), and the moderating effect of government financial support between I–U–R alliance portfolio diversity and firm innovation performance is in line with our previous estimates ($\beta = 0.569$, $p < 0.1$).

5. Discussion

5.1. Theoretical Implications

This study examines the impact of I–U–R alliance portfolio diversity on a focal firm's innovation performance. Based on datasets of 176 manufacturing firms listed on the Chinese main board, our results suggest that I–U–R alliance portfolio diversity exerts a positive influence on firm innovation performance. In addition, a firm's absorptive capacity acts as a moderator in the relationship, which enhances the positive effect of I–U–R alliance portfolio diversity on firm innovation performance. Furthermore, government financial support also positively moderates the effect of I–U–R alliance portfolio diversity on firm innovation performance. These results provide novel insights into the role of I–U–R alliance portfolio diversity and generate several theatrical implications for extant literature in the following aspects.

First, the study contributes to the literature on I–U–R collaborations by introducing a new construct and investigating the effect of its diversity on firm innovation performance. Though a great body of prior studies examine the impact of the I–U–R collaboration on innovation performance [7,11], they only focus on the individual I–U–R collaboration and use the single I–U–R collaboration as the analysis unit, overlooking the common phenomenon that firms participate in multiple I–U–R alliances simultaneously. Different from previous studies, our study develops a new construct, I–U–R alliance portfolio, and reveals how I–U–R alliance portfolio diversity influences a focal firm's innovation performance, thereby extending the research on I–U–R collaborations. Second, the study adds to the triple helix theory by exploring the impact of government financial support in firm-led I–U–R collaborations and examining the effect of triple helix relations on innovation at the firm level. Although the triple helix theory has been widely used in previous literature [18,19], it mainly pays attention to the innovation at the macro-level of the region. Thus, how triple helix collaborations influence firm-level innovation remains unknown. In addition, the triple helix theory cannot explain how the government plays a role in firm-led I–U–R collaborations, because it does not emphasize which is the mainstay of innovation. This study indicates that government financial support can enhance the positive impact of I–U–R alliance portfolio diversity on firm innovation performance, and suggests how the characteristic of the triple helix of university–industry–government relations influences firm innovation performance, thus providing new insights into the triple helix theory. Third, our study extends the alliance portfolio literature that investigates the association between alliance portfolio diversity and firm innovation performance. A lot of prior research has examined the common alliance portfolio and explored the effect of its diversity on a focal firm's innovation performance [13,78], but it neglects the I–U–R alliance portfolio phenomenon and does not specifically study the portfolio of I–U–R alliances. In this study, we indicate that I–U–R alliance portfolio diversity exerts a positive influence on a focal firm's innovation output, which is different from the inverted U-shape relationship that most alliance portfolio literature argues between common alliance portfolio diversity and firm innovation performance [13,23]. By focusing on the I–U–R alliance portfolio phenomenon and examining the performance implication of its diversity, our study adds to prior alliance portfolio studies that investigate the association between alliance portfolio diversity and firm innovation performance.

Furthermore, this study examines the positive effect of I–U–R alliance diversity on firm innovation performance, whereas we only focus on the partner diversity. Extant research on common alliance portfolios has investigated performance implications of other kinds of I–U–R alliance portfolio diversities, such as the technological diversity [59], the resource diversity [79], the functional diversity [80], and the geographic diversity [12]. In view of this, future research might also take into account these diversities in the context of I–U–R alliance portfolios. Finally, we only explore the consequence of I–U–R alliance portfolio configurations in terms of the partner diversity and neglect the antecedents of I–U–R alliance portfolio configurations and formation. Thus, it might be an interesting avenue for future research to investigate the factors that influence I–U–R alliance portfolio configurations or formation.

5.2. Managerial Implications

This study provides several useful implications for managers to enhance firm innovation performance and sustainable development. Our findings suggest that higher I–U–R alliance portfolio diversity increases firm innovation performance, implying that managers need to recognize the benefits of diverse partner types in I–U–R alliance portfolios. Therefore, firms should actively establish or participate in I–U–R collaborations and select different kinds of alliance partners, to offer a wider variety of knowledge and information that are essential to generate firm innovation performance. Besides, our results reveal that a firm's absorptive capacity positively moderates the impact of I–U–R alliance portfolio diversity on firm innovation performance. Hence, managers should strengthen the construction of a firm's absorptive capacity within firms. For example, managers can carefully select qualified employees, enhance the training of employee skills, and attempt to form good atmospheres of learning and cooperation within firms. For the new knowledge and information acquired from external partners, firms need to continuously assimilate, transform, and fully exploit their values to enhance absorptive capacity, and ultimately convert them into innovative outputs. Furthermore, this study also urges managers to actively seek government financial support. Our findings show that government financial support strengthens the relationship between I–U–R alliance portfolio diversity and a firm's innovation performance. Thus, managers should attempt to seek government financial support, especially for firms in emerging markets where governments offer various kinds of financial support.

5.3. Limitations and Further Research

This study also has several limitations, which provide some opportunities for future research. First, the research setting is limited to Chinese listed firms in the manufacturing industry, thus restricting the generalizability of our findings. Hence, future research could attempt to take into account settings with different industries or different countries. Second, constrained by secondary data, we can only use the proxy variable to measure absorptive capacity. Absorptive capacity is considered as a multidimensional construct including acquisition capacity, assimilation capacity, transformation capacity, and exploitation capacity [33], and there has been a commonly accepted scale including 21 items measuring the four dimensions [81]. Thus, future research could use this scale to measure absorptive capacity and investigate the role of each dimension of absorptive capacity in our research model. Finally, our study does not consider how firms manage I–U–R alliance portfolios. Previous research has indicated that alliance portfolio management mechanisms can explain performance heterogeneity among firms [82]. Therefore, future research on the I–U–R alliance portfolio could consider I–U–R alliance portfolio management.

6. Conclusions

Does I–U–R alliance portfolio diversity lead to a focal firm's innovation performance? This study aims to explore the association between I–U–R alliance portfolio diversity and firm innovation performance and the contingencies in this relationship. From the perspective of KBV, our results

suggest that I–U–R alliance portfolio diversity has a positive effect on firm innovation performance. In addition, the results reveal the importance of a firm's absorptive capacity in enhancing the positive impact of I–U–R alliance portfolio diversity on firm innovation performance. Finally, our findings indicate that government financial support plays an important role in the association between I–U–R alliance portfolio diversity and firm innovation performance, that is, the positive impact of I–U–R alliance portfolio diversity on a firm's innovation performance will increase with the increasing of government financial support.

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