

“Does public support moderate the relationship between firms’ external knowledge sourcing and innovation? Evidence from manufacturing firms in Thailand”

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DOES PUBLIC SUPPORT MODERATE THE RELATIONSHIP BETWEEN FIRMS' EXTERNAL KNOWLEDGE SOURCING AND INNOVATION? EVIDENCE FROM MANUFACTURING FIRMS IN THAILAND

Abstract

The primary objective of this study is to examine how public support moderates the effect of external knowledge sourcing on firms' innovation performance. It contributes to the literature on external knowledge acquisition, as the moderating effect of public support on external knowledge sourcing for innovation has rarely been investigated. This study uses postal survey data from 423 manufacturing firms in Thailand, collected between March and August 2021, with key respondents including senior managers and firm owners. The Negative Binomial Regression is used for data analysis, as the dependent variable – the number of registered intellectual property rights – is a count variable with a non-normal distribution. The key findings reveal that public support has a positive direct effect on firms' innovations. However, its interaction with external knowledge sourcing is negative to innovation performance. Thus, contrary to expectation, public support negatively moderates the relationship between external knowledge sourcing and innovation, suggesting that receiving more support weakens the effect of external knowledge sourcing on innovation performance. Moreover, public support does not positively moderate the inverted U-curve relationship between external knowledge sourcing and innovation by augmenting the optimal efficiency of firms' knowledge sourcing activities. Instead, firms that receive more support tend to achieve optimal efficiency in knowledge sourcing faster than those that receive less. Therefore, rather than complementing external knowledge sourcing, public support appears to serve as a substitute for it: receiving public support reduces firms' need to seek external knowledge to strengthen their innovative capabilities.

Keywords

public support, external knowledge sourcing, firm innovation, Thai manufacturing industry

JEL Classification

O31, O36, O38, H20

INTRODUCTION

In the contemporary business landscape, characterized by dynamic market demands and rapid technological advancement, firms are increasingly compelled to seek external knowledge to augment and extend their internal capabilities. This practice of external knowledge sourcing functions as a critical mechanism for developing new technologies and innovations in response to environmental dynamism (Chesbrough, 2003; West & Bogers, 2014). However, this strategy entails significant costs and risks. Consequently, excessive reliance on external sources can impair the effectiveness of the sourcing activity itself, ultimately diminishing its returns on innovativeness (Laursen &

Salter, 2006). This suggests that the relationship between external knowledge sourcing and innovation is not linear but rather follows an inverted U-shape: the effect is positive up to an optimal point, beyond which further sourcing yields negative returns (Berchicci, 2013).

Scholars have posited that public support mechanisms can serve a vital function in mitigating the private costs and risks inherent to external knowledge acquisition (Roh et al., 2021; Song et al., 2022). Furthermore, such support is instrumental in enhancing firms' human capital (Gyamfi et al., 2024), which is crucial for upgrading their absorptive capacity (i.e., ability to assimilate and utilize external knowledge) (Lund Vinding, 2006). This suggests that public support can enhance the efficiency of external knowledge sourcing (Ahn et al., 2020), thereby amplifying the positive effect of external knowledge on innovation outcomes and elevating the overall returns on knowledge-sourcing investments.

The existing literature has not sufficiently explored the role of public support within the framework of firms' external knowledge sourcing for innovation. A notable gap exists in empirical research on public support as a moderating factor that may alter the relationship between a firm's external knowledge acquisition and subsequent innovation performance. Consequently, the extent to which public support strengthens the effects of external knowledge sourcing and enhances the innovative returns on knowledge sourcing activities remains an unresolved empirical question.

1. LITERATURE REVIEW AND HYPOTHESES

1.1. External knowledge sourcing and innovation

In the Schumpeterian perspective, firms can remain innovative by investing considerable resources in R&D, thereby reaping the benefits of scale economies associated with R&D investment. From this perspective, firms are assumed to innovate in isolation as long as they have sufficient internal resources to invest in innovation activities, provided that the conditions of appropriability are strong (Cohen, 2010). However, as technologies have become more complex and technical changes have become more rapid, the innovation model based on a closed system of knowledge creation has become less relevant. The open innovation (OI) perspective challenges the conventional view of closed innovation management, criticizing it for not being suitable as an innovation management model in a highly dynamic market environment. The OI approach posits that firms can remain innovative by reconfiguring their innovation management practices toward an open system. It also argues that to benefit from open innovation, firms can (and should) acquire external

knowledge to complement their internal knowledge production capability or use external paths to commercialize their inventions (Bigliardi et al., 2021; Chesbrough, 2003).

External knowledge sourcing is claimed to be conducive to innovativeness in many ways. First, sourcing knowledge from various external sources extends a firm's knowledge base, thereby increasing the probability of knowledge recombination. As innovation is essentially achieved by recombining different knowledge components (Xiao et al., 2022), the more firms search for and acquire knowledge from diverse external sources, the greater the variety of new information that can be combined to generate new knowledge (Flor et al., 2018; Radicic, 2021).

Second, from the resource-based view (RBV), networking with various partners enables firms to access resources they do not readily possess, thereby allowing them to utilize resources obtained from partners as complementary resources to their own (Grimpe & Kaiser, 2010). Knowledge is a vital resource for innovation, so finding complementary knowledge resources is crucial to maintaining innovation. Firms that pursue an open innovation strategy and network with various external knowledge partners can find complementary knowledge resources to produce innovations (Caloghirou et al., 2004).

Third, when firms establish linkages with external knowledge sources and allow a continuous inflow of new information, they can avoid the risk of cognitive lock-in (i.e., the inability to discover or develop better solutions). The problem of cognitive lock-in is associated with the over-exploitation of existing knowledge and expertise without exploring new insights to extend the knowledge base. This lock-in will ultimately undermine firms' innovativeness (Piao & Zajac, 2016). External knowledge acquisition, particularly from diverse knowledge sources, is thus proposed as a strategy to prevent cognitive lock-in and maintain long-term innovativeness (Chiang & Hung, 2010).

