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Persistence of Open Innovation: An Organizational Learning Approach

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Abstract

little is known about the dynamic of open innovation over time due to the shortage of studies based on longitudinal data. We address this gap from the lens of organizational learning theory. Firstly, do firms move to adopt more open innovation strategy through time? secondly does practising open innovation strategy at year t stimulate adopting open innovation strategy at year t+1. Our analysis based on panel data of 5699 German enterprises that participated in five waves of German CIS between 2007 and 2015. Results support Chesbrough's paradigm shift towards more open innovation strategy particularly after 2009. This occurred as a reverberation of the global financial crises in 2008 that pushed firms to search for more collaborative innovation to reduce the related risk and to rejuvenate their business. Results also assure that practising an open innovation strategy in the past induce and determine the persistence of openness at the presence.

1- Introduction

It has been widely admitted that innovation is not yet a purely internal matter. firms' orientation towards building an external network also might play a vital role (Cohen & Levinthal 1990; von Hippel 1978). Open innovation literature further the idea of shifting from closed innovation paradigm towards a more open innovation strategy through knowledge inflows and outflows between the firms and external innovation partners (Chesbrough 2006). There is a bulk of literature that supports the reinforce the positive role of openness on firms' innovation performance, but this beneficial role is limited with a specific degree of openness (Laursen & Salter 2006; Katila & Ahuja 2002).

Within open innovation literature, there is a little knowledge about openness as a learning process (James H. Love 2015). This limitedness may be partially due to the scarcity of longitudinal data or because of scholars' instant focus on case studies or cross-section data at best cases (Eelko K.R.E. Huizingh 2011). Open innovation literature intensively followed those both early installed research designs (e.g. Chesbrough 2003; Laursen & Salter 2006), which restricted the analysis of open innovation as a learning process that evolves over time. This paper fills this gap and explores the dynamic of open innovation strategy over time based on panel longitudinal for ten years. This data extracted from the German Community Innovation Survey CIS between 2007 and 2015. We use this data to explore the impact of adopting openness at a time (t) on the persistence of openness at the time point (t+1). Organizational learning is widely recognized as a change in the organization's knowledge that occurs over time as the organization acquires experience (Argote et al. 2011). We, therefore, approaching open innovation form an organizational learning lens and introduce plausible reasons to assume the persistence of openness as a learning process. The openness of innovation is an interactive process of identifying the appropriate partner, selecting the right time and mechanism of collaboration, developing routines of interaction, creating a stock of knowledge, and establishing a managerial system of openness. To end up with building a structured open innovation process, firms go in a long journey of learning such activities over time by doing, piling up experiences, accumulating knowledge until the institutionalization of openness (Argote et al. 2011; Zynga et al. 2018). In organizational learning terms, this could be seen as a development from intuition to an institution (Crossan et al. 1999) and from experience to knowledge (Argote et al. 2011). From a resource-based perspective, this is considered as an improvement of dynamic capabilities in external linkages (Wernerfelt 2007). Or could be seen in evolutionary terms as a continuous path-dependent improvement of open innovation organizational routines (Nelson & Winter 1982). Therefore, we expect that the adoption of openness in one period will stimulate the persistence of openness in the second periods due to the experience of practising open innovation activities.

The contribution of this paper is to provide an analysis of the suggested growing adoption of open innovation strategy and figure out the dynamic of openness over time. in addition, we seek to propose the previous degree of openness as an influential determinant of firms' current degree of openness based on organizational learning effect. To this end, we base our analysis on a balanced and unbalanced paned sample of German enterprises that covers five waves of the German CIS between 2007 and 2015. The main finding provides evidence that firms that had practised open innovation in the previous period have a higher probability to persistently adopt open innovation strategy than firms who were closed innovator at that time.

2- The Paradigm Shifts Toward Open Innovation

Firms increasingly realize that internal R&D is prohibitively expensive and does not mean to be first movers in the market(Chen 2011). Therefore, over the past decades, firms prone to open their innovation process's boundaries toward external sources of knowledge to raise up their innovation capacity(West et al. 2014, Chesbrough 2003).

Theoretically, we are following Cohen & Levinthal (1990), who argued that firms' ability to innovate on a competitive level is conditioned by their ability to absorb external knowledge, combine and integrate it with their internal innovative capabilities which he called firms' absorptive capacity (Spithoven et al, 2011). Chesbrough (2003) also, argued that innovative firms are moving to apply more open innovation strategy (OI) through drawing knowledge from a wide range of external sources and actors to create new products & services and processes. To expand their innovation competencies, firms are shifting to drawing knowledge from its external origin sources such as customers, suppliers, universities, individual innovators, entrepreneurs, online communities, etc(Chen et al. 2016).

Empirical research underscores that openness toward external sources of knowledge is increasingly adopted within both large firms (Huston & Sakkab 2007) and SMEs (Narula 2004; van de Vrande et al, 2009) and it also goes beyond high-tech sector where open innovation concept is born(Enkel et al, 2009). Van de Vrande et al, (2009) measured open innovation with eight innovation practices reflecting technology exploration and exploitation in SMEs. They showed that the responding SMEs engage in many open innovation practices and have increasingly adopted such practices within seven years. However, prior studies found variations in the degree to which firms use external ideas.

Laursen & Salter, (2006) relied on United-Kingdom Community Innovation Survey UK CIS to operationalize the number of external sources to measure the degree of openness toward external sources of knowledge. They suggested that firms draw knowledge from external sources, either broadly or deeply, based on their internal absorptive capacity and appropriation capabilities (Laursen & Salter 2014). They concluded that an open innovation strategy in terms of the broader search strategy is more widely practised than in-depth external search. They defined openness towards seven external partners out of ten as a tipping point any increase over it will negatively affect firms' innovative performance. Practising a degree of openness toward external partners is also a matter of learning by doing (Cohen & Levinthal 1990). Therefore, Vahter et al., (2015), defined at least five previously practised linkages before the benefits of learning how to manage external linkages can materialize. Moreover, effective networking is being considered as one of the main levers of persuading effective openness towards external partners particularly for SMEs (Pullen et al. 2012). S. Lee, Park, Yoon, & Park, (2010b) analyzed Korean technology innovation survey data to understand the current condition of innovation activities among Korean SMEs. They explored the role of external actors in their innovation process. Their research supports the concept of open innovation in SMEs by indicating effective networking as one possible way to facilitate their innovation capabilities. (Lee et al. 2010). In line with Laursen & Salter, (2014) they indicated that SMEs search broadly rather than deeply to draw knowledge from external sources. Barge-gil, (2010) defined different degrees of openness namely closed innovation, semi-opened innovation, and fully opened innovation, based on the importance of external sources of knowledge compared to the importance of internal innovation capabilities. To do so, the Spanish CIS dataset is being operationalized to conclude that semi-open innovation is the most commonly adopted strategy, whereas closed innovation is more widely adopted than open innovation.

In contrast to these above-mentioned studies, Vahter et al., (2015) used the Irish dataset to investigate whether open innovation has the same impact on small and medium firms or not.

They found little evidence in the Irish dataset supporting the idea of a "paradigm shift" towards more open innovation among small or large firms. These small pieces of evidence in the Irish context could not be substantiated by studies that relied on less developed economies. Chinese SMEs experienced many barriers to adopting open innovation(H.-C. Huang et al. 2015). Based on his analysis, Huang et al,(2015) suggested that there is no need for emerging economies like China to follow the emerging trend of moving from closed to open innovation. They argued that Chinese firms first need to develop the required capabilities to identify, assimilate and commercialize knowledge and technologies obtained from external sources. In the same line, Y. Lee et al., (2009) argued that an open innovation strategy may be good for large companies that have sufficient internal capabilities, where a closed innovation strategy is positively related to the financial performance of SMEs. In contrast to these studies from China, Chen et al. (2011) argued that open innovation is adopted broadly and deeply within Chinese firms indicating that OI is also relevant beyond science and technology-based innovation. One study addressed the adoption of open innovation in the African context based on CIS dataset collected from manufacturing and service enterprises in Nigeria. The study posed a challenge for open innovation by arguing that the western accepted approach to external search is not necessarily always the best. Its utility depends on the firm's current level of innovative success, which poses a challenge for open innovation (Egbetokun 2015).

3- The conceptual framework of Organizational learning effects in the persistence of Openness

In principle, persistence means that a specific behaviour is continuously or prolongedly existed over time. There are various potential sources for persistent behaviour (Peters 2009). First, unconditional-state dependence where persistence might appear as a result of the previous degree of openness or other certain firms' characteristics such as size, R&D intensity, or industrial sectors(Ganter & Hecker 2013). This deceptive persistence exists if the firm has specific characteristics which make it particularly 'openness-prone' to the extent that these characteristics themselves show persistence over time and consequently induce persistence in innovation strategy(De Jong et al. 2007).In this case, the past degree of openness may appear to affect the current degree of openness merely because it absorbs the effect of the persistent unobservable characteristics(James H, Love 2015). Secondly, persistence could be caused by a conditional true state dependence. This implies that a causal behavioural effect exists in the sense that the probabilities of practising open innovation strategy in one period are conditioned with a degree of openness that firms persuaded during the previous period (Tavassoli & Karlsson 2015). In the paper, we will only explore whether persistence of openness occurs or not (i.e. Unconditional state dependence).

Open innovation literature intensively addressed the main structural determinants related to firms' characteristics that stimulate moving towards a more open strategy. Three main structural factors that almost are the main factors that undermine or underpin adoption of more opened innovation strategy: namely firm size(Christensen et al, 2005); R&D intensity(Cohen & Levinthal 1989; Spithoven et al. 2013); and industrial sector(van de Vrande et al, 2009).The main argument of our paper is that, not only structural variables that induce the adoption of open innovation, but also the earlier managerial decision of adopting of open innovation and learning process of applying open innovation are a crucial determinant of open innovation persistence. In the next section, we frame the persistence of openness as organizational learning effects.

Besides the above-mentioned determinants that facilitate the adoption of open innovation strategy, we introduce, in this section, the persistence of open innovation from an organizational learning perspective. Because the innovation is costly, risky and uncertain, firms are motivated to establish a collaborative innovation process with external partners. (Brunswicker et al. 2012).

The fundamental idea of open innovation is that the larger the external linkages the higher innovation performance to achieve(Chesbrough & Brunswicker 2014). However, these benefits are limited with firms ability to manage their external degree of openness(Laursen & Salter 2006). Over-searching external sources and building a complexly nested linkage can negatively distract firms and lead to misallocation of their attention between different ideas and, consequently, slow down the whole innovation process instead of accelerating it. (Kang & Kang 2009)(James H. Love 2015). On the other hand, searching external sources is costly as firms need to select the right partner, negotiate them and set up the appropriate contractual agreement(Enkel et al. 2009). Firms also have to define the best collaboration mechanism and select an appropriate method to protect their ideas and selectively revealing the other to capture the value of openness (Henkel 2006).

Therefore, firms require more time to practice open innovation to be able to materialize and capture the value of openness(JAMES H. LOVE 2015). This learning by doing process creates success stories of openness over time that yields more payoffs for the firms. the success breeds new success and motivates firms to allocate more money for applying more open innovation strategy persistently(Ganter & Hecker 2013). Where open innovation might be an intended strategy that firms adopt, it is at the most start as based leadership or R&D employees personal initiative or individual intuition(Crossan et al. 1999). Then, firms recognize overtime importance of building external connection practising open innovation. Through time firms pile up a mountain of experiences of learning which collaboration to pursue and how to behave within a complex context of cooperative innovation. (Argote et al. 2011). Managers also learn how to resist the resistance behaviour against the openness of innovation (e.g. Not Invented Here syndrome)(Katz & Allen 1982). The experience obtained from a specific kind of collaboration can be used with other more diverse combination of partnership. This experience is not only reflecting on the skills of the managers or the employees but rather it also develop into dynamic capabilities in it is on the right(Vahter et al. 2015). These experiences in forms of shared understandings of how to manage open innovation can be disseminated on the group level through an interactive system(Crossan et al. 1999). Through time, these gathered experiences become a function of knowledge accumulated embedded in the individual; cognitive skills and creativity of management team (Cohen & Levinthal 1990). Based on this accumulated knowledge, firms develop organizational routines and establish stable mechanisms for managing lucrative collaboration with external partners(Spithoven et al. 2011). At this point, firms start to transfer from having just experienced individuals to build a stock of knowledge on a group level, to develop organizational routines, rules and procedures of openness that anyone inside the firms can rely on maximizing the value of openness(Argote et al. 2011). Firms do that to transfer gradually and smoothly form intuition, to experience, to knowledge until being able to institutionalize a stick of open innovation process(Zynga et al. 2018).

The question is do firms that practised open innovation at the time(t) really have a higher probability to more opened at (t+1) than firms who were closed innovators at the same time windows?

4- Methods
4-1 Data

Data in this study is a part of firm Mannheim Innovation Panel (MIP) collected annually by the Leibniz Centre of European Economic Research (ZEW). The target population covers all legally independent firms with at least five employees where surveys are drawn as stratified random samples included the German manufacturing enterprises (e.g. mining. energy, water) and service sector (e.g. transportation, consultancy, telecommunication, etc). The degree of openness data in this study comes from five waves of the German Community Innovation Survey (CIS) in 2007,2009, 2011, 2013, and 2015. The CIS 2007 covers the period 2005–2006 and CIS 2009 covers the period 2007–2008 and so on. Hence, using the five waves provides us

with information about the innovation activities of firms for over ten years. The survey methodology and innovation definition comply with the Oslo Manual (OECD,2005). Every two years the survey represents the German contribution to the European wide harmonized Community Innovation Surveys (CIS). We selected a panel of five waves conducted every two years according to the consistency between surveys being used that fit the European standardized community innovation survey. The samples are constructed as panels of around 5568 firms voluntarily participate to fill out the survey for each wave. This corresponds to an average response rate of 25% of the targeted community. Since participation is voluntary, A large part of the firms takes part only once or twice and small part who consecutively participated in filling out the survey.

Therefore, we created a balanced panel dataset consists of 1985 observations corresponding to 397 firms that took part consecutively in all the targeted five waves. In addition, we created an unbalanced dataset of 28.495 corresponding to 5699 firms that participated in at least two years consecutively. The main sample of German CIS was stratified and selected carefully to represent the German market based on industrial sector and firm size factors. To answer the first question related to whether a paradigm shift exists or not, all types of sample were used to have the full picture. However, for analyzing the persistence of open innovation; only firms that consecutively participated in the survey can be taken into account.

Finally, we extracted, from the survey, data related to the degree of openness for two types of innovation; product& service innovation, and process innovation. We use balanced and unbalance datasets between 2007 and 2015 in investigating the persistence of openness (next section).

Table (1) pooled Sample, balanced panel, and unbalanced panel description 2007 – 2015

Samples		Pooled Sample	Balanced Panel	Unbalanced Panel
Industrial Sector	Manufacturing	60.3	62.4	60.9
	Service	39.7	37.6	39.1
Size	Small	62.1	66.8	63.3
	Medium	26.1	22.9	25.7
	Large	11.8	10.3	11
No. of Firms		15747	397	5699
No. of consecutive Obs.			Five	Two
Time period		2007-2015	2007-2015	2007-2015
Total No. Observations			1985	28.495

Table (1) indicates that both balanced panelled and unbalanced panel data we created is representing (i.e. size and industrial sector) the original pooled sample created by ZEW to reflect German economic diversity. Manufacturing enterprises were more than service enterprises, and small enterprises between 5 and 49 employees are more than medium-sized or large firms in all our datasets (European Commissio.2005). This sample representativeness furthers the generalization from our created balanced panel dataset over the pooled sample.

4-2 measurement of openness degree

Measuring the degree of openness is a problematic issue within open innovation literature. Most of the literature followed the creative breadth and depth measurement(Laursen & Salter 2006; Verbano et al. 2015; Idrissia et al. 2012). This measurement relied on firm's evaluation for the importance of a list of external sources of knowledge in a scale of 0, 1, 2, and 3 where 0 means the source is not used and 3 means it highly used. The list of sources involved customers and

clients, suppliers of material, universities, and research institutes and other sources (see for instance Laursen & Salter 2006). Our point of view is that in spite of the valuable progress this measurement added to open innovation literature, we see it a very loose measurement and does not reflect the reality of openness. For instance, it is well known within literature that developing contractual R&D agreement with scientific institutions takes a long time, effort and cost more money than collaboration with supply chain partners such as customer or suppliers. (Goduscheit & Knudsen 2015; Brunswicker & Vanhaverbeke 2015) However, this measurement blindly sums the importance ratio up and equalize all sources. if the firm gives 1 to the university and 3 for the customer then the customer is more important regardless of the nature of each type of collaboration and knowledge drawn upon that.

We follow Barge-gil (2010) and use another question in CIS to measure the degree of openness. In the survey, firms were being asked if they developed or enhanced a product, service or process innovation within two years or not. firms that said yeas were being followed and asked who developed this innovation; the firm internally alone, or through collaboration with external partners, or totally developed by external partners. We emphasize here that the question was about newly developed or enhanced innovations not about buying some material from external partners. Therefore, we defined three levels of openness; closed-innovation strategy: refers to firms that developed their innovations alone; Semi-open innovation strategy: refers to firms that developed their innovation in collaboration with external partners, and full-open innovation strategy: refers to firms that developed their innovations by external partners.

5- Results

### 5-1 A paradigm shifts towards open innovation strategy

Since product and service, and process innovations are different by nature according to the definition listed in the CIS, we expect that different degrees of openness might ensue. Tables 2,3 and 4 and Graph 1,2 and 3 compares between different degrees of openness in both types of innovations throughout our three different established datasets; pooled sample, unbalanced panel sample, and balanced panel sample over five waves.

Table 2 Degrees of openness in pooled sample datasets 2007-2015

Type of openness	Degree of openness	Pooled sample between 2017-2015				
		2007	2009	2011	2013	2015
Product& innovