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Linking open innovation, innovation barriers and performance of Indonesian firms

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Abstract

Purpose – This study aims to examine open innovation that consists a wide range of external knowledge search activities, such external search breadth and depth, external R&D, cooperation and acquisition activities, as a response to different innovation barriers faced by Indonesian firms.

Design/methodology/approach – Data are derived from Indonesia innovation survey. Exploratory factor analysis is used to identify and combine innovation barriers variables. Ordered logistic estimation is used to measure the impact of innovation barriers on firm openness decision. Logistic regression is used to measure the impact of innovation barriers on firm openness indicators such as external R&D, cooperation and acquisition as the variables are binary. Finally, Tobit regression is used to measure the impact of firm openness decision on innovation performance.

Findings – The main findings indicate that different barriers to innovation lead to different firms' openness decisions, and different decisions on openness have differentiated influence on innovation performance.

Originality/value – This study contributes to the innovation barrier literature by empirically testing whether experiencing barriers to innovation is associated with a broader external knowledge search activity. Previous studies tend to link innovation barriers with a narrow activity as indicated by external knowledge searching widely and deeply.

Keywords Open innovation, Innovation performance, Indonesian firms, Innovation barriers

Paper type Research paper

1. Introduction

A firm's openness has become a prominent issue in both theory and practices over the past decades, especially after the concept of open innovation (OI) was coined by Chesbrough (2003). Firms become more open and permeable to their external environment for several reasons. Many firms lack the adequate resources and capabilities to deal with market and technological uncertainty of innovation, the rising cost of internal R&D and risks and shorter product life cycles, as consequently, a large majority of firms can hardly address those challenges by relying solely on their resources and capabilities (Chesbrough, 2006). In the context of developing countries, issues related to innovation barriers are more relevant, as firms naturally face substantial barriers innovation related to institutional, resources and capabilities (Fu *et al.*, 2014). Hence, firms in developing countries have been found not to

perform R&D (Goñi and Maloney, 2014), unable to catch-up with developed countries (Gorodnichenko and Schnitzer, 2013), to pursue different innovation strategies (Gault, 2010), have underdeveloped absorptive capacity than their counterparts in developed countries (Bilgili *et al.*, 2016), and as a result, to engage with greater breadth and depth of external knowledge to overcome innovation barriers (Fu *et al.*, 2014).

Any factors that impede, delay or completely block innovation can be seen as innovation barriers (Mirow *et al.*, 2008). The terms barriers, hurdles, impediments and obstacles can be used interchangeably (Hueske and Guenther, 2015). It is argued that a better understanding of innovation barriers can help firms to create the development of an environment that supports innovation (Hadjimanolis, 1999). The 3rd edition of *Oslo Manual* (OECD and EUROSTAT, 2005) that used by many developed countries (e.g. European countries) as guidelines for collecting and interpreting innovation data, divided any factors that hamper innovation activities into cost factors, knowledge factors, market factors, institutional factors and other reasons for not innovating. Such different factors exist and influence the success of innovation since the nature of innovation process is "complex, uncertain, somewhat disorderly, and subject to changes of many shorts" (Kline and Rosenberg, 2010, p. 275).

Although a substantial number of studies on innovation barrier have been conducted, the studies tend to focus on financial factors that hinder innovation activities (Altomonte *et al.*, 2016; Canepa and Stoneman, 2002, 2008; Crisóstomo *et al.*, 2011; Efthyvoulou and Vahter, 2016; Hall *et al.*, 2016; Lööf and Nabavi, 2016; Mohnen *et al.*, 2008a, 2008b; Savignac, 2008; Silva and Carreira, 2012; Ughetto, 2009) and perception of innovation barriers (Baldwin and Lin, 2002; D'Este *et al.*, 2008, 2012; Demirbas *et al.*, 2011; Frenkel, 2003; Galia *et al.*, 2012; Hölzl and Janger, 2013, 2014; Iammarino *et al.*, 2007; Segarra-Blasco *et al.*, 2008; Shiang and Nagaraj, 2011; Tourigny and Le, 2004; Xie *et al.*, 2010). Issues related to financial constraints include the importance between financial and non-financial constraints; comparison financial constraints across firms' size, sectors, technology intensity, export orientation, as well as the influence of financial constraints on not starting, being delayed or postponed projects. The issues studied in the perceived innovation barriers include the comparison between innovative and non-innovative firms; between users and non-users of technology; between small and large firms; and among firms in European countries.

This study intends to directly link innovation barriers with firms' openness decision that has hitherto received little attention in the academic literature. In previous studies, which employed data from innovation survey [e.g. community innovation survey, also known as community innovation survey (CIS)], innovation barriers tend to be linked with narrow firm's openness indicators and focuses exclusively on the inbound perspective of OI, i.e. the external search for information and cooperation to innovate internally. More precisely, those indicators encompass external search breadth and depth based on Laursen and Salter's (2006) framework (Fu *et al.*, 2014; Garriga *et al.*, 2013; Keupp and Gassmann, 2009), cooperation activities (Antonioli *et al.*, 2017) and breadth of cooperation activities with local and foreign partners (Drechsler and Natter, 2012). Hence, this paper intends to extend these studies by linking innovation barriers with a broader firm openness decision (beyond external search breadth and depth) using innovation data derived from a developing country, i.e. Indonesia Innovation Survey 2014 (IIS 2014).