On the other hand, sourcing knowledge from outside poses considerable challenges and costs that may hamper firms' innovation performance. Based on the transaction costs approach, knowledge linkages with external partners may increase the transaction costs in some ways. First, as information on some important attributes of knowledge partners is not always perfect, there is a high risk of adverse selection. Consequently, external knowledge linkages may lead to opportunism and knowledge leakages, thereby undermining the efficiency of knowledge-sourcing activities (Shi et al., 2019; Vivona et al., 2023). Second, coordination costs will increase as firms establish external linkages with various partners. Linkages with different knowledge partners require different governance structures and contractual arrangements. Ideally, firms should choose the appropriate governance structure that minimizes coordination costs, but this is not always the case. Depending on the size, structure, and diversity of knowledge networks, coordination costs may prevent firms from fully maximizing the benefits of external knowledge networking activities (Sampson, 2004). Additionally, as firms transition toward more open innovation, they may need to adjust their organizational structure and managerial practices to accommodate open innovation activities effectively. This action will increase firms' adjustment costs, thereby reducing the efficiency of external knowledge sourcing (Vivona et al., 2023).

Moreover, excessive external knowledge sourcing would lead to the exhaustion of firms' absorptive capacity, which encompasses the ability to identify the proper knowledge, acquire it, and integrate it into a firm's existing knowledge base, ultimately converting it into commercial value (Cohen &

Levinthal, 1990). Some empirical studies (Berchicci, 2013; Kobarg et al., 2019; Laursen & Salter, 2006; Shi et al., 2019) indicate that an insufficient absorptive capacity can lead to a negative impact of external knowledge sourcing on innovation. This is especially the case when firms source knowledge from distant knowledge domains that are not (or less) related to their existing knowledge base.

In summary, the existing literature suggests that external knowledge sourcing enhances innovation by facilitating the recombination of novel knowledge, providing access to complementary resources, and ensuring a continuous influx of new information. However, this relationship is tempered by the inherent risks, uncertainties, and transaction costs associated with external knowledge acquisition, as well as the significant resources it requires. Consequently, beyond a certain threshold, further external knowledge sourcing may have a detrimental effect on innovation outcomes. Thus, the relationship between external knowledge sourcing and innovation performance is not linear but instead follows an inverted U-shaped curve.

1.2. The moderating effect of public support

There are some reasons to expect that public support can foster firms' external knowledge linkages and innovation performance. First, based on the absorptive capacity perspective (Cohen & Levinthal, 1990), it can be argued that government support can augment firms' absorptive capacity, making their external knowledge sourcing more efficient. Generally, public support encompasses both financial and non-financial assistance, which is crucial for R&D investment and human capital enhancement, thereby strengthening firms' absorptive capacity. Financial assistance is commonly provided in the form of funding for corporate R&D projects, low-interest loans, and credit guarantees for innovation investments. In contrast, non-financial assistance is mainly provided through training and consultation services (Bloom et al., 2019; Cano-Kollmann et al., 2017; Gyamfi et al., 2024).

When firms receive financial subsidies for their R&D projects, they generally can invest more in R&D (González & Pazó, 2008; Szücs, 2020), there-

by enhancing their absorptive capacity (Griffith et al., 2003). According to Cohen and Levinthal (1990), R&D not only enables firms to innovate but also enables them to assess and acquire valuable knowledge, assimilate it, and apply it to generate commercial value. Firms with more R&D investment can generate more innovation from their external knowledge-sourcing activities (Cassiman & Veugelers, 2006; Clausen, 2013; Hagedoorn & Wang, 2012) and can delay the diminishing returns of external knowledge-sourcing, making firms' knowledge-sourcing activities more efficient (Berchicci, 2013; Grimpe & Kaiser, 2010). Moreover, non-financial assistance provided through training and consultation services can improve firms' human capital and absorptive capacity. Human capital, which is generally embedded in skilled workers, is a vital factor of absorptive capacity (Lund Vinding, 2006). Firms with a high share of human capital tend to have sufficient absorptive capacity to acquire and utilize external knowledge more efficiently (Lopez-Garcia & Montero, 2012). Nguyen et al. (2023) find that firms receiving public support for human capital upgrading are more likely to innovate.

Second, public support can enhance trust and reciprocal relationships between collaboration partners, thus reducing transaction costs and promoting strong knowledge networks where partners can benefit from knowledge flow (Okamuro & Nishimura, 2015). Based on the transaction cost approach, there are considerable risks in establishing knowledge linkages and sourcing insights from external entities. As information about knowledge partners is generally incomplete and asymmetrical, firms may choose unsuitable or opportunistic partners. In markets with imperfect information, the costs of searching for the right partners, monitoring them, and coordinating transactions can be too high, reducing the efficiency of external knowledge-sourcing activities (Vivona et al., 2023). Public support can help reduce transaction costs by establishing screening and matching processes to ensure the right counterparts, and by installing monitoring and coordination processes to reduce opportunistic behavior among the parties involved (Greco et al., 2017).

Greco et al. (2017) note that funding agencies generally require applicants to provide detailed documentation regarding partner attributes,

project plans, and coordination procedures, and tend to monitor the projects closely, thereby resulting in higher partner and coordination qualities and increasing the chance of project success. Okamuro and Nishimura (2015) find that public subsidies are essential in enhancing trust between research counterparts, leading to superior innovation performance of research collaboration partners. Levén et al. (2014) suggest that, through deliberate network design and orchestration, the government-sponsored network promotes strong partnerships, knowledge transfer, and innovation of local industries. Bianchi et al. (2019) demonstrate that public subsidies signal a quality attribute of subsidized firms and their resource potential, which can be leveraged to develop new technologies. Consequently, firms receiving subsidies are more likely than their non-subsidized counterparts to attract high-quality research partners.

Therefore, the literature suggests that public support enhances the effectiveness of firms' external knowledge sourcing for innovation. It does so by augmenting absorptive capacity, lowering the private cost of R&D, and reducing transaction costs inherent in knowledge exchange. This support exerts a dual moderating effect on the knowledge sourcing-innovation relationship: first, by directly strengthening the positive impact of external knowledge on innovation output; and second, by improving the efficiency of sourcing activities, thereby extending the tipping point of optimal efficiency, effectively shifting the inverted U-curve that describes the relationship between knowledge sourcing and innovation performance.

