# A Comparative Analysis of Knowledge Sourcing Strategies and Innovation: Manufacturing Firms in High- and Middle-Income Countries

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## Abstract

This study compares knowledge sourcing strategies (KSS) employed, and innovation performed, by manufacturing firms in high-income (HI) and middle-income (MI) countries using global innovation data derived from the UNESCO Institute for Statistics (UIS). KSS consists of both closed innovation (internal R&D) and open innovation. This study provides new empirical evidence at country level on the link between KSS and innovation across manufacturing firms in HI and MI countries. In the case of R&D activities, evidence from this study reveals that there is a significant different between manufacturing firms in HI and MI countries. Manufacturing firms in the former group of country is significantly performing internal R&D greater than in the latter group of country. Within HI and MI economies, practicing open innovation in isolation alone does not lead to high level of innovation output. Evidence from HI countries shows that other factors such as R&D activities and R& investment that is also supported by IPRs are correlated to innovation. The key contribution of this study is to provide new empirical evidence on the comparison of KSS – innovation association in the context HI and MI countries that to date is relatively few. Relevant theoretical and practical implication are drawn from this study.

## Keywords
knowledge sourcing strategies, innovation performance, manufacturing firms, high-income countries, middle-income countries

## 1. Introduction
Successful innovation depends not only on firms' internal competencies but also on their ability to absorb external knowledge and technologies (e.g., Cassiman and Veugelers 2006; Roper et al. 2010; Segarra-Blasco and Arauzo-Carod 2008). Therefore, searching for new ideas to solve firms' existing problems increasingly goes beyond the firm boundaries in order to explore other institutions' capacities (Vega-Jurado, Gracia, and de-Lucio 2009). However, firms' search strategies critically rely on their ability to recognize and exploit external knowledge to be used in the innovation process, as the concept of absorptive capacity highlights (Cohen and Levinthal 1989, 1990). In addition, nowadays, the innovation process is viewed as a highly interactive process, and as a result, firms tend to rely on both internal and external knowledge (Tödtling et al. 2011). Consequently, a critical issue for firms is to determine and balance the sources of knowledge that most influence their innovation output and innovation performance, i.e., whether it comes from internal or external sources or both, as well as any factors that hinder their knowledge sourcing strategies (KSS).

KSS is defined as "a firm's approach to generating incoming knowledge flows through knowledge creation or knowledge acquirement" (Wen Lin and Hung Wu 2010, p.582). According to Roper, Du and Love (2008) the main part of the knowledge sourcing activity consists in assembling the different types of knowledge used for innovation. "Firms may interact via various ways to access knowledge outside their boundaries" and "interaction is a key concept for knowledge creation and innovation" (Caloghirou et al. 2004, p. 29). Therefore, firms strongly rely on networks, collaboration and partnerships in which they are able to access resources, knowledge and information, which is then circulated rapidly at low cost (Chesbrough and Teece 1996). In this study, KSS is divided into closed or internal – KSS and open innovation – KSS in order to contrast closed versus open innovation against innovation performed by manufacturing firms in high-income (HI) and middle-income (MI) countries.

Open innovation studies can be analyzed from different perspectives such as individuals, groups/projects, business units, ecosystems/communities, firms, and regions or national innovation systems (West, Vanhaverbeke, and Chesbrough 2006). In relation to the later unit of analysis, Herstad et al., (2008) commented that recently open innovation is connected to policy discussion because its possible impact on national/regional innovation systems and dealing with government policies. However, there are relatively few open innovation studies at country level, and most of them are limited to a context of advanced economies. Open innovation is defined as "the use of purposive inflows and outflows of knowledge to accelerate internal innovation and expand the market for external use of innovation" (Chesbrough 2006, p.1). Therefore, the firms that use an open innovation model can and should use internal and external ideas, internal and external paths to market in order to explore and realize innovative opportunities and the model can be compared with the closed model in which the firms generate, develop, and market their own ideas usually by conducting internal R&D activities (de Jong et al., 2008). In addition, "the open innovation paradigm does not imply that internal R&D is obsolete. Internal R&D can still be a source of better performance like it was in the old days. It also increases absorptive capacity to better benefit from external sources" (de Jong et al. 2008, p. 5). This study aims to identify and compare different KSS – innovation association across manufacturing firms by using the first global innovation data derived from UNESCO Institute of Statistics (UIS), which was launched in 2013 Attempts to compare open innovation at firm level across country have been conducted. For examples, Ahn et al., (2014) compared longitudinal trends of open R&D strategies and innovation performance between the UK and Korea based on two panel data sets, i.e., the UK Community Innovation Survey (CIS) 2004-2008 and the Korean Innovation Survey (KIS) 2005-2010. Herstad et al., (2008) and Ebersberger et al., (2012) explored, constructed and measured open innovation against innovation performance by using the CIS4 dataset across four European countries: Austria, Belgium, Denmark, and Norway. Battisti et al., (2014) explored open innovation on 19 service sectors across 18 European countries by using the Eurostat CIS4 dataset. Those studies provide new insights, for examples, new construction of open innovation dimension based on CIS databases, open innovation in various service sectors, and longitudinal impact of open innovation on innovation performance. However, most studies only focused on open innovation at firm level in technologically advanced countries (Podmetina et al., 2014). This study aims to fill the gap by analysing and comparing closed (internal R&D) and open innovation across manufacturing firms in 61 HI and MI countries. In particular, this study aims to answer the following question: *What is the difference in the association between KSS (internal R&D and open innovation) and innovation among manufacturing firms in HI and MI countries?*