Firm openness decision can be based on different activities that are operationalised differently by different authors (Barge-Gil, 2010). A broad definition of openness is proposed by Chesbrough (Chesbrough, 2003), it emphasises that valuable ideas emerge and can be commercialised from inside and outside the firm. This is the most commonly used definition in the literature (Dahlander and Gann, 2010). Other scholars identified three cores OI

processes such as the outside-in process, the inside-out process and the coupled process (Gassmann and Enkel, 2004). While others identified three strategic characteristics of OI such as opportunity-seeking prospector, dual-oriented analyser and market segment securing defender (Bader and Enkel, 2014). Openness studies using innovation surveys data tended to use the inbound breadth and depth framework developed by Laursen and Salter (2006). Based on a bibliographic analysis of previous openness studies, the outside-in process can consist of firms' sourcing and acquiring activities (Dahlander and Gann, 2010). Other scholars, Drechsler and Natter (2012) propose the degree of openness based on a firm's external domestic and foreign collaboration partners. Other scholars use three ways for firms to be open such as information transfer from informal the network, R&D collaboration and technology acquisition (Kang and Kang, 2009). While, Huang and Rice (2009) argue that openness can include acquisitions; the purchase of technology rights through licensing; the contracting out of internal R&D to external agents, other firms or research institutions; and the use of formal and informal inter-organizational networks. Hence, this study employs firm openness decision that differs from previous CIS-based innovation barrier studies, that encompass external search breadth and depth, external R&D, cooperation and acquisition (machinery, equipment and software). External R&D, cooperation and acquisition activities imply that firms' partners share their resources and knowledge.

This study intends to answer whether firms that face different barriers to innovation are more likely to open up their innovation process, as can be reflected from external search breadth and depth, external R&D, cooperation and acquisition activities. Subsequently, this study intends to measure the impact of firm openness decision on innovation performance. It is expected that this research contributes to two key issues in the innovation literature. First, this study employs a broader firm openness decision than previous CIS-based innovation barrier studies. Therefore, this study looks at whether a broader firm openness might be a viable strategy to cope with different barriers to innovation. Second, this study examines the impact of a broader firm openness decision on innovation performance, while previous CIS-based studies tended to focus on the impact of external search breadth and depth on innovation performance.

2. Literature review and hypotheses development
2.1 Common barriers to innovation
The first common factor that hinders innovation activities that have been studied extensively in the financial factor. Most research was conducted in developed countries empirical setting, for examples, across European countries (Altomonte et al., 2016; Canepa and Stoneman, 2002; Efthyvoulou and Vahter, 2016; Hall et al., 2016), in the UK (Canepa and Stoneman, 2008), in Spain (González et al., 2005), in Sweden (Lööf and Nabavi, 2016), in Netherland (Mohnen et al., 2008a, 2008b), in France (Savignac, 2008), in Portugal (Silva and Carreira, 2012) and in Italy (Ughetto, 2009). In contrast, there are a few studies that focus on financial factors as barriers to innovation in developing countries, for instance, a study conducted by Crisóstomo et al. (2011).

Based on data used in the financial barriers studies, it can be divided into CIS-based innovation barriers studies (Canepa and Stoneman, 2002, 2008; Efthyvoulou and Vahter, 2016; Mohnen et al., 2008a, 2008b; Savignac, 2006) and non-CIS-based innovation barrier studies (Altomonte et al., 2016; Crisóstomo et al., 2011; González et al., 2005; Hall et al., 2016; Lööf and Nabavi, 2016; Savignac, 2008; Ughetto, 2009). CIS-based innovation barriers studies provide a different insight into how financial factors affect innovation. Financial factors, especially lack of the appropriate source of finance found to be the most important barrier than other factors that affect innovation projects to be delayed, abandoned, or even

not started (Canepa and Stoneman, 2002; Mohnen *et al.*, 2008a, 2008b). Financial factors also severely impact innovative activity, especially in high technology sectors and smaller firms (Canepa and Stoneman, 2008). Furthermore, it affects the innovation performance in the production sector stronger than in the service sector (Efthyvoulou and Vahter, 2016). Using data similar to French CIS, Savignac (2006) reveals that innovative firms without financial constraints have a better profile in economic performance, financing structure and risk than non-innovative firms. Besides, firms having innovative projects that face financial constraints tend to reduce the implementation of innovative investments (Savignac, 2006). Based on Portuguese CIS data, (Silva and Carreira, 2012) found that financial constraints hinder investment in R&D and innovation, but subsidy as part of public financial support did not help to overcome such constraints.

Different impacts caused by financial factors on innovation activities also can be found in previous non-CIS studies. For instance, a mutual relationship exists among exporting, productivity and financial constraint. For example, exporters and high productivity firms are less likely to be credit constrained and better access to credit is associated with firms with larger productivity and a higher probability of exporting (Altomonte *et al.*, 2016). Altomonte *et al.* (2016) concluded that financial constraints have an indirect effect on innovation by reducing incentives to innovate, rather than by reducing the ability to innovate. In the case of firms in an emerging country, the study shows that although recent institutional framework changes and market advances started since the 1990s, Brazilian firms face financial constraints when they implement innovation projects (Crisóstomo *et al.*, 2011). A positive impact of financial incentive in the form of subsidies on R&D activities also has been found. For example, subsidies stimulate R&D and some firms would stop performing R&D in the absence of subsidies (González *et al.*, 2005). In the case of exporters, high technology innovative firms tend to exploit internal cash resources if they face financial shock, while there is no relationship between financial factors and innovation in medium and low technology exporters (Lööf and Nabavi, 2016).

The second main strand of innovation barriers literature is related to the perception of innovation barriers. The literature is dominated by CIS-based studies in developed economies context except for Shiang and Nagaraj's (Shiang and Nagaraj, 2011) study. An interesting finding from these studies is that barriers to innovation in innovation survey should be considered as indicating how successfully a firm can overcome barriers (Baldwin and Lin, 2002; Tourigny and Le, 2004). Clausen (Clausen, 2008) suggested that instead of obstacles variables, the real obstacles are the obstacles perceived by the managers. Hence, innovative firms are more inclined to perceive obstacles and as a result, the perception of obstacles would be positively linked with the propensity to innovate. In relation to that, D'Este *et al.* (2012) argue that we need to differentiate between deterring barriers to innovation that deter firms from engaging in innovation activities and revealed barriers that are experienced by firms as they are performing innovation activities.

Another issue of the perception of innovation barriers discussion is what are the most important barriers commonly faced by firms. In this case, previous studies consolidate a list of obstacles from innovation survey into fewer groups of obstacles. The four sets of innovation barriers that are identified and usually studied are cost factors, knowledge factors, market factors and regulation factors (Galia *et al.*, 2012). Examples of innovation barriers groups from the previous studies are as follows. Baldwin and Lin (2002) grouped innovation barriers related to cost, institution, labour, organisation and information. A slightly different group of obstacles also can be found in D'Este *et al.* (2012) study such as cost, knowledge, market and regulation. Using principal component analysis (PCA), Galia and Legros (2004) distinguish groups of obstacles faced by firms that postponed and

abandoned innovative projects. In the former project, obstacles consist of three groups such as rigidities and information; risk, cost and source of finance; and customer response and skilled personnel. While, in the later project, obstacles can be grouped into organisational rigidities; risk and skilled personnel; and cost, finance, institution and market. A fewer group of innovation barriers can be found in the study using Spanish CIS such as the cost of innovation, lack of knowledge and market characteristics (Segarra-Blasco et al., 2008).

In the context of Indonesia, using data derived from IIS 2011, Hartono and Kusumawardhani (2019) explore the nature and importance of innovation constraints faced by manufacturing firms and its impact on innovation performance was examined. The study groups innovation constraints into "market and institution", "employee and organisation attitude", "finance and risk" and "knowledge and cooperation". Factors related to financial and risk are perceived to be the most important constraints. The study shows that different innovation barriers influence types of innovation and innovation performance differently. As the IIS 2011 only surveyed Indonesian manufacturing firms, insights on how non-manufacturing firms experiencing innovation barriers do not exist. The IIS 2014 data used in this study covers seven industry sectors, including both manufacturing and services firms, extends that body of knowledge by providing insights covering a wider context.

2.2 Innovation barriers and firms' openness relationship

In the context of a developing country, Fu et al. (2014) use push and pull framework to group barriers innovation into institutional, financial and knowledge/skill and subsequently link the barriers with breadth and depth of OI performed by Chinese manufacturing firms. They found that the three groups of obstacles are significantly associated with the firms' breadth and depth of openness in innovation. This suggests that the Chinese firms facing to a higher extent three groups of barriers are more likely to engage with OI in greater breadth and depth to mitigate the barriers. Furthermore, the firms' openness varies across different firms' ownership, size and technology intensity. Finally, Fu et al. (2014) suggest that future studies that link innovation barriers and firm openness should beyond inbound or outside-in process as the indicator of firm openness.

Using the exploration–exploitation framework, Keupp and Gassmann (2009) examine the impact of information- and capability-related constraints and risk-related constraints on firms' openness based on Swiss CIS data. They found that the two types of constraints positively and significantly influence the breadth and depth of OI. This suggests that firms face greater the two constraints are more likely to use external knowledge broader and deeper. Using similar CIS, i.e. Swiss CIS, Garriga et al. (2013) linking constraints on resources to firms' openness i.e. breadth and depth of OI. It turned out that such constraints have a different direction of impact on the firms' openness. The constraints positively influence the breadth of OI, by contrast, the constraints have a negative impact on the depth of OI. This indicates that the firms are more likely to engage in wider external knowledge search and are less likely to engage in deeper external knowledge search to overcome constraints related to firms' resources.

Using French CIS, Antonioli et al. (2017) conducted a recent study the impact of obstacles related to cost, market and knowledge on the firms' probability to cooperate with any partners and specific partners such as firms and research organisation. The study shows that financial constraint is a robust and significant driver of cooperation, both in general and across different partners. Firms experiencing financial constraints tend to cooperate with research organisations. Furthermore, interaction among the three barriers to innovation and its impact on cooperation activities are also tested. One of the most consistent findings is that the combination of cost and knowledge barriers significantly decrease the propensity to

engage in cooperation activities. Based on the German CIS, scarce firm resources that consist of financial and knowledge gaps are also linked to the degree of firms' openness in innovation that is measured by the breadth of firms' involvement in cooperation activities with local and foreign partners (Drechsler and Natter, 2012). The finding shows that scarce financial resources drive firms to increase their openness.

Based on the previous studies review, the following hypothesis related to the impact of innovation barriers on a broader firm openness can be drawn:

H1. Firms experiencing greater innovation barriers are more likely to adopt greater openness of innovation that can be reflected from external search breadth and depth, external R&D, cooperation and acquisition activities.

2.3 Impact of firms' openness on innovation performance

Studies on the relationship between innovation barriers and firms' openness tend to treat innovation barriers as determinants of OI and do not link firm openness to innovation performance (Drechsler and Natter, 2012; Fu *et al.*, 2014; Keupp and Gassmann, 2009). Laursen and Salter (2006), pioneering a study to examine the impact of firm openness, as indicated by external search breadth and depth, on innovation performance using a large scale data derived from UK innovation survey. The study found that breadth and depth positively affect innovation performance, however, over searching on external knowledge tend to diminish the return of innovation performance. Following Laursen and Salter (2006), several CIS-based OI studies have been conducted; however, the studies tend to be conducted in developed economies context. Evidence from OI studies in developing economies are rather scarce and research methods used limited to qualitative because data collection is rather complicated (Podmetina *et al.*, 2014).

Studies on firm openness and innovation performance relationship in both developing and developed economies tend to support Laursen and Salter's (2006) work. An OI study using data from IIS 2011 found that firm openness, that is measured by external search breadth and depth, positively influence innovation performance of Indonesian manufacturing firms (Hartono and Kusumawardhani, 2018). However, decreasing returns in over searching on external search breadth and depth also can be found among Indonesian manufacturing firms. A survey on how innovative performance is affected by the breadth, depth and orientation of firms' external search strategies among Chinese firms has been conducted (Chen *et al.*, 2011). The study found that the greater breadth and depth improve innovation performance, however, decreasing returns of innovation performance are not always present and are contingent on the innovation modes. Another study based on Indian firms shows that "inbound open innovation is crucial in helping firms to catch-up and move toward the technological frontier" (Kafouros and Forsans, 2012, p. 362). CIS-based OI studies using various innovation surveys in different developed countries (Ahn *et al.*, 2014; Battisti *et al.*, 2015; Ebersberger *et al.*, 2012; Laursen *et al.*, 2007; Salge *et al.*, 2012) also reveal a significant and positive relationship between firms' openness and innovation performance.

Hence, the following hypothesis related to firms' openness and innovation performance (measured by the share of product innovation new to the markets and the firms) relationship can be proposed:

H2. Firm openness as indicated by external search breadth and depth, external R&D, cooperation and acquisition are positively affecting sales' proportion of product innovation new to the market and the firms.

3. Research methodology

3.1 Data

Data used in this study is collected and managed by Centre for Science and Technology Development Studies (PAPPIPTEK), Indonesian Science Institute (LIPI). Data were drawn from the IIS 2014, and multi-stage random sampling is used; a total of usable 927 questionnaires were successfully collected. The IIS 2014 covered innovation activities performed by Indonesian firms during 2011 – 2013. The surveyed firms are classified based on the International Standard Industrial Classification (ISIC) Rev. 3.1. Both manufacturing and services firms were surveyed in the IIS 2014. Table 1 presents classification of the surveyed firms based on the ISIC Rev. 3.1. codes.

The IIS 2014 used the *Oslo Manual* (OECD and EUROSTAT, 2005) as the guideline for collecting and interpreting innovation data. For the analysis purpose, the sample comprises only innovative firms, that is firms producing any product, process, organisational and marketing innovation and expend non-zero or positive innovation activities expenditure during 2011–2013 period. From the IIS 2014 data set of 927 Indonesian firms, a sample of 535 innovative manufacturing and services firms was finally retained.

A firm size indicator is based on the number of employees, i.e. small (5–19 employees), medium (20–99 employees) and large (more than 100 employees) firms. Of 535 firms, small firms outnumbered the proportion (55.33%), then followed by medium (32.52%) and large (12.15%) firms. In terms of firm ownership, the proportion of national firms is highly dominated, i.e. around 91%. While the rest of them accounted for small proportion i.e. multi-national firms (2.80%) and joint venture (5.79%).

3.2 Variable definition and measurement

3.2.1 Innovation barriers. The IIS 2014 contains 18 Likert-scale items used to question firms regarding the extent to which a specific barrier had significant negative consequences on innovation activities. The items are rated from 0 (no negative consequence) to 4 (strong negative consequence). Table 2 displays the innovation barrier variables used in this study.

3.2.2 Firm openness. This study employs BREADTH, DEPTH, external R&D, cooperation and acquisition (e.g. acquisition of machinery, equipment and software) as the firm openness indicators. Construct of BREADTH and DEPTH follows Laursen and Salter (2006) study based on nine external sources of knowledge used for innovation present in the IIS 2014 data set, such as suppliers of equipment, materials, components or software (SUPPLIERS); clients or customers (CUSTOMERS); competitors or other enterprises (COMPETITORS); consultants, commercial laboratories or private R&D institutes (CONSULTANTS); universities or other higher education institutions (UNIVERSITIES); government or public research institutes (GOV_RD); professionals and industry

No.	ISIC Rev. 3.1. codes	Types of the firms	(%)
1	ISIC 10 – 14	Mining and quarrying	5
2	ISIC 15 – 37	Manufacturing	8
3	ISIC 40 – 43	Electricity, gas and water supply	7
4	ISIC 45	Construction	5
5	ISIC 50 – 55	Trading, hotel and restaurants	55
6	ISIC 60 – 64	Transport, storage and communication	8
7	ISIC 65 – 67; 71 – 74	Financial intermediation	12

Source: The IIS 2014

Table 1.
Surveyed firms'
classification

Table 2.
Innovation barriers and its definition

Abbreviations	Definition
INFUND	Lack of funds within your enterprise or group
EXFUND	Lack of finance from sources outside your enterprise
COST	Innovation costs too high
RISK	Excessive perceived economic risks
STAFF-RESIST	Staff resistance (being not open) towards change
MGR-RESIST	Manager resistance (being not open) towards change
ORG-RIGID	Organizational rigidities within the enterprise
PERSONNEL	Lack of qualified personnel
TECH-INFO	Lack of information on technology
MKT-INFO	Lack of information on markets
COOPERATION	Lack of ability to find cooperation partners for innovation
LABOUR	Inability to allocate labour in innovation activities because production has higher priority
MARKET-DOM	Market dominated by foreign established enterprises
UNCER-DEMAND	Uncertain demand for innovative goods/services
CUSTOM-ACCEPT	Lack of customers' acceptance
INFRASTRUCTURE	Lack of sufficient infrastructure to support innovation activities
IND-STANDARD	Lack of industry standard
GOVREG	Lack of government regulation

Source: The IIS 2014

associations (ASSOCIATIONS); conferences, trade fairs, exhibitions (EVENTS); and scientific journals and trade/technical publications (SCIENCE_PUB).

BREADTH is defined as the total number of sources used and ranges from 0 when no external information is used, to 9 when all external information is used. Each of the nine sources is coded as a binary variable, 0 being no use and 1 being the use of the given knowledge source. Then, the 9 sources are simply added up so that each firm gets a 0 when no external knowledge sources are used, while the firm gets the value of 9 when all external knowledge sources are used.

In the case of DEPTH measurement, firstly, each of the nine sources is coded with 1 when the firm uses the source to a high degree and 0 in the case of not used, low, or medium use of the given source. Then, the nine sources are added up so that each firm gets the value of 9 when all knowledge sources are used to a high degree, while each firm gets 0 when no knowledge sources are used to a high degree. Each BREADTH and DEPTH then classified into the following ordinal variables: 1 (1–3) means low; 2 (4–5) means medium; 3 (6–9) means high.

3.2.3 Innovation performance. Sales' proportion of product innovation new to the market (NEW2MARKET) and new to the firms (NEW2FIRMS) are used in this study as the indicator of innovative performance.

3.2.4 Control variables. In this study, the following common control variables in OI literature is included such as absorptive capacity (AC), firm size, firm ownership and firm sectors. To date, there is no consensus on the measurement of the AC construct. Instead of using a single indicator of AC variable that is commonly used in previous innovation barriers studies, for instance, R&D intensity (Keupp and Gassmann, 2009) and internal and external R&D (Fu *et al.*, 2014), this study modified an integrated AC used in the previous studies (Escribano *et al.*, 2009; Kostopoulos *et al.*, 2011). In this study, the integrated AC consists of:

- the firm total innovation activities expenditures;
- proportion of employees with bachelor's degrees;
- proportion of employees work in R&D department; and
- a dummy that equals to 1 if a firm had provided training.

In terms of innovation activities expenditures, this study classifies into 1 for very small, 2 for small, 3 for medium and 4 for a high amount of budget.

3.2.5 Firm size. Based on IIS 2014, there are three different firms' size i.e. small, medium and large firms. This study measures firm size based on the number of employees. Subsequently, a discrete variable that equals to 1 for small firms, 2 for medium firms and 3 for large firms was created. Firm Ownerships. The ownership is also divided into three i.e. national (coded 1), multinational (coded 2) and joint venture (coded 3). Lastly, firm sectors, it consists of seven sectors such as mining and quarrying (ISIC 10–14); manufacturing (ISIC 15–37); electricity, gas and water supply (ISIC 40–43); construction (ISIC 45); trading, hotel and restaurants (ISIC 50–55); transport, storage and communication (ISIC 60–64); and financial intermediation (ISIC 65–67; 71–74).

3.3 Statistical analysis procedures

The following are statistical procedures used in this study. Exploratory factor analysis is used to identify and combine innovation barriers variables. Ordered logistic estimation is used to measure the impact of innovation barriers on firm openness decision, i.e. BREADTH and DEPTH as the two dependent variables are ordinal. Logistic regression is used to measure the impact of innovation barriers on firm openness indicators such as external R&D, cooperation and acquisition as the variables are binary. Tobit regression is used to measure the impact of firm openness decision on innovation performance that consists of sales' proportion of product innovation new to the market and to the firms.

4. Data analysis and results

4.1 Descriptive statistics

Table 3 reports the results of the descriptive statistics. On average, the innovative firms produce a higher proportion of product innovation new to the firms (NEW2FIRMS) than product innovation new to the market (NEW2MARKET), 32.13% versus 19.91%, respectively.

Surprisingly, there is no big gap between the mean of innovation barriers. The average of barriers related to high cost and risk of innovation is slightly higher than the rest of innovation barriers i.e. around 2.60. In terms of firms' openness, on average, Indonesian firms use between 5 and 6 sources of external knowledge in innovation activities. While the firms source external knowledge intensively from 1 to 2 external knowledge providers. Acquisition activities of machinery, equipment and software, on average, have a greater proportion (i.e. around 70%) than external R&D and cooperation that accounted for lower than 30%. Table 3 displays correlation outputs among the studied variables. In general, no correlation coefficient may indicate multicollinearity among the variables Table 4.

4.2 Factor analysis

Table 5 displays the results of the factor analysis of the 18 innovation barrier factors. Factor loadings above 0.40 were retained for factor grouping. The Kaiser-Meyer-Olkin measure of sampling adequacy is 0.92, which is well above the acceptable range of greater than 0.50 (Hair *et al.*, 2014). The scale reliability value for each factor (coefficient alpha) is 0.93. Based

VARIABLES	OBS	MEAN	SD	MIN.	MAX.
Innovation performance					
NEW2MARKET (%)	535	19.912	27.060	0	100
NEW2FIRMS (%)	535	32.125	32.931	0	100
Innovation barriers					
INFUND	535	2.550	1.102	0	4
EXFUND	535	2.273	1.114	0	4
HIGH-COST	535	2.695	1.049	0	4
HIGH-RISK	535	2.660	1.020	0	4
STAFF-RESIST	535	2.265	1.046	0	4
MGR-RESIST	535	2.099	1.074	0	4
ORG-RIGID	535	2.142	1.075	0	4
PERSONNEL	535	2.409	1.077	0	4
TECH-INFO	535	2.348	1.058	0	4
MKT-INFO	535	2.333	1.046	0	4
COOPERATION	535	2.398	1.086	0	4
LABOUR	535	2.176	0.994	0	4
MARKET-DOM	535	2.507	1.084	0	4
UNCER-DEMAND	535	2.394	1.015	0	4
CUSTOM-ACCEPT	535	2.265	1.011	0	4
INFRASTRUCTURE	535	2.391	1.084	0	4
IND-STANDARD	535	2.314	1.099	0	4
GOVREG	535	2.144	0.870	0	3
Firm openness					
BREADTH	535	5.222	2.612	0	9
DEPTH	535	1.533	1.483	0	8
EXTERNAL_RD	535	0.170	0.376	0	1
COOPERATION	535	0.273	0.446	0	1
ACQUISITION	535	0.708	0.455	0	1
External sources of information					
SUPPLIERS	535	2.725	1.124	1	4
CUSTOMERS	535	3.318	0.868	1	4
COMPETITORS	535	2.779	1.040	1	4
CONSULTANT	535	1.852	1.009	1	4
UNIVERSITIES	535	1.527	0.827	1	4
PUBLIC_RD	535	1.439	0.749	1	4
EVENTS	535	2.021	1.069	1	4
PUBLICATION	535	1.763	0.963	1	4
ASSOCIATION	535	1.968	1.053	1	4
Absorptive capacity					
INNOVATION_EXPEND.	535	1.817	1.053	1	4
BACHELOR_STAFF (%)	535	20.056	26.685	0	100
R&D_STAFF (%)	535	5.363	12.654	0	100
TRAINING	535	0.634	0.482	0	1
Firms characteristics					
Firm Size	535	1.568	0.699	1	3
Ownership: *National*	535	0.914	0.281	0	1
Ownership: *Multi-national*	535	0.028	0.165	0	1
Ownership: *Joint-venture*	535	0.058	0.234	0	1

Table 3.
Descriptive statistics

VARIABLES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. NEW2MARKET	1.0														
2. NEW2FIRMS	−0.12	1.0													
3. STAFF and ORG.	0.01	0.04	1.0												
4. INSTITUTION	0.06	0.00	0.03	1.0											
5. FINANCE and RISK	−0.06	−0.10	0.06	0.13	1.0										
6. KNOWLEDGE	−0.02	−0.02	0.17	0.06	0.13	1.0									
7. MARKET	0.00	0.03	0.06	0.09	0.09	0.11	1.0								
8. BREADTH	0.12	0.00	0.15	0.31	−0.04	0.02	0.05	1.0							
9. DEPTH	0.14	0.01	0.20	0.18	0.08	0.10	0.07	0.38	1.0						
10. EXT-RD	0.05	0.03	0.08	−0.02	−0.06	−0.003	−0.004	0.21	0.08	1.0					
11. ACQUISITION	0.07	−0.10	0.10	0.03	−0.05	0.02	−0.09	0.10	0.07	0.17	1.0				
12. INNOV_EXPEND	0.15	−0.13	0.01	0.03	−0.07	−0.06	−0.07	0.20	0.08	0.31	0.18	1.0			
13. BACHELOR	−0.05	−0.04	−0.11	−0.08	0.08	0.02	0.05	0.04	−0.01	0.02	0.01	0.00	1.0		
14. R&D-STAFF	0.02	−0.03	−0.03	0.04	−0.01	−0.02	−0.04	0.06	0.00	−0.04	0.02	−0.02	0.20	1.0	
15. TRAINING	0.12	0.07	0.13	0.04	−0.07	−0.07	−0.06	0.21	0.14	0.16	0.14	0.13	−0.05	0.04	1.0

Table 4.
Correlation outputs

INNOVATION BARRIERS	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
INFUND			0.64		
EXFUND			0.62		
COST			0.67		
RISK			0.53		
STAFF-RESIST	0.71				
MGR-RESIST	0.81				
ORG-RIGID	0.79				
PERSONNEL	0.61				
TECH-INFO				0.58	
MKT-INFO				0.58	
COOPERATION				0.48	
LABOUR					
MARKET-DOM					0.45
UNCER-DEMAND					0.43
CUSTOM-ACCEPT					
INFRASTRUCTURE		0.52			
IND-STANDARD		0.81			
GOVREG		0.81			
Eigenvalue	3.28	2.69	2.29	1.60	1.08
Cronbach's alpha			0.93		
Kaiser-Meyer-Olkin (KMO)			0.92		
% of total variance explained			0.91		

Table 5.
Components loading for innovation barriers

Notes: Factor 1 Human resources and organisation capabilities (HR and ORG); Factor 2 Industry standard and government regulation barriers (STANDREG); Factor 3 Financial and risk barriers (FIN and RISK); Factor 4 Knowledge and cooperation barriers (KNOW and COOP); Factor 5 Market domination and uncertainty barriers (MKT and UNCER)

on factor analysis, barriers to innovation can be categorised into five factors, namely, "human resource and organisation capabilities" (HR and ORG), "standard and regulation" (STANDREG), "financial and risk" (FIN and RISK), "knowledge and cooperation" (KNOW and COOP) and "market domination and uncertainty" (MKT and UNCER).

Factor 1, HR and ORG, consists of four items including staff resistance (being not open) towards change; manager resistance (being not open) towards change; organizational rigidities within the enterprise; and lack of qualified personnel. This classification is in line with previous studies that classified barriers related to organisation such as organisational barriers (Oduro, 2020), employee and organization attitudes (Hartono, 2018; Hartono and Kusumawardhani, 2019) and organisational rigidities (Jung et al., 2016).

Factor 2 is innovation barriers related to STANDREG which consists of three factors such as lack of sufficient infrastructure to support innovation activities; lack of industry standard; and lack of government regulation. STANDREG barriers also emerged in the previous studies such as regulation factor (Coad et al., 2016; D'Este et al., 2012) and laws and regulations (Zhu et al., 2012).

The third factor is the most common barriers faced by the firms which related to FIN and RISK. Such barriers include lack of funds within your enterprise or group; lack of finance from sources outside your enterprise; innovation costs too high; and excessive perceived economic risks. This finding supports a large number of studies such as Coad et al. (2016), Hartono (2018); Hartono and Kusumawardhani (2019), Jung et al. (2016); Moraes Silva et al. (2020); and Shiang and Nagaraj (2011).

Factor 4 is impediments related to KNOW and COOP which include lack of information on technology; lack of information on markets; and lack of ability to find cooperation partners for innovation. Such barriers also can be found in the previous studies such as Hartono (2018), Hartono and Kusumawardhani (2019); Hölzl and Janger (2013, 2014); Keupp and Gassmann (2009); and Xie *et al.* (2010).

The last factor is MKT and UNCER barriers that related to domination of established firms in the market and uncertain demand for innovative products. Similar obstacles also have been discussed in the previous studies (Coad *et al.*, 2016; D'Este *et al.*, 2012; Hartono, 2018; Hartono and Kusumawardhani, 2019; Jung *et al.*, 2016).

4.3 Impact of innovation barriers on firms' openness
Table 6 displays ordered logistics and logistics regressions outputs of the impact innovation barriers on firms' openness. Constraints related to HR and ORG are positively and significantly affect external search breadth and depth, cooperation and acquisition activities. This type of constraints may relevant to a phenomenon so-called "not-invented-here" syndrome (Katz and Allen, 1982) that hinder firm openness (Burcharth *et al.*, 2014). This finding suggests that the greater firms experiencing resistance against change and innovation from inside the firms, the more likely firms' response by performing greater external search breadth and depth, external R&D, cooperation and acquisition. Constraints related to STANDREG have a positive and significant association with breadth and depth. This indicates that the greater the firms lack sufficient infrastructure, industry standard and government regulation, the more likely the firms' source information from external broadly and deeply. However, there is no positive evidence between STANDREG constraints and the rest of openness indicators. This finding supports the previous study in a developing country context (Fu *et al.*, 2014).

Turning to constraints related to FIN and RISK, Table 5 shows that overall, the constraints tend to have negative direction on firms' openness, however, a significant impact

Barriers	BREADTH	DEPTH	EXT_RD	COOPERATE	ACQUISITION
HR and ORG.	0.23** (0.10)	0.51*** (0.12)	0.22(0.15)	0.29** (0.12)	0.26** (0.12)
STANDREG	0.64*** (0.10)	0.39*** (0.13)	−0.06(0.15)	0.07(0.12)	0.08(0.12)
FIN and RISK	−0.14 (0.11)	0.08 (0.14)	−0.17 (0.16)	−0.31** (0.13)	−0.16 (0.13)
KNOW and COOP	0.06 (0.11)	0.26* (0.15)	0.08 (0.18)	0.20 (0.15)	0.12 (0.14)
MKT and UNCER	0.08 (0.13)	0.08 (0.16)	0.12 (0.20)	0.09 (0.16)	−0.27* (0.16)
Innovation activities expend.	0.31*** (0.09)	0.12 (0.11)	0.53*** (0.12)	0.21* (0.11)	0.34*** (0.11)
% Staff with bachelor's degree	0.006* (0.003)	0.0001 (0.004)	0.01 (0.005)	0.005 (0.004)	0.003 (0.004)
% R&D staff	0.01 (0.01)	0.005 (0.01)	−0.02 (0.01)	−0.0003 (0.01)	0.003 (0.01)
Training	0.70*** (0.19)	0.52** (0.25)	0.62** (0.31)	1.01*** (0.25)	0.44** (0.21)
Firm size	0.28** (0.14)	0.05 (0.17)	0.51*** (0.19)	0.24 (0.16)	0.12 (0.17)
Ownership: *National*					
Ownership: *Multi-National*	−0.30 (0.53)	0.49 (0.62)	0.35 (0.65)	−1.43* (0.81)	−0.01 (0.71)
Ownership: *Joint Venture*	0.17(0.35)	−0.57 (0.57)	0.54 (0.47)	0.72* (0.42)	−0.32 (0.43)
Log likelihood	−529.877	−292.337	−205.377	−279.608	−297.582
Number of obs.	535	535	535	535	535
LR chi2(14)	114.39	58.35	77.2	67.93	50.65
Prob > chi2	0.00	0.00	0.00	0.00	0.00
Pseudo R2	0.097	0.091	0.158	0.108	0.078

Notes: Significant levels: *< 0.10; **< 0.05; ***< 0.01; Standard errors are in parentheses

Table 6.
Impact of innovation barriers on firms' openness

can be found in cooperation. This indicates that when firms face FIN and RISK constraints, the less likely firms do cooperation with external parties. Since any cooperation activities require financial resources and involve risk. This finding supports not only the previous study that used cooperation activities as the firm openness indicator (Drechsler and Natter, 2012) but also a majority of studies on the relationship between financial constraints and innovation.

The remaining innovation barriers, i.e. KNOW and COOP, tend to have no significant association with firm openness indicators. A marginal positive and significant association can be found between KNOW and COOP barriers and external search depth. By contrast, a marginal negative and significant correlation exists between MKT and UNCER and acquisition. Based on the explained findings, hence, *H1* is partially supported.

Turning to control variables, of AC indicators, innovation activities expenditure and training activity tend to have consistent positive impacts on firm openness indicators. Firm size has a positive and significant impact on external search breadth and external R&D. This indicates that larger firms tend to source external knowledge broadly and perform external R&D. This is a reasonable finding since larger firms tend to have better financial and non-financial resources to support external knowledge sourcing and external R&D than smaller firms. While, firm ownership and sectors, overall have no significant impact on firm openness indicators.

4.4 Firms' openness decision on innovation performance

Table 7 displays the outputs of Tobit regression on the impact of firms' openness on innovation performance. Surprisingly, only external search depth significantly and positively influences the share of product innovation new to the market. This suggests that the depth of external sourcing information is positively associated with innovation performance. In the previous studies, both external search breadth and depth positively

	NEW2MARKET[a]	NEW2FIRMS[b]
BREADTH	0.87 (0.98)	0.04 (0.86)
DEPTH	3.61** (1.58)	0.87 (1.43)
EXTERNAL_RD	−0.77 (6.40)	10.24* (5.76)
COOPERATION	8.47 (5.23)	6.90 (4.70)
ACQUISITION	3.07 (5.15)	−10.17** (4.48)
Innovation Expenditure	6.77*** (2.38)	−6.93*** (2.15)
% Staff with bachelor's degree	−0.09 (0.09)	−0.05 (0.08)
% R&D staff	0.13 (0.18)	−0.12 (0.16)
Training	11.85** (5.02)	9.34** (4.44)
Firm size	−4.07 (3.55)	−1.66 (3.22)
Ownership: *National*	−	−
Ownership: *Multi-National*	0.67 (13.62)	10.66 (12.12)
Ownership: *Joint Venture*	8.35 (9.40)	0.96 (8.55)
Log likelihood	−1538.74	−2054.93
Number of obs.	535	535
LR chi2(14)	56.38	36.75
Prob > chi2	0.00	0.01
Pseudo R2	0.018	0.01

Table 7.
Impact of firms' openness on innovation performance

Notes: Sig. levels *< 0.10; **< 0.05; ***< 0.01; standard errors are in parentheses; [a]Sales' proportion of product innovation new to the market; [b]Sales' proportion of product innovation new to the firms

influence the share of product innovation new to the market of Indonesian manufacturing firms (Hartono and Kusumawardhani, 2018) as well as in the UK manufacturing firms (Laursen and Salter, 2006). While external R&D has a positive marginal impact on the share of product innovation new to the firms, the acquisition has a negative impact on the share of incremental innovation. A possible reason could be that acquisition of machinery, equipment and software will demotivate firms to perform incremental product innovation as this can be replaced by performing acquisition activities. Based on such findings, hence, *H2* is partially accepted.

Turning to the AC construct, results are more ambiguous. While innovation activities expenditure is positively related to the introduction of new to the market novelties, they are negatively associated with new to the firm innovations. The same pattern is observed for the percentage of staff with a bachelor's degree seems to negatively – though not in a statistically significant manner – influence innovation performance. On the other hand, training is positively related to both innovation performance types. Lastly, all firm sectors tend to perform more innovation new to the market than to the firms.

5. Discussion and conclusion

Opening up the innovation process has become an important strategy for firms to overcome any internal and external constraints that may hinder innovation activities. This study aims to examine the impact of barriers that impede innovation activities on firm openness using data derived from Indonesia Innovation Survey (IIS) 2014. This study extends the previous innovation barrier studies using a broader firm openness indicator that consists of external search breadth and depth, external R&D, cooperation and acquisition activities. Subsequently, the study examines the impact of firm openness decision on innovation performance that is measured by the share of product innovation new to the market and the firms. Innovation barriers faced by Indonesian firms can be divided into human resource and organisation attitude, institution, financial and risk, knowledge and market. The first key finding of this study is that different barriers to innovation lead to different firm openness decisions. Sourcing external information broadly and deeply, performing cooperation and acquisition activities are openness decision conducted by the firms if they are experiencing human resource and organisation related barriers. While focusing on external search breadth and depth is openness decision as the response of the firms face institution barriers. Less performing cooperation activities is the firm's response if they experience financial and risk constraints.

Concerning the control variables, the study shows that absorptive capacity (i.e. the innovation activities expenditure and training activities) facilitates the firms to be more open. This indicates that to be more open, firms not only need innovation funding but also skill and knowledge gained from training activities. Regarding the firm size, larger firms are more open than smaller firms. This can be seen from the positive association between firm size and external search breadth and between firm size and external R&D.

In terms of firm openness and innovation performance relationship, the major key finding is that dependent on the decision firms make regarding openness, the innovation performance is influenced differently. In particular, sourcing external search depth leads to a positive impact on the share of product innovation new to the market, while external R&D contributes to the share of product innovation new to the firms. However, acquisition activities lowering sales' proportion of product innovation new to the firms. Looking at the control variables, absorptive capacity (i.e. innovation activities expenditure and training) consistently and positively affect innovation performance. Lastly, all firm sectors tend to contribute positively to the share of product innovation new to the market.

5.1 Implications for theory and practice

This study contributes to the innovation barrier literature by empirically testing whether experiencing barriers to innovation is associated with involvement a broader firm openness decision that has not been accommodated in the previous CIS-innovation barrier studies. Previous studies tend to link innovation barriers with a narrow firm openness decision. The important finding is that different openness decision can be used to overcome different constraints to innovation. Internal constraints from inside firms related to human resource and organisation resistance to innovation were responded by firms implementing the greater number of openness indicator than other types of constraints. Besides, firms also tend to avoid any openness decision, e.g. external R&D and cooperation, that involve financial and risk constraints. Hence, to facilitate firms to be more open, this study suggests that firms need to invest in a greater amount of innovation activities expenditure and training activities. In this case, larger firms have better ability in facilitating such investment, as a result, larger firms are more open than smaller firms. This study also enriches the innovation studies literature on the understanding that different firm openness decision has a different impact on innovation performance. In this study, of firm openness decision, sourcing external information intensively and performing external R&D contribute to innovation performance. While the decision on acquisition will diminish the return of incremental innovation.

From a practitioner point of view, this research calls attention not to merely focus on a narrow firm openness decision to overcome internal and external innovation constraints. Moreover, firms should think beyond sourcing external information widely and deeply that has been recommended enormously by previous OI studies. However, the more open the firms, the greater the innovation activities expenditure. In this case, there is an emerging challenging decision for balancing innovation barriers, firm openness and innovation performance. On the one hand, in order to improve their resilience, firms need to be more open. On the other hand, to be more open and to increase innovation performance, firms need greater financial investment to support innovation activities such as external R&D, cooperation, acquisition and training activities.

5.2 Limitations and future research direction

Some limitations of the study are worth mentioning alongside the opportunities for future research they recommend. First, the analysis of innovation barriers' impact on firm openness decision was based on cross-sectional data. Hence, this database did not facilitate the consideration of dynamic effects of innovation barriers on firm openness decision. Hence, further studies should cover the long-term effect of innovation barriers on firm openness decision using panel data of innovation survey. Second, only a single developing country (i.e. Indonesia) is used in this study, thus, the findings may be subjectively applying to Indonesian firms only as country-specific conditions may involve the pattern of innovation barriers and firms' openness decision. A further comparison study among developing countries would be interesting to be conducted to identify the common pattern on innovation barriers, firms' openness and innovation performance.

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