This study aims to address a gap in the existing literature regarding the impact of public support on corporate innovation (Jugend et al., 2020). It is done by conceptualizing public support as a moderating variable that influences the relationship between external knowledge sourcing and innovation performance. The analysis is guided by two primary objectives: first, to investigate whether public support strengthens the effect of external knowledge sourcing on innovation; and second, to analyze whether the influence of external knowledge sourcing on innovation follows an inverted U-shaped relation-

ship and, if so, to determine whether public support elevates the point of peak returns from the knowledge-sourcing activities.

Three hypotheses are formulated for empirical analysis as follows:

- H1: The relationship between external knowledge sourcing and innovation has an inverted U-curve pattern, suggesting a decreasing innovation return to the external knowledge sourcing scale.*
- H2: Public support positively moderates the relationship between external knowledge sourcing and innovation and strengthens the effect of knowledge sourcing on firms' innovation performance.*
- H3: Public support moderates the inverted U-curve relationship between external knowledge sourcing and innovation performance by extending the maximum efficiency point in such a relationship.*

2. METHODS

2.1. Data collection

This paper is based on a research project that assessed the effectiveness of 24 public support programs implemented by research-granting agencies under the Ministry of Higher Education, Science, Research, and Innovation (MHESRI), Thailand (Appendix A). These programs can be categorized into two groups based on their primary objective. The first group encompasses financial support programs, including R&D grants, low-interest loans, credit guarantees, and R&D tax deductions (No. 1-16). The other group focuses more on non-financial support, which can be provided through training, consultation, or information services (No. 17-24).

The primary objective of the project was to evaluate the effectiveness of these 24 programs in fostering the innovation performance of manufacturing firms. The findings are intended to provide Thailand Science, Research, and Innovation (TSRI), the public research budget allocation

agency under the MHESRI, with information to improve the Research, Development, and Innovation (RDI) support initiatives administered by MHESRI's granting agencies.

The data used for analysis were collected through the administered survey. Initially, a draft questionnaire was developed based on relevant literature and in consultation with executive members of the TSRI, the research fund allocation agency under MHESRI. Five technology and innovation management experts assessed the draft questionnaire on its validity and understandability, and it was revised according to their comments and suggestions. We utilized the manufacturing firm database provided by the Department of Industry Work (DIW), which was regularly updated and offered free access to necessary information, including names and postal addresses of firms, telephone numbers, and email addresses of contact persons. This database contained 73,000 firms registered with the DIW as of January 2021. From this database, 5,000 firms were randomly selected as a sample for the survey.

The survey was conducted in two rounds. The first round took place between March and May 2021, during which questionnaires were sent to all 5,000 firms. A cover letter was attached to each questionnaire, detailing the background, objectives, and necessity of the research. It respectfully requested the cooperation of the Chief Executive Officer (CEO), a senior executive, or the business owner to complete the questionnaire, ensuring the most comprehensive and accurate data. Furthermore, the letter provided assurances that the information would be used solely for academic research purposes and would not be exploited for any commercial gain. The confidentiality of all provided data was guaranteed, with a firm commitment that no company-specific information would be disclosed under any circumstances without prior explicit consent. These measures were implemented to assure respondents that all data shared among the research team would be securely protected against any unauthorized disclosure.

By May 2021, only 193 firms returned questionnaires with complete information. Due to the

low response rate in the first round, a second-round survey was conducted between June and August 2021, during which questionnaires with cover letters were sent to 2,000 firms that did not respond in the first round. In this round, telephone calls and emails were used to follow up on the matter. By the end of this round, an additional 230 questionnaires were returned by sample firms. Thus, the sample consists of 423 firms in total.

A non-response bias test was conducted using an independent *t*-test to compare first- and second-round respondents on age, number of employees, export share, and foreign investment share. We found no statistically significant differences in these characteristics, suggesting that non-response bias is not a serious issue in the data.

2.2. Variable construction

2.2.1. Dependent variable

The dependent variable in this study is firms' innovation performance, which is measured as the number of intellectual properties (IPR) owned by the sample firms. This information is derived from the following question: How many intellectual properties (patents, petty patents, trademarks, industrial designs, and copyrights) has your firm registered in the past three years? This information is advantageous for measuring innovation performance because it encompasses various types of innovations, including product, process, and market innovations. Additionally, it had a relatively high degree of novelty, as the newness and uniqueness of products and technologies are verified by the government agency, the Department of Intellectual Property (DIP).

Besides IPR, two other proxies are used to capture innovation performance. The first proxy is the number of new products firms have launched over the past three years (*NewProd*). The second one is the types of innovation firms have introduced (*InnoType*). This variable is measured on an ordinal scale from 0 to 2 (i.e., 0 = no innovation introduced, 1 = introduced either product or process innovation, and 2 = introduced both product and process innovation). These two proxies are used for supplementary analysis

as a robustness test. The distribution of innovation performance variables (*IPR*, *NewProd*, and *InnoType*) is shown in Table 1.

Table 1. Number of innovations introduced by sample firms in the last three years

Number of innovations	Frequency	Percent
Number of registered IPs		
0	356	84.16
1-5	53	12.53
6-10	7	1.65
11-50	4	0.95
More than 50	3	0.71
Number of new products		
0	248	58.63
1-5	121	28.61
6-10	23	5.44
11-50	27	6.38
More than 50	4	0.95
Innovation types introduced		
No innovation (0)	158	37.35
Product or process innovation (1)	133	31.44
Both product and process innovation (2)	132	31.21

Note: n = 423.

2.2.2. Independent variables

This study focuses on two key independent variables: external knowledge sourcing and public support. The first variable, external knowledge sourcing (*ExSource*), is based on Laursen and Salter's (2006) concept of knowledge search breadth (i.e., acquiring knowledge widely from numerous sources). *ExSource* is measured as the number of knowledge actors from which focal firms source information. In the survey, firms were asked to rate, from 0 (not at all) to 5 (highest), the extent to which they acquired knowledge from eight sources in the past three years, including competitors, suppliers, clients/customers, knowledge service providers, business/industrial associations, universities, public research organizations, and government agencies. The answers were coded as follows: 0 if firms obtained information from each source, and 1 otherwise. The variable *ExSource* is derived by summing the contributions from all eight sources. Thus, this variable is measured on a scale from 0 (not obtaining knowledge from any source) to 8 (obtaining knowledge from all sources). The square term of *ExSource* (*ExSourceSqr*) is also constructed to test for the inverted U-Curve relationship between external knowledge sourcing and innovation.

The second independent variable is public support (*PubSupport*), measured as the number of programs from which firms received support over the past five years (2016–2020). In the questionnaire, firms were given a list of 24 programs (Appendix A) and asked to indicate whether they received support from each program: 0 = if they did not receive it, and 1 = if they did receive it. Then, the variable *PubSupport* is derived by summing up these answers. Thus, this variable ranges from 0 (received no support from any program on the list) to 24 (received support from all 24 programs on the list). According to Falk (2007), measuring public support in this way can reduce the selection bias that often arises when the analysis focuses on a particular support program.

2.2.3. Control variable

The analysis includes six control variables (*SIZE*, *AGE*, *SKILL*, *R&D*, *HighTech*, and *BMR*) to control for their effects on firms' innovation performance. *SIZE* is measured as the natural logarithm of the number of workers. This variable is expected to positively affect innovation performance, as larger firms have more resources to devote to innovation (Chandy & Tellis, 2000). *AGE* is also measured as the logarithm of the years that firms have been operating (2021 – the year of establishment). The effect of age on innovation can be either positive or negative. On the one hand, older firms with more business experience may be better positioned to innovate (Withers et al., 2011). On the other hand, young firms may drive their competitiveness by launching innovations, as it is the best way to enter and compete for market share with incumbent firms (Huelgo & Jaumandreu, 2004). *SKILL* is measured as the share of workers with higher education in a firm, and it is used to capture the positive effect of human capital on innovation (Sun et al., 2020). *R&D* is the logarithm of firms' average annual R&D spending over the past three years. The positive effect of R&D on innovation is well-established in prior studies (Cohen & Levinthal, 1990); thus, we expect a similar positive effect of this variable accordingly.

HighTech and *BMR* are binary dummy variables. *HighTech* is assigned a value of 1 if a focal firm is in the high-tech sector (e.g., computer, electronics, automotive, medical devices); otherwise, it is

assigned a value of 0. This variable is expected to have a positive effect as high-tech firms tend to drive their competitiveness through innovations. *BMR* denotes the location of the focal firm in the Bangkok Metropolitan Region (BMR), known as Thailand's largest industrial agglomeration and economic center. This variable takes the value of 1 if the focal firm is located in the BMR and 0 otherwise. It is included to capture the effect of agglomeration economies that can positively affect innovation performance (Hervas-Oliver et al., 2018).

2.3. Analysis method

We test the hypotheses statistically based on the following regression models:

$$\begin{aligned} IPR_i = & \beta_0 + \beta_1 PubSupport_i + \beta_2 ExSource_i \\ & + \beta_3 ExSourceSqr_i + \beta_4 AGE_i \\ & + \beta_5 SIZE_i + \beta_6 SKILL_i + \beta_7 R \& D_i \\ & + \beta_8 HiTech_i + \beta_9 BMR_i + \varepsilon_i. \end{aligned} \quad (1)$$

$$\begin{aligned} IPR_i = & \beta_0 + \beta_1 PubSupport_i + \beta_2 ExSource_i \\ & + \beta' ExSource_i \cdot PubSupport_i \\ & + \beta_4 AGE_i + \beta_5 SIZE_i + \beta_6 SKILL_i + \beta_7 R \& D_i \\ & + \beta_8 HiTech_i + \beta_9 BMR_i + \varepsilon_i. \end{aligned} \quad (2)$$

$$\begin{aligned} IPR_i = & \beta_0 + \beta_1 PubSupport_i + \beta_2 ExSource_i \\ & + \beta_3 ExSourceSqr_i + \beta' ExSource_i \cdot PubSupport_i \\ & + \beta_4 AGE_i + \beta_5 SIZE_i + \beta_6 SKILL_i + \beta_7 R \& D_i \\ & + \beta_8 HiTech_i + \beta_9 BMR_i + \varepsilon_i. \end{aligned} \quad (3)$$

The first model tests Hypothesis 1. In this model, we are interested in the curvilinear relationship between external knowledge sourcing (*ExSource*) and innovation performance (*IPR*), controlling for the influence of other variables, including public support (*PubSupport*). If β_2 is positive and statistically significant, and β_3 is negative and statistically significant, then an inverted U-curve relationship exists between *ExSource* and *IPR*.

In the second model, the interaction term ($ExSource_i \cdot PubSupport_i$) is included. Restructuring the model algebraically produces the term $(\beta_2 + \beta_3 PubSupport_i) \cdot ExSource_i$. This term indicates that the effect of *ExSource* on *IPR* depends on the specific value of *PubSupport*. Thus, in this model, we

are interested in the coefficient of the interaction term (i.e., β_3). If β_3 is positive and significant, public support strengthens the relationship between external knowledge sourcing and innovation, thereby supporting Hypothesis 2.

Finally, in the third model, the interaction term $ExSource_i \cdot PubSupport_i$ is introduced, along with the linear and squared terms of external knowledge sourcing, to test whether a curvilinear relationship exists between external knowledge sourcing and innovation performance at different levels of public support. If Hypothesis 3 is to hold, we expect the interaction term coefficient (i.e., β'') to be positive and significant so that a turning point in the inverted U-curve relationship can be reached at a higher level of public support.

Note that variables *ExSource*, *ExSourceSqr*, and *PubSupport* are mean-centered to facilitate meaningful interpretation and reduce multicollinearity when introducing higher-order and interaction terms. As the dependent variable (*IPR*) is a count variable with many zeros, Negative Binomial Regression (NBR) is used to analyze the above three models. The NBR is suitable for analyzing data where the mean and variance of the dependent variable are unequal, which is often the case with count-dependent variables.

3. RESULTS

Table 2 presents the descriptive statistics and bivariate correlations between each pair of variables. Each pair of variables exhibits a low correlation ($r < 0.4$), suggesting no multicollinearity problem. Table 3 presents three model specifications, each of which tests the three hypotheses. The first thing to note is the diagnostic statistics for each model, which show that each model specification is reliable and has an acceptable fit. The Likelihood Ratio Chi-Square is statistically significant at $p < 0.01$, suggesting that the independent variables' coefficients are simultaneously not equal to zero. Hence, the set of independent variables is predictive of *IPR*. The Deviance and Pearson Chi-Square statistics, which measure the discrepancy between the predicted values and the observed data, are not significant, indicating that the models fit the data well.

In Model 1, the variable *ExSource* has a positive and significant coefficient ($p < 0.01$), while its square term (*ExSourceSqr*) has a negative and significant coefficient ($p < 0.01$). This result suggests that external knowledge sourcing can enhance a firm's innovation performance, but only up to a certain point. As firms increase their external knowledge-sourcing activity beyond that point, this activity becomes detrimental to innovation. In other words, this finding supports Hypothesis 1 and confirms the inverted U-curve relationship between external knowledge sourcing and innovation.

Model 2 and Model 3 aim to examine the moderation effect of public support on the relationship between external knowledge sourcing and innovation performance based on Hypothesis 2 and Hypothesis 3, respectively. Model 2 tests whether public support complements external knowledge sourcing in enhancing firms' innovativeness, while Model 3 investigates whether the inverted U-curve relationship between external knowledge sourcing and innovation is moderated by public support.

In Model 2, we remove the variable *ExSourceSqr* and add the interaction term (*PubSupport*·*ExSource*) to examine whether the effect of external knowledge sourcing on innovation performance is strengthened by the public support that firms receive. If Hypothesis 2 is supported, the coefficient of the interaction term must be positive and statistically significant. Contrary to our expectation, the coefficient of the interaction term is negative and statistically significant ($p < 0.05$). This finding contradicts Hypothesis 2. Instead of strengthening the relationship between external knowledge sourcing and innovation, as hypothesized, public support weakens that relationship. Note that the main effects of *PubSupport* and *ExSource* on *IPR* are positive and significant ($p < 0.05$), indicating that both public support and external knowledge sourcing are crucial for firms' innovations.

Model 3 includes both *ExSourceSqr* and *PubSupport*·*ExSource* to see whether public support positively moderates the inverted U-curve relationship between external knowledge sourcing and innovation performance. The result shows that the coefficient of *ExSourceSqr* is negative and significant (p

< 0.01), while the coefficient of *PubSupport-ExSource* is negative but only moderately significant ($p < 0.10$). This result suggests that, to some extent, public support negatively moderates the curvilinear effect of external knowledge sourcing on firms' innovation performance, which is contrary to Hypothesis 3. The result may suggest that an optimal point in the inverted U-curve relationship between external knowledge sourcing and innovation can be reached more quickly at a higher level of public support.

It is essential to note that the primary effect of public support is consistently positive and statistically significant in all models, as evidenced by the positive coefficients of *PubSupport* and its significance at an acceptable level. This result confirms that public support is crucial for firms' innovation. Firms receiving more support tend to innovate more. However, when interacting with *ExSource*, the effect becomes negative, suggesting the nega-

tive moderation of public support and indicating that support may be a substitute for external knowledge sourcing to stimulate firms' innovation.

To aid in the interpretation of the findings in Table 3, we plot the effect of external knowledge sourcing on innovation performance, conditional on public support, using the simple slope approach (Aiken & West, 1991; Dawson, 2014). This is achieved by evaluating the impact of external knowledge sourcing on innovations at varying levels of public support. To do this, we choose three values of *PubSupport*: minimum, mean, and one standard deviation above the mean. As *PubSupport* is a mean-centered variable, the mean value of this variable is zero, and the original value is approximately one (i.e., receiving support from one public program in the past five years). The minimum value refers to receiving zero (no) support at its original value, and one standard deviation above

Table 2. Descriptive statistics and bivariate correlations

	Variables	Mean	SD	1	2	3	4	5	6	7	8	9
1	IPR	1.480	13.394	1								
2	ExSource	0.000	2.957	.164**	1							
3	PubSupport	0.000	2.237	.106*	.151**	1						
4	AGE	2.823	0.925	.048	-.069	-.030	1					
5	SIZE	4.018	1.664	.297**	.185**	.071	.382**	1				
6	SKILL	0.286	0.264	.121*	.089	.206**	-.204**	-.121*	1			
7	R&D	3.919	6.537	.366**	.248**	.290**	.128**	.356**	.236**	1		
8	HiTech	0.080	0.272	-.063	-.059	.012	-.054	-.053	.004	.074	1	
9	BMR	0.641	0.480	.104*	-.077	-.032	.058	-.049	.155**	.064	.040	1

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

Table 3. NBR results

Variables	Model 1		Model 2		Model 3	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Intercept	-3.837***	0.406	-3.816***	0.404	-3.848***	0.407
PubSupport	0.078*	0.042	0.130**	0.054	0.149***	0.056
ExSource	0.840***	0.188	0.103**	0.043	0.840***	0.195
ExSourceSqr	-0.078***	0.019			-0.078***	0.019
PubSupport*ExSource			-0.050**	0.024	-0.048*	0.025
AGE	-0.063	0.123	0.003	0.122	-0.045	0.124
SIZE	0.591***	0.058	0.542***	0.056	0.586	0.058
SKILL	-0.791*	0.461	-0.401	0.446	-0.814*	0.465
R&D	0.067***	0.013	0.073***	0.013	0.068***	0.013
HighTech	0.307	0.353	0.330	0.353	0.318	0.355
BMR	1.002***	0.201	1.037***	0.201	0.994***	0.202
Likelihood Ratio Chi-Square (df)	497.890(9)***		483.077(9)***		501.375(10)***	
Deviance (Value/df)	1.494		1.529		1.489	
Pearson Chi-Square (Value/df)	7.689		9.076		7.536	
Observations	423		423		423	

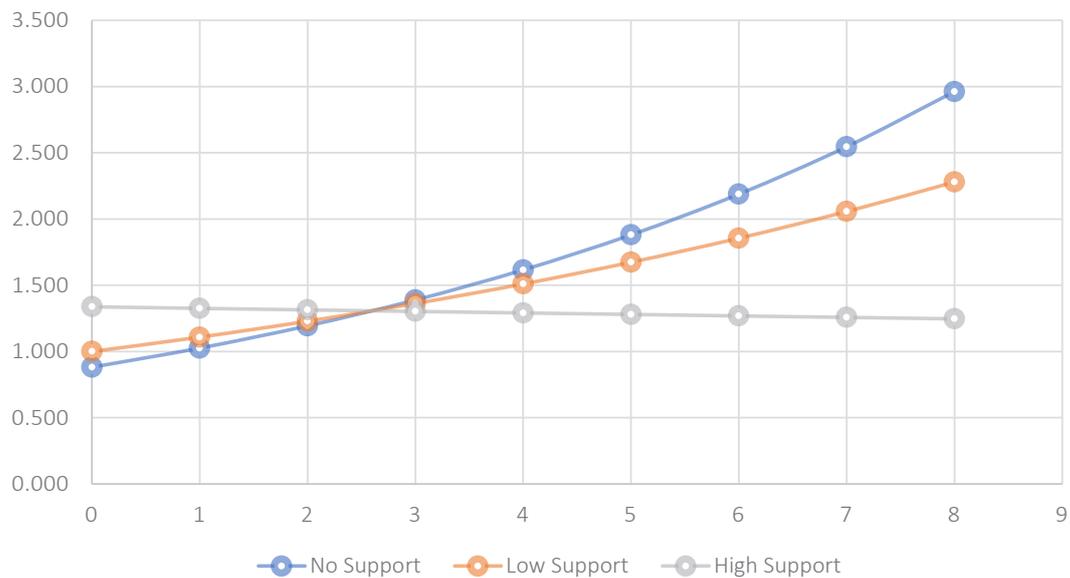
Note: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

the mean denotes receiving support from approximately three programs. Thus, we have three levels of public support: “No Support,” “Low Support,” and “High Support,” measured at the variable’s minimum value, mean, and one standard deviation above its mean, respectively.

Figure 1 illustrates the moderation effect across the three levels of public support, based on the results of Model 2. It demonstrates that the relationship between external knowledge sourcing and innovation performance is not always a positive

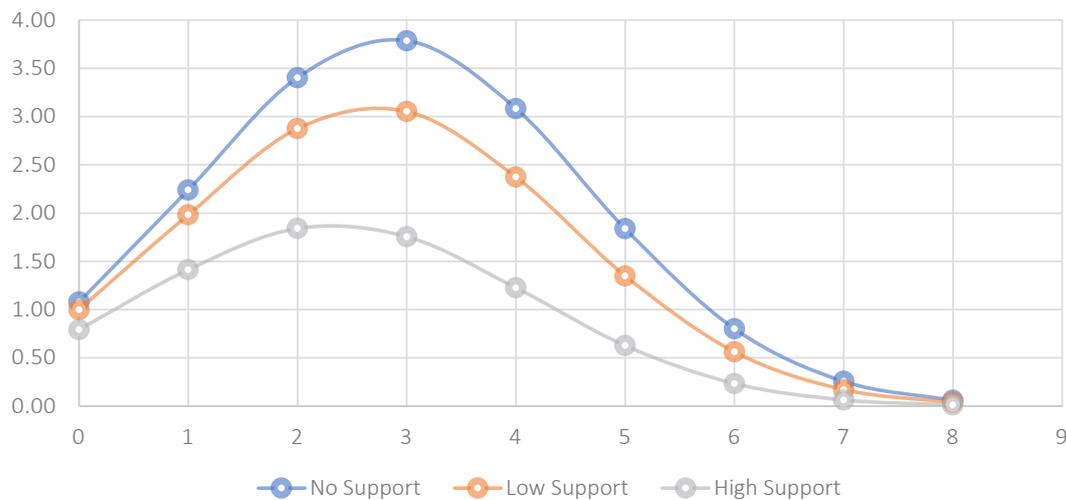
one. The relationship is highly positive when there is no support. However, as the level of support increases, the relationship becomes weaker. It suggests that public support can serve as a substitute for external knowledge sourcing. In other words, firms receiving less public support are more likely to source external knowledge to enhance their innovation performance.

Figure 2 shows that the inverted U-curve relationship holds across all levels of public support. However, a more substantial relationship exists



Note: The horizontal axis represents the number of external knowledge sources, and the vertical axis represents the expected number of registered IPs.

Figure 1. The moderating effect of public support for Model 2



Note: The horizontal axis represents the number of external knowledge sources, and the vertical axis represents the expected number of registered IPs.

Figure 2. The moderating effect of public support for Model 3

at the lower level of public support. At the high support level, the optimal point can be achieved at the lower level of external knowledge sourcing. As we move from high to low and no support, the optimal points are attained at the higher levels of knowledge sourcing. This happens because the coefficient of the interaction term in Model 3 (i.e., β_4) is negative. Overall, this graphical examination suggests that firms with less support can enhance their innovation performance by sourcing more external knowledge than firms receiving more public support. In other words, external knowledge sourcing and public support are substitutes for each other in the pursuit of optimal innovativeness.

We perform the robustness check for our findings in two ways. First, we use the count of firms' new products over the past three years as a dependent variable and re-estimate Models 1-3 using the NBR. Second, we convert the IPR variable into an ordinal variable with three values: 0 = no registered IPs over the past 3 years; 1 = a small number of registered IPs ($1 \leq \text{IPs} \leq 3$); and 2 = a large number of registered IPs ($\text{IPs} > 3$). Then, we estimate Models 1-3 using an ordinal regression (OR). The analysis result tables are not displayed here to save space, but are available upon request. Key findings are as follows.

- For the first model of both analyses, *ExSource* is positive and statistically significant ($p < 0.01$ in NBR and $p < 0.05$ in OR analyses). *ExSourceSqr* is negative and significant ($p < 0.05$) in OR analysis but not significant in NBR analysis.
- For the second model, the coefficient of the moderator variable (*PubSupport*) is positive and statistically significant ($p < 0.01$) in both NBR and OR analyses. The coefficient of the interaction variable (*PubSupport*ExSource*) is negative and significant ($p < 0.01$) in both analyses.
- For the third model, the NBR analysis reveals that *PubSupport* and *ExSource* are positive and significant (both at $p < 0.01$), *ExSourceSqr* is negative but not significant, and the interaction term is negative and significant ($p < 0.01$). The OR analysis shows that *PubSupport* is

positive and significant ($p < 0.01$), *ExSource* is positive and significant ($p < 0.05$), *ExSourceSqr* is negative and significant ($p < 0.10$), and the interaction variable is negative and significant ($p < 0.05$).

Overall, the robust test suggests that our main analysis results in Table 3 are robust to different measurements of dependent variables and statistical analysis approaches. Therefore, the findings can be summarized in relation to the hypotheses as follows:

- The analysis reveals a significant inverted U-shaped relationship between external knowledge sourcing and innovation performance, indicating that the marginal returns to sourcing diminish at higher levels. This finding supports Hypothesis 1.
- Public support was found to negatively moderate the relationship between external knowledge sourcing and innovation, thereby strengthening the overall effect of knowledge sourcing on innovation performance. Thus, Hypothesis 2 is rejected.
- The results indicate that public support does not shift the inflection point of the inverted U-curve to a higher level of external knowledge sourcing. Consequently, Hypothesis 3 is not supported.

4. DISCUSSION

The results offer some theoretical implications. First, based on the external knowledge search literature (Kobarg et al., 2019; Laursen & Salter, 2006), it is hypothesized that the effect of external knowledge sourcing on firms' innovation is subject to diminishing returns, exhibiting an inverted U-shape pattern. The analysis results support this hypothesis: sourcing knowledge externally is conducive to firms' innovativeness up to a certain point, and innovative outcomes diminish beyond that point. As external knowledge sourcing in this study is measured in terms of search breadth, the result is consistent with Laursen and Salter (2006), Ardito and Petruzzelli (2017), Kobarg et al. (2019), and Radicic (2021), who also find the curvilinear

ear effect of search breadth, taking the inverted U-shape pattern. This is commonly referred to as the over-search effect (Laursen & Salter, 2006) and is likely to occur when the external knowledge-sourcing costs outweigh its benefits.

Though benefits from external knowledge sourcing arise in terms of resource complementarity (Caloghirou et al., 2004; Grimpe & Kaiser, 2010), information variety (Abdul Basit & Medase, 2019; Rodriguez et al., 2017), and reduced risk of technological lock-in (Choi et al., 2018; Stucki & Woerter, 2022), it can induce considerable coordination and managerial costs if firms source knowledge widely from multiple actors. Based on transaction cost economics, it can be argued that external knowledge sourcing is subject to asymmetric information, as firms cannot thoroughly monitor all partners' real intentions and behaviors. This may lead to selecting the wrong partners, posing a high risk of opportunism and knowledge leakage. Too many knowledge partners may increase managerial and coordination costs, making external knowledge-sourcing activities less efficient (Vivona et al., 2023). Additionally, according to the absorptive capacity perspective, benefits from external knowledge sourcing will be augmented if firms have sufficient absorptive capacity to acquire and utilize external ideas (Cohen & Levinthal, 1990). When firms extend their search activities beyond their absorptive capacity, this capacity will be exhausted, leading to diminishing returns on the search (Berchicci, 2013; Kobarg et al., 2019; Shi et al., 2019). Thus, the first finding of this study is consistent with the inverted U-curve relationship between external knowledge search and innovation performance, confirming the existence of the over-search effect (Laursen & Salter, 2006).

Second, this study makes an original contribution by examining the linear moderation effect of public support on the relationship between external knowledge sourcing and innovation performance, a less-explored aspect in the extant literature. Although the relationship between external knowledge sourcing and firms' innovation performance has been extensively examined, the role of public support in moderating this relationship is less well understood. Open innovation has been adopted to enhance interactive learning in the innovation systems in many countries. Accordingly, many public

support schemes have been directed toward promoting knowledge linkages to enhance corporate innovative capabilities (Greco et al., 2017; Jugend et al., 2020). It is thus interesting to examine the extent to which public support strengthens the relationship between firms' external knowledge linkages and innovation performance.

Contrary to Hypothesis 2, this study finds a negative rather than a positive moderation effect. To interpret this result, we draw on the literature that suggests internal knowledge-generating capabilities can substitute for external knowledge sourcing to enhance innovation performance (Dikova, 2015; Hess & Rothaermel, 2011; Laursen & Salter, 2006). Accordingly, when firms' internal knowledge-generating capabilities increase (e.g., firms invest more in R&D), it reduces the need to source external knowledge to enhance innovation. Thus, a negative moderation effect suggests that public support may increase firms' internal knowledge-generating capabilities. As shown in Table 3, the bivariate correlation between public support and firms' R&D investment is positively correlated and statistically significant ($r = 0.290, p < 0.01$). It is likely that when firms receive public support, they can invest more in R&D to produce innovation, reducing the necessity to source knowledge from outside. Moreover, public support may enhance firms' human capital, enabling them to generate knowledge in-house efficiently. As found in some studies, firms that receive non-financial support, such as training and consultation services, tend to be more innovative than those that do not (Chundakkadan & Sasidharan, 2020; Nguyen et al., 2023). In this case, they may substitute their external knowledge sourcing with internal knowledge production to improve their innovativeness.

Finally, this study extends scholarly efforts to identify the moderating factor that determines the curvilinear relationship between external knowledge sourcing and firms' innovations. While many empirical studies have shown that external knowledge sourcing is associated with decreasing innovation returns (Kobarg et al., 2019; Laursen & Salter, 2006; Shi et al., 2019), there is limited understanding of the factors that may moderate this relationship. Although some studies show that firms' internal research capabilities (Berchicci, 2013) and effective human resource management

(Ardito & Petruzzelli, 2017) significantly moderate the relationship, no study has examined the moderating role of public support. This study proposes that receiving public support may enhance firms' knowledge resources and absorptive capacity, thereby increasing the efficiency of external knowledge sourcing. Thus, the original contribution is to empirically test whether public support moderates the inverted U-curve relationship between firms' external knowledge sourcing and innovation performance by delaying the decreasing return of knowledge sourcing.

The results show that public support does not positively moderate the U-shaped relationship between external knowledge sourcing and firms' innovation performance in a manner that extends the optimal efficiency point in this relationship. As shown in Figure 2, the relationship between external knowledge sourcing and firm innovation is stronger for firms that receive no support and weaker for firms that receive more support. Although the U-shaped relationship is generally observed, regardless of the degree of support received, firms without support tend to reach optimal efficiency when sourcing knowledge from a larger number of actors than those that receive support. This result suggests that public support tends to substitute for external knowledge sourcing in firms' innovation processes. In this case, firms tend to utilize public support to enhance their innovative capabilities, reducing the need to source knowledge from outside.

This finding extends the literature, highlighting the positive moderating role of firms' absorptive capacity in external knowledge sourcing for innovation. Many studies suggest that absorptive capacity increases the efficiency of external knowledge sourcing, making firms' knowledge interactions with various knowledge actors more effective in strengthening innovation perfor-

mance (Berchicci, 2013; Cassiman & Veugelers, 2006; Clausen, 2013; Grimpe & Kaiser, 2010; Hagedoorn & Wang, 2012). However, as this study finds, it is possible that when firms receive public support, their internal knowledge-generation capability may increase, making it less necessary to source outside knowledge to produce innovations. Moreover, this finding informs the external knowledge sourcing and open innovation literature that public support may serve as an alternative source of firms' innovation improvement. Interactions with government agencies, particularly those offering financial and non-financial support, can also stimulate firms' innovative activities. However, studies on the effects of firms' interactions with public R&D agencies on innovation are still limited. Therefore, further studies on this issue are necessary.

The policy implication that can be drawn from the findings of this study is that public support can be used to foster firms' innovation performance. However, it may not be conducive to strengthening firms' external knowledge sourcing for innovation. Public funding agencies, particularly in Thailand, may sometimes require firms to network with knowledge organizations (e.g., universities, public research organizations, and knowledge-intensive service providers) as a condition of receiving RDI support. However, this condition may not be sufficient to ensure that knowledge networking will translate into superior innovation performance. For networking to be crucial for firms' innovation, it is necessary that firms find the right knowledge partners and form trust-based relationships with them in order to increase the effectiveness and efficiency of knowledge transfer. In this sense, public funding agencies should act as intermediaries to establish knowledge networks and coordinate and monitor relationships among actors to ensure that knowledge networking is meaningful for innovative performance.

CONCLUSION

This study aims to investigate how public support moderates the link between external knowledge acquisition and firm innovation. While sourcing external knowledge is vital for innovation, its efficiency can be hindered by risks, uncertainties, and constraints in firms' resources and competencies. The findings suggest that public support mitigates these challenges, thereby improving the efficiency of external knowledge sourcing.

Firms have been increasingly acquiring knowledge from external organizations to improve their innovativeness. However, external knowledge acquisition is costly and requires considerable resources and capabilities. Firms, especially those in developing economies, face resource and capacity constraints. In this sense, government agencies may play a complementary role in providing RDI support to increase the resources and capacities of firms, enabling them to source external knowledge more efficiently. The existing literature has not sufficiently examined this issue. Our study contributes to the existing literature by examining the moderating role of public support on firms' external knowledge sourcing for innovations.

The first finding in this study reveals an inverted U-shaped relationship between external knowledge sourcing and firm innovation. This finding confirms that external information sourcing is costly, and the optimal efficiency of sourcing can be attained at a certain level. If firms continue to source beyond that level, it may adversely affect their innovation performance. Additionally, the analysis of the moderation effect of public support on the relationship between external knowledge sourcing and innovation reveals that public support acts as a substitute for external knowledge sourcing, thereby moderating the relationship negatively. For firms receiving more support, the effect of external knowledge sourcing on their innovation performance is less pronounced than for those receiving less support. Due to this negative moderating effect, firms that receive more support tend to achieve optimal efficiency in external knowledge search more quickly than those that receive less support.

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APPENDIX A

Table A1. RDI programs covered by the current study

Program Titles
1. Financial Support for Innovation Networking
2. From Technology to Capital
3. Technical Research Grant
4. Zero Loan Interest for Potential Innovations
5. Innovation Coupon
6. Startup Voucher
7. Hi-Tech Startup Joint Venturing Program
8. Low-Interest Loan for Technology Development
9. Research Gap Fund (Grant for commercializing new technologies)
10. Innovation Technology Assistance Program (ITAP)
11. Talent Mobility (Secondment of university researchers to firms)
12. The Ten Targeted Industries Research Grant
13. Research and Researchers for Industry
14. 300% Tax Deduction for R&D Investment
15. Startup and Innovative Business Credit Guarantee
16. OTOU Coupon (Grant for S&T development of local products)
17. IPR Licensing Support
18. Science Park Services
19. Tech-business Incubation Services
20. Thai Innovation Listing (for public procurement)
21. Thai Invention Listing (for standardization)
22. IPR Consultation Services
23. SME StandardUP (Technological upgrading of SMEs' production system)
24. Thailand Trust Mark (Branding of Thai innovative products)