## 2. Literature Review and Hypotheses Development

### 2.1. Internal – KSS: A Cross Country Comparison

In this study, internal KSS is defined as internal R&D activity. Firms decide to employ internal KSS for innovation for several reasons. Having high level technological resource availability or R&D intensity provides firms with an advantage in regard to the vertical integration of R&D activities and therefore a diminished probability of the externalisation of R&D (Williamson 1985). Firms' internal resources positively influence innovation performance, while knowledge created from external networks has a limited impact (e.g., Freel 2003; Oerlemans, Meeus, and Boekema 1998). Performing internal R&D and other internal innovation activities is essential for firms to develop sufficient absorptive capacity i.e., firms' ability to recognise and adapt to externally acquired knowledge (Cohen and Levinthal 1990). Knowledge inside firms may be transferred more often than external knowledge due to the ease of communication between insiders in terms of accessing that knowledge, such as through informal means such as phone calls and meetings (Darr et al. 1995).

Although internal KSS provides a crucial benefit in regard to developing firms' capabilities, such a strategy has several limitations. The quality, innovativeness, and scope of internally generated knowledge may be limited by a firm's existing knowledge base (Oxley and Sampson 2004). Segarra-Ciprés et al. (2012) argue that "competitive advantage in innovation is not based so much on an organisation's internal resources as on its capacity to detect valuable external knowledge and integrate it into its own innovation process". Chesbrough (2006) stresses the importance of external knowledge for firms' innovation through his open innovation paradigm, and argues that internal R&D and internal knowledge alone are no longer the exclusive source of strategic assets.

It is argued that KSS in the context of HI countries has shifted from an internal, closed or traditional approach to a more open approach. From the traditional perspective of producing knowledge, internal R&D is seen as the main source of knowledge generation (e.g., Rothwell 1992) and therefore firms need to protect their ideas using intellectual property rights (Battisti et al. 2014). In this sense, firms may gain strong incentives if their innovation activities are dominated by secretive and self-contained internal R&D. A large body of empirical studies supports this traditional perspective of innovation activities pursued according to a closed innovation model. For example, the studies conducted by Freel (2003) in the UK and Oerlemans et al., (1998) in the Netherlands show that innovation performance is mainly influenced by firms' internal resources and that knowledge from external networks has a limited impact. A recent study shows that innovation leaders, which consist of advanced countries in the EU, tend to rely on an internal source of knowledge, i.e., performing internal R&D activities, to produce radically innovative products, instead of performing an open innovation strategy (e.g., Battisti et al. 2014).

This study proposes that firms in HI countries make more use of internal R&D than their counterparts in MI countries, and the following arguments support that premise. First, the level of R&D differentiates innovation activities between firms in developed and developing economies. As argued by Hobday (2005, 136), "the empirical evidence on latecomer innovation contrasts markedly with traditional "Western" models of innovation and places advanced R&D at the centre of innovation". Second, internal R&D activities in HI countries are dominated by the business sector, while in MI countries, governments are the main funders of R&D activities (Dahlman, 2010). Accordingly, innovation activities in HI countries are dominated by firms' internal R&D activities, while in MI countries firms rely on public or government R&D activities. Third, globally, the top performers and spenders in terms of R&D are dominated by firms in developed countries (Dahlman, 2010). Hence, the following hypothesis is proposed:
*H1 Proportion of manufacturing firms in HI countries that engages in internal R&D is higher than their counterparts in MI countries.*

## 2.2. Open innovation – KSS: A cross country comparison

It is often argued that many firms in the developing economies rely on "reinventing the wheel" strategy and do not heavily rely on R&D efforts (Basant and Fikkert 1996); accordingly imitation and acquisition technology seem to be more important than performing R&D and innovation activities (Bell and Pavitt 1993). Fu et al. (2015) argue that most firms are still in a transition stage in order to catch-up and to build innovation capability; therefore, innovation can be viewed as a process of learning and assimilisation of knowledge in order to catch-up with technological frontiers (Fransman and King 1984). Even the most technology advanced firms in developing economies are involved in external knowledge sourcing activities (Freeman 1989). Hence, cultivation of indigenous innovation capability can be based on sourcing activities of external resources and knowledge (Kim 1997a, b).

Relationship between internal R&D and external knowledge sourcing activities (e.g., acquired technology) have been studied in the context of developing economies. Deolalikar and Evenson (1989) found complementary effect between internal R&D and technology transferred abroad among Indian firms. In Brazilian industry case, a robust complementary relationship is found between technology firm effort and technology firm buying (Braga and Willmore 1991). In a recent study, Kafouros and Forsans (2012) examined the interaction between internal R&D and sourcing external scientific knowledge activities as well as the impact of those activities on Indian firms' financial performance. They reveal that internal R&D has stronger impact on performance for firms that are more open to external scientific knowledge and technologies. Such a finding is in line with open innovation paradigm and it implies that firms should carefully determine the balance between internal and external knowledge, firms do not heavily rely on everything inside firms, and substituting internal research with external knowledge is likely to decrease firms' performance (Kafouros and Forsans 2012). A positive and significant effect of R&D intensity on openness also found in a study based on Chinese innovation survey data conducted by Fu et al. (2015).

In the case of developing economies comparison analysis, Hou and Mohnen (2013) studied knowledge sourcing strategies across 24 developing countries. More specifically, they examined a complementary relationship between internal R&D activities (MAKE) and external technology sourcing (BUY) and the role of the two sources of knowledge on manufacturing firms' productivity. They found that firms in low-income countries rely more on sourcing external knowledge activities, while firms in middle-income countries rely more on internal/in-house R&D. The finding seems in line with recent evidence from BRIC countries' members such as China and India shown that both countries have shifted from production to build innovation capabilities through a combination of innovation system, global value chains and professional networks (Altenburg, Schmitz, and Stamm 2008). Guan et al., (2009) added that during economic transition, China has started for not relying on imported technology and equipment and started to use indigenous R&D efforts to innovate. The finding may imply that the higher level of countries' income, the higher propensity to perform "traditional" innovation activities such as internal R&D instead of employing a new emerging innovation model for example open innovation model. Despite the growing concern for using indigenous R&D efforts in the innovation process in emerging countries, however "opening up the innovation process is likely to be a natural choice for latecomers in emerging economies to mitigate R&D pressure, overcome various constrains, diversity risks and share uncertainties" (Fu et al. 2015, p.177) and as an effort to catch-up with advanced economies. In relation to developed economies, an extensive number of open innovation studies have been conducted including the usage of large-scale databases (e.g., innovation survey). The relationship between internal R&D and openness is however inconclusive. Using the third UK community innovation survey data, Laursen and Salter (2006) found a substitution effect between R&D intensity and openness. From an internal knowledge perspective, previous scholars suggested for not overestimating the use of external knowledge in the firms' innovation process because innovation efforts are not only made by firms themselves but also are generated in the house (e.g., Nelson, 2000); weakening the firms' core competence (e.g., Coombs, 1996); the firms' internal resources positively influence innovation performance and external knowledge creates from external networks has limited impact (e.g., Freel, 2003). Furthermore, identifying the most valuable innovations from external sources of innovation is a major challenge for firms (West and Bogers, 2014).

By contrast, innovation activities depend not only on firms' internal factors, but also external factors, "even the largest and most self-contained of organisations requires information from beyond its boundaries" (Veugelers, 1997, p.303). Scholars from innovation network theory (e.g., Baptista and Swann 1998) also added that only few firms perform innovation on their own, ability to build strong links with external parties is highly involved in the introduction of new products into the market. To reduce over emphasise on either internal or external knowledge, firms need to integrate both sources of knowledge. Previous scholars argued that the acquisition of internal and external knowledge can be complementary activities in the firms' innovation strategy (e.g., Battisti and Stoneman, 2010, 2013; Cassiman and Veugelers, 2006; Veugelers, 1997). The open innovation model (Chesbrough 2003) also suggests that external idea is important input to be used in the innovation process.

The open innovation perspective emphasizes the important value of external knowledge and internal R&D activities as efforts to absorb the available external knowledge outside the firms' boundaries. Some recent studies also support the importance of internal and external knowledge integration for innovation. For instances, Berchicci (2013) found that better innovative performance can be gained by performing an internal and external R&D system. Segarra-Cipres, Bou-Llusar, and Roca-Pui (2012, p. 203) argue that "competitive advantage in innovation is not based so much on an organisation's internal resources as on its capacity to detect valuable external knowledge and integrate it into its own innovation process".

The followings are examples of studies' findings from internal and external knowledge integration perspective: the more intense firms perform R&D, the greater external links sourced to acquire technology (Arora and Gambardella 1990); external knowledge generation stimulates internal R&D activity for the firms with R&D departments (Veugelers 1997); complementarities between internal R&D and external knowledge acquisition exist in relation to innovation performance (Cassiman and Veugelers 2006); and firms that use specialist knowledge (private and public) tend to complement such knowledge with internal and external sources of new ideas such as suppliers, customers, and competitors (Tether and Tajar 2008).

Open innovation comparisons across developed economies have been conducted (e.g., Ahn, Minshall, and Mortara 2014; Battisti et al. 2014; Ebersberger et al. 2012). A comparison across 18 EU countries on open innovation practice show that service firms in innovation leaders (using radical innovation as the indicator) tend to use internal knowledge for innovation, while innovation followers putting external knowledge as an important source of information for innovation (Battisti et al. 2014). Varieties among open innovation (i.e., searching, sourcing, collaboration, and appropriability breadth and depth) also were found in a longitudinal comparative study between the UK and Korea firms (Ahn, Minshall, and Mortara 2014), and a cross-sectional analysis between Austria, Belgium, Denmark, and Norway (Ebersberger et al., 2012). Hence, a hypothesis may be developed:
*H2 Manufacturing firms in MI countries perform open innovation greater than their counterparts in HI countries.*

## 2.3. KSS and innovation output association
A majority of innovation studies in advanced economies reveal that internal R&D activities are positively and significantly associated with innovation and productivity (Griffith, Redding, and Van Reenen 2004; Griffith et al. 2006; Mohnen, Mairesse, and Dagenais 2006). Evidence from developing and newly industrialised countries also shows a positive association between R&D, innovation and productivity, with examples including Argentina (Chudnovsky, Lopez, and Pupato 2006), Malaysia (Hegde and Shapira 2007), China (Jefferson et al. 2006) and Taiwan (Yan Aw, Roberts, and Yi Xu 2008). Firms that have higher levels of investment in R&D are more likely to introduce

technological innovation as was found in Argentina (Arza and Lopez 2010), Brazil (Raffo, Lhuillery, and Miotti 2008) and Bulgaria (Alvarez, Bravo, and Navarro 2010).

In terms of open innovation studies, in both developing economies (e.g. Chiang and Hung 2010, Kafouros and Forsans 2012) and developed economies (e.g. Ahn et al., 2014; Battisti et al., 2014; Ebersberger et al., 2012; Laursen and Salter, 2006; Laursen et al., 2007; Salge et al., 2012) reveal a significant and positive relationship between openness and innovation performance with variations on the relationship due to differentiation on external search breadth versus depth and the use of domestic versus overseas sources of knowledge. Based on an open search strategy study of Taiwanese electronic firms, Chiang and Hung (2010) found that search depth is positively related to firms' incremental innovation, while search breadth is positively related to firms' radical innovation. External knowledge from domestic and foreign countries has different impact on Indian firms' performance (Kafouros and Forsans 2012). They found that external scientific knowledge sourced from overseas results in superior performance.

Despite such positive association has been found, some studies reveal that "over searching" on external knowledge tend to diminish innovation performance. For example, Laursen and Salter (2006) found that relationship between openness and innovative performance was curvilinear (taking inverted U-shape). Using panel Finnish firms, Laursen et al., (2007) reveal that the relationship between firms' openness to external knowledge and its profitability is a curvilinear, showing that there is decreasing returns to external knowledge searching activity. A curvilinear relationship between open innovation and innovation performance also was found in the context of small firms. For example, evidence of such relationship can be found in Irish small firms (Vahter, Love, and Roper 2012).

Regarding comparative studies, evidence based on longitudinal trends of the UK and Korea innovation survey data show that there is a significant relationship between openness and firms' performance (Ahn, Minshall, and Mortara 2014). In the same vein, open innovation has a strong impact on innovation performance across firms in Austria, Belgium, Denmark, and Norway (Ebersberger et al. 2012). External search depth performed by service sectors in 18 EU countries positively influence firms' incremental innovation products (innovation followers), however, it has an insignificant impact on firms' radical innovation products (innovation leaders) (Battisti et al. 2014).
Based on the aforementioned explanation, both internal – KSS and open innovation – KSS can be seen as input used in innovation process and then it can be linked to innovation output. The logic behind such argument is the innovation process can be seen as the transformation of tangible and non-tangible innovation inputs or knowledge capital (e.g. technology, equipment, human capital, scientific and creative capital) and innovation activities into innovation output such as product, process, organisational and marketing innovation (Cirera et al., 2015). Therefore, the following hypotheses are developed:
*H3 Internal R&D has positive association with innovation output across manufacturing firms in both HI and MI countries.*
*H4 Openness towards external knowledge increases innovation output (i.e., product and process innovation) produced by manufacturing firms in both HI and MI countries.*

# 3. Methods

## 3.1. Statistical Analysis

Nonparametric statistics is also well known as assumption-free tests because it uses fewer assumptions of the data type used for analysis and most of the work principle is based on the data ranking (Field, 2009). Nonparametric statistics is employed in this study due to only small sample of countries are used and it may cause problem the distribution of the data set. In addition, skewness/kurtosis tests for normality output (see appendices 3 and 4) show that some variables have non-normality distribution.

### 3.1.1. Two independent samples Wilcoxson rank-sum test

In this study, the differences on the main variables across manufacturing firms in HI and MI countries are tested using Wilcoxson rank-sum (Mann-Whitney U) test. The test is used when "the original measurements of a dependent variable are distributed in some highly-distorted fashion so as to violate the basic assumptions of the t test (normality and homogeneity of group variances)" (Cooksey, 2007, p.199). Mean rank is used to evaluate the significance difference on the studied variables between two independent groups, i.e., manufacturing firms in HI and MI countries.

#### 3.1.2. Spearman's rank correlation

Spearman's rank correlation is another nonparametric test that is used to test proposed hypotheses in this study based on rank ordered of open innovation and innovation output.

### 3.2. Open innovation indicators

To measure hypothesis related to open innovation, this study develops measurement of external search breadth (SBREADTH) and external search depth (SDEPTH). Following Laursen and Salter (2006) study, SBREADTH is constructed based on 9 external sources of information for innovation present in the UIS dataset, namely: (1) suppliers of equipment, materials, components or software (SUPPLIERS); (2) clients or customers (CUSTOMERS); (3) competitors or other enterprises (COMPETITORS); (4) consultants, commercial laboratories or private R&D institutes (CONSULTANTS); (5) universities or other higher education institutions (UNIVERSITIES); (6) government or public research institutes (RES_INSTITUTES); (7) conferences, trade fairs, exhibitions (EVENTS); (8) scientific journals and trade/technical publications (PUBLICATIONS); and (9) professionals and industry associations (ASSOCIATIONS). The SBREADTH 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. In relation to breadth, Laursen and Salter (2006, p. 140) argue that "firms that use higher numbers of sources are more open, with respect to search breadth, than firms that are not". Hence, the higher number of breadths, the more open a country.

In the case of SDEPTH measurement, this study follows Battisti et al., (2014) study. Firstly, national average of the 9 external sources of information is calculated. Subsequently, each source of information is coded as a binary variable, 0 is coded if the proportion is below or equal to the national average and 1 is coded if the proportion above the national average. Finally, each code is added up, a country has total value 0 when no single external information used is below the national average, while a value of 9 if a country has each external source of information greater than the national average. Overall, the reliability of the SBREADTH and SDEPTH as measured by Cronbach's alpha is 0.60 that represents a reasonably good reliability due to the items measuring the SBREADTH and SDEPTH are dichotomous variables (Ebersberger et al., 2012).

## 4. Data Collection

All the aggregated micro-data on innovation indicators used in this study such as sources of information for innovation, product innovation (PRODINOV), process innovation (PROCINOV), and internal R&D (INTERNAL_RD) are drawn from the first global innovation data of the UNESCO Institute for Statistics (UIS). The majority of the innovation data in the UIS is described in the 3rd edition of the Oslo Manual (OECD, 2005). The UIS developed a database of cross-nationally comparable statistics on innovation by collecting pilot data on innovation in 2011. Then, based on the pilot study's results, global data collection covering all countries with innovation surveys was launched in August 2013. However, the data only covers innovation data on manufacturing firms. This study uses data that represents the innovation indicators of manufacturing firms across 61 HI and MI countries from the most populated datasets i.e., 2010. Where data are not available or accessible, the data from the closest year have been used. Of 72 surveyed countries, lower income countries were excluded, and to maintain the data completeness, 61 countries were selected in this study. Appendix 2 presents the list of countries used in this study. The countries are listed based on their gross national income (GNI) per capita, in order (rank) from the highest to the lowest; the first 34 countries are classified as HI countries, while the rest are classified as MI countries, which consist of upper- and lower-middle income countries. The countries' classification in this study is based on the World Bank country classification, which uses GNI per capita to group the countries. The country classification is divided into two groups (1) high-income group (HI) - countries that have a GNI per capita of USD 12,616 or more, and (2) middle income group (MI) - countries that have a GNI per capita of USD 1,036 to 12,615.

Other innovation inputs are also added in order to provide more insightful discussion on the association between a number of innovation inputs (beyond internal – and open innovation – KSS) and innovation output. Innovation inputs also represent a wide range of countries' specific conditions across HI and MI countries. Additional innovation inputs consist of total public expenditure (current and capital) on education expressed as % of the Gross Domestic Product (EDU_SHARE); science and technology variable such as countries' R&D expenditure as the % of GDP (GERD), the number of scientific and technical journal articles (SCIENCE_PUB), the number of residential patent applications (PATENT), and the number of residential trademark applications (TRADEMARK).

## 5. Results and Discussion

### 5.1 Internal – KSS Comparison

Prior running statistical analysis to test hypotheses, skewness/kurtosis tests for checking the normality of sources of information, open innovation, innovation output, innovation impact and internal R&D variables across manufacturing firms in high- and middle-income countries were performed (see appendix 3 and 4 for the tests output). The appendix 3 and 4 clearly show that based on the joint p values on skewness/kurtosis reject normality of some investigated variables across high- and middle-income countries. Therefore, nonparametric statistics need to be undertaken due to not all the variables normally distributed.

Table 1 lists main variables in this study and it divided into four columns. The first column consists information for all countries, while the second and the third columns for HI and MI countries, respectively. The last column consists of Z scores and significance levels of the Wilcoxson rank-sum test. In terms of INTERNAL_RD, on average, nearly 50% of manufacturing firms in both country groups performed such activities. The proportion of manufacturing firms in HI countries that perform internal R&D is higher than in MI countries, 56.99% and 42.27%, respectively. Hence, hypothesis 1 is accepted.

### 4.2. External Knowledge Comparison

Table 1 also shows that overall sources of information such as CUSTOMERS, SUPPLIERS and EVENTS are in the top three positions, 37.57%, 28.78% and 18.15% respectively. By contrast, three sources of information from ASSOCIATIONS, UNIVERSITIES, and RES_INSTITUTES have low proportion i.e. 8.89%, 6.69% and 6.47% respectively. The similar order of sources of information also can be found in the MI country group. While in the HI country group is slightly different i.e., information from COMPETITORS is in the third position. The results from the table 1 are in line with previous studies on innovation activity across advanced and developing economies. For example, external sources of information from clients, suppliers and competitors are highly important in the context of European countries (e.g., Ebersberger et al. 2012; Battisti et al. 2014) and across developing countries (e.g., Bogliacino et al. 2012).

Based on mean rank, Wilcoxson rank-sum test is used to evaluate the significance difference on the sources of information variables across manufacturing firms in high- and middle-income countries. Table 1 shows that only three sources of information namely RES_INSTITUTE, EVENTS, and PUBLICATIONS are found significantly different across the firms in high- and middle-income countries with p values of less than 0.10, 0.05, and 0.10 respectively.

Table 1 Average of main variables by countries' group

| List of variables | | | | Grouping variable: country groups (HI and MI countries) Median test |
|---|---|---|---|---|
| | **ALL** | **HI** | **MI** | **$X^2$** |
| ***Internal – KSS*** | | | | |
| INTERNAL_RD | 48.90 | **55.98** | **41.55** | 5.68** |
| | | | | |
| ***External sources of information*** | | | | |
| SUPPLIERS | 28.59 | 28.01 | 29.19 | 0.17 |
| CUSTOMERS | 37.19 | 36.86 | 37.50 | 0.17 |
| COMPETITORS | 17.80 | 16.63 | 18.87 | 0.69 |
| CONSULTANTS | 10.83 | 10.54 | 11.11 | 0.49 |
| UNIVERSITY | 6.63 | 5.14 | 8.12 | 0.72 |
| RES_INSTITUTE | 6.35 | **3.79** | **9.03** | 3.44* |
| EVENTS | 17.98 | **16.39** | **19.70** | 5.13** |
| PUBLICATION | 12.51 | **10.56** | **14.64** | 6.76*** |
| ASSOCIATION | 8.80 | 7.41 | 10.45 | 2.19 |
| | | | | |
| ***Open innovation - KSS*** | | | | |
| SBREADTH | 8.49 | 8.77 | 8.22 | - |
| SDEPTH | 3.45 | 3.50 | 3.41 | 0.02 |
| | | | | |
| ***Other input variables*** | | | | |
| EDU_SHARE | 5.47 | **5.67** | **5.19** | 4.36** |
| GERD | 1.35 | **1.96** | **.69** | 18.78*** |
| SCIENCE_PUB | 9474.16 | **12758.91** | **6189.41** | 7.69*** |
| PATENT | 856.79 | **1283.92** | **327.95** | 9.59*** |
| TRADEMARK | 6370.85 | 7055.50 | 5578.11 | 0.63 |
| | | | | |
| ***Innovation output*** | | | | |
| PRODINOV | 26.82 | **28.16** | **25.48** | 2.77* |
| PROCINOV | 26.03 | 27.07 | 24.94 | 1.60 |

*Sig. ≤ 0.1; **Sig. ≤ 0.05; ***Sig. ≤ 0.01

## 4.3. Open innovation – KSS comparison

Table 1 also reports comparison open innovation indicators i.e., SBREADTH and SDEPTH. Surprisingly, variables SBREADTH and SDEPTH between HI and MI countries have no significant differences. On average, SBREADTH is higher than its intensity (SDEPTH) across manufacturing firms in all countries, 7.23 and 3.44 respectively. It means that each firm on average use 7 to 8 different sources of external information for innovation and use 3 to 4 external sources of information intensively. The table clearly shows that there is no big gap in the usage of external information widely and deeply across manufacturing firms in HI and MI countries i.e., around 8 and 3, respectively. Based on the table 1 output, as a result, the hypothesis 2 that proposes manufacturing firms in MI countries are more open towards external knowledge than their counterparts in HI economies is rejected.

## 4.4. Others variable comparison

In terms of EDU_SHARE, interestingly, the table 1 shows that all countries, HI and MI countries share nearly the same proportion in EDU_SHARE, i.e., around 5%. All countries, on average invest 1.34% of GDP to support public R&D (GERD). HI economies, on average invest almost three times higher than MI economies, 1.95% and 0.66%, respectively. On average, HI economies publish more scientific and technical journal articles (SCIENCE_PUB) than MI economies, 10,202.52 and 5,567.08, respectively and even higher than the average of all countries (7,884.80). HI countries, on average, also submits higher number of PATENT (1189.26), compared to MI (362.17) and all countries (828.35). Lastly, HI economies outnumbered the average of TRADEMARK of MI and all countries, 5,855.85 and 6,693.39 respectively. This finding in line with a study that compares technology absorption between developed and developing economies (Arogyaswamy and Elmer 2005). The study found that the developed country has greater: number of scientists and engineers in R&D (per million people); number patents granted to residents (per million people); R&D expenditures (% of GDP); and high-tech exports (% of merchandise exports).

In terms of innovation output, proportion of PRODINOV and PROCINOV are produced slightly higher by manufacturing firms in HI countries than their counterparts in MI countries. However, actual different on innovation output, only can be found in PRODINOV, the firms in HI countries produce around 2.5% higher than the firms in MI countries. Unfortunately, there is no information on the novelty of product and process innovation (either new to the firms or new to the markets) can be disclosed in this study due to such data is not provided in the UIS innovation dataset. Further analysis on interaction between internal R&D, open innovation, IPRs and innovation output will be analyzed using spearman's rho coefficients in the next section.

## 4.5. KSS and innovation output association

Analysis of the relationship among the main variables in this study is expected able to address the question whether the country group that more open towards external knowledge or more intends perform internal R&D is also produces more innovation output. To answer the question, this study uses nonparametric spearman's rank correlation analysis due to such analysis can be used to measure correlation of pairs of ordinal variables and between an ordinal and an interval/ratio (Bryman 2012). Tables 2 and 3 report the spearman's rank correlation coefficient (rho) of the main variables in HI and MI countries.

Table 2 presents spearman's rho correlation output of the main variables within HI countries. External search depth (SDEPTH) has negative and significant correlations to innovation inputs such as GERD, EDU_SHARE and PATENT. In contrast, INTERNAL_RD has positive and significant correlation to innovation output (i.e., PRODINOV) and PATENT. Therefore, within HI countries, the higher proportion of manufacturing firms performs INTERNAL_RD, the higher proportion of PRODINOV and number of PATENT can be produced. However, statistically, there is no correlation indication between INTERNAL_RD and open innovation. Therefore, it may be concluded that within HI economies, the presence of the higher proportion of GERD and stringent intellectual property protections (e.g., PATENT), the lower level of the intensity of external knowledge (SDEPTH) is sourced by the firms. To be innovative, manufacturing firms in HI economies cannot solely rely on SDEPTH. The intensity of internal R&D activities (INTERNAL_RD) and countries' investment in R&D (GERD) that is supported by IPRs (PATENT) positively encourage innovation.

Table 2 Spearman Rank Correlation Output of Main Variables (HI countries)

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.PRODINOV | 1 | | | | | | | | | |
| 2.PROCINOV | **.72***** | 1 | | | | | | | | |
| 3.SBREADTH | -.21 | .02 | 1 | | | | | | | |
| 4.SDEPTH | -.27 | -.25 | .38 | 1 | | | | | | |
| 5.INTERNAL_RD | **.67***** | .32 | -.26 | -.29 | 1 | | | | | |
| 6.GERD | **.53**** | .20 | -.30 | **-.54**** | .33 | 1 | | | | |
| 7. EDU_SHARE | .35 | **.55**** | -.35 | **-.42*** | .19 | .30 | 1 | | | |
| 8. SCIENCE_PUB | **.44*** | .15 | -.16 | -.28 | .07 | **.64***** | -.09 | 1 | | |
| 9.PATENT | **.62***** | .12 | -.30 | **-.42*** | **.54**** | **.65***** | .27 | **.45*** | 1 | |
| 10.TRADEMARK | .22 | .17 | -.02 | -.08 | .05 | .06 | .06 | -.11 | .01 | 1 |

*Sig. ≤ 0.1; **Sig. ≤ 0.05; ***Sig. ≤ 0.01

In the case of MI countries (see table 3), in comparison to HI countries, open innovation, i.e., SBREADTH has strong, positive and significant correlation to INTERNAL_RD and statistically has no significant correlation to innovation output. Therefore, it can be concluded that the wider external knowledge is sourced, the more intends INTERNAL_RD is performed by manufacturing firms. In this case, the MI country group follows the open innovation principle by integrating internal and external sources of knowledge. Surprisingly, such integration is not correlated to the higher proportion of PRODINOV and PROCINOV. This may suggest that to be innovative, manufacturing firms in MI countries should implement the same innovation strategy performed by their counterparts in HI countries i.e., combining SBREADTH with INTERNAL_RD activities and public R&D investment (GERD) that is also supported by IPRs policy such as PATENT and TRADEMARK.

Table 3. Spearman Rank Correlation Output of Main Variables (MI countries)

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.PRODINOV | 1 | | | | | | | | | |
| 2.PROCINOV | **.88***** | 1 | | | | | | | | |
| 3.SBREADTH | -.12 | -.28 | 1 | | | | | | | |
| 4.SDEPTH | -.16 | -.23 | **.75**** | 1 | | | | | | |
| 5.INTERNAL_RD | .37 | .22 | **.68**** | .45 | 1 | | | | | |
| 6.GERD | .45 | .21 | -.23 | -.09 | .30 | 1 | | | | |
| 7. EDU_SHARE | .48 | .21 | -.14 | -.38 | .25 | .41 | 1 | | | |
| 8. SCIENCE_PUB | -.12 | -.21 | -.06 | -.13 | -.13 | .41 | .08 | 1 | | |
| 9.PATENT | -.33 | -.15 | .12 | -.10 | .24 | -.16 | -.27 | -.08 | 1 | |
| 10.TRADEMARK | -.53 | -.30 | -.40 | -.30 | -.42 | -.38 | -.21 | -.45 | .52 | 1 |

*Sig. ≤ 0.1; **Sig. ≤ 0.05; ***Sig. ≤ 0.01

Table 2 shows that within HI countries, PRODINOV has positive and significant association with the following inputs INTERNAL_RD, GERD, SCIENCE_PUB and PATENT. While, PROCINOV only has positive and significant correlation with EDU_SHARE. Within MI countries, table 3 shows no positive and significant correlation between INTERNAL_RD and PRODINOV, between INTERNAL_RD and PROCINOV. Based on this, hence, hypotheses 3 can be answered partially.

In terms of open innovation, Table 2 and 3 show surprising results for both country groups, SBREADTH and SDEPTH are not correlated to innovation output. Within HI countries, the lower level of SDEPTH is correlated to the higher level of various innovation inputs such as GERD, EDU_SHARE and PATENT. While in the MI countries, the higher level of SBREADTH is correlated to the higher level of INTERNAL_RD activities. In other words, within both the country groups, practicing open innovation in isolation does not lead to the high level of innovation output. Hence, hypothesis 3 is rejected. This finding is contradictive to many previous open innovation studies that reveal open innovation have positive impacts on innovation performance.

In relation to the link between INTERNAL_RD, open innovation, IPRs, and innovation output, statistically, both country groups show different direction. Within HI countries, open innovation alone (i.e., SDEPTH) does not lead to the high level of innovation performance. However, the presence of INTERNAL_RD, GERD and IPRs (PATENT) enhance the higher level of innovation output (PRODINOV). In the MI countries, openness (i.e., SBREADTH) leads to the higher proportion of INTERNAL_RD. The absence of significant correlation between public R&D investment (GERD) and IPRs do not lead to the higher level of innovation output.

## 6. Conclusion

This study provides new empirical evidence at country level on the link between KSS and innovation across manufacturing firms in HI and MI countries. KSS in this study is divided into internal R&D and open innovation in order to compare how manufacturing firms in HI and MI use and exploit different KSS. A vast majority of previous studies on the linkage between internal R&D and innovation has been conducted in both developed and developing economies. However, there is few studies that attempt to investigate and compare open innovation globally. Hence, this study aims to address the gap by using the UNESCO institute of statistics (UIS) global innovation data that was launched in 2013.

In the case of R&D activities, evidence from this study reveals that there is a significant different between manufacturing firms in HI and MI countries. Manufacturing firms in the former group of country is significantly performing internal R&D greater than in the latter group of country. This finding is in line with previous study (e.g., Battisti et al., 2014) that argues innovation leaders, i.e., countries that engaging in radical products, tend to rely on internal sources of R&D activities, not external sources of knowledge. Within HI and MI economies, practicing open innovation in isolation alone does not lead to high level of innovation output. Evidence from HI countries shows that other factors such as R&D activities and R& investment that is also supported by IPRs are correlated to innovation.

Of the external sources of information used for innovation, information from government or public research institutes (RES_INSTITUTE) and open sources such as EVENTS and PUBLICATION that significantly different across manufacturing firms in HI and MI economies. A possible reason is because in most developing countries "the government is the main financier and the main performer of R&D" and "the private sector is generally less developed and comprises smaller firms whose limited capabilities still keep them behind the global technological frontier" (World Bank, 2010, p.141). In contrary, in developed countries e.g., OECD countries, the proportion of R&D activities that is financed by the business sector is 63%, while government and other sectors finance 30% and 7% respectively (World Bank, 2010). Furthermore, at the firm level, the proportion of manufacturing firms that perform internal R&D in MI countries is significantly lower than in HI countries. At the country level, governments of HI economies also spend higher investment in GERD compared to MI economies.

It is expected that manufacturing firms in MI countries have greater openness towards external knowledge than their counterparts in HI countries because such practice naturally is the right choice for developing economies to overcome various constrains, risks and uncertainties (Fu, 2015). However, evidence from this study shows different result because no significant differences on open innovation was found across HI and MI countries. The higher the level of countries income has no correlation to the openness towards external knowledge. External search breadth tends to be complemented to internal R&D activities by manufacturing firms in the MI countries. While in the HI countries, external search depth tends to be substituted to investment in R&D and IPRs such as patent and trademark.

In the link between open innovation and innovation, evidence shows that such practices are not correlated to high proportion of innovation output. This finding is contradictive to a large number of open innovation studies that reveal positive impact of open innovation on innovation performance. Due to small number of sample as well as the usage of nonparametric in this study, a causal effect between open innovation and innovation output cannot be measured accurately.

## 6.1. Theoretical implications

The key finding of this study contributes to the enrichment of innovation studies literature in conceptualising how variation of KSS (internal R&D and open innovation) – innovation association are performed differently by manufacturing firms in the HI and MI economies. Previous comparison studies on open innovation mostly were conducted in advance countries context (e.g., Ahn, Minshall, and Mortara 2014; Battisti et al. 2014; Ebersberger et al. 2012), therefore knowledge on open innovation comparison between HI and MI countries is relatively scarce. In the context of MI countries, open innovation studies also have been conducted; however, most of them mostly are in the single country context such as in China and India. Hence, the findings are expected shed the light on the variation of open innovation across HI and MI countries.

## 6.2. Practical implications

Based on the study findings, practical implications related to innovation policy, more specifically for MI economies may be proposed. The most challenging part for innovation policy makers that is linked to the findings of this study is balancing between investing the right amount of investment for R&D budget in order to support and strength national innovation capability and creating the right policies to complement or substitute R&D investment. In the case of innovation followers, picking such options is more challenging because increasing massive R&D spending does not automatically yield high level of return, while taking complementary efforts to R&D investment such as improving and strengthening: human capital quality, research institutions, national innovation system, and private sectors quality is not easy task (see Goñi and Maloney, 2014).

Despite the open innovation concept gains a lot of attention recently, to overcome with any firms' shortages related to innovation capability, policy makers in the innovation followers (catching-up economies) do not rush start to design and implement policies that foster open innovation as "catching-up innovation policies need to be more centered on a task of creating a framework for developing institutional capacities and capabilities across the innovation system" (Karo and Kattel 2011). Bogliacino et al., (2012) emphasised that the gap between innovation leaders and followers is not simply about a quantitative in nature e.g., amount of investment in R&D, higher education, and high technology but lack of national innovation system integration in the areas such as production system, financial sector, research and education activities, and policies of the public sector.

To encourage the private sector to undertake more R&D activities, governments in catching-up economies have to create innovation policies that able to stimulate R&D activities, for examples offering duty-free imports research equipment and materials, accelerating depreciation, and offering tax incentives. In the early of technological development stage, firms in catching up economies can implement open innovation by absorbing advance knowledge from technology frontiers countries such as "technology in-licensing agreements to get access to technologies", "long-term alliances with foreign partners to access the latest development of technologies", "collaborations with local universities and R&D institutes to broaden their technology strengths", and "collaborations with the local industrial community to deepen their existing technology competences" (Wang et al., 2012).

### 6.3. Limitations of the study and future research direction

Despite this study provides novelty on the comparison KSS – innovation association across manufacturing firms in HI and MI economies, however limitations of this study need to be addressed. First, this study only focuses in one period and it becomes a severe limitation of the study. Therefore, the future study should address this limitation by employing longitudinal study to portray the change of KSS – innovation association over time. Second, the 2013 UIS global innovation data may has a comparable problem. Although, the Oslo Manual is used as the methodological guidelines for the collection and interpretation of innovation data that are reliable and internationally comparable (UIS, 2015). However, not all countries adopt the same methodological procedures to carry out their national innovation surveys. Surveyed countries were asked to report data only for manufacturing, however, in practice not all countries were able to supply data that solely and fully covered manufacturing as well as to produce estimations (UIS, 2015). Third, this study has lack of information on financial performance on the innovative products. Most previous studies on open innovation use sales turnover of innovative products to measure innovation performance; however, in this study such measurement cannot be accommodated due to there is no sales turnover variable in the UIS innovation data. This study simply uses the proportion of product and process innovation. The future study may use sales turnover to measure innovation performance comparison between HI and MI countries. Lastly, only small number of countries involved in this study. In the future study, high number of countries can be used to perform causality analysis, e.g., using multiple regression analysis, of KSS – innovation relationship across HI and MI countries.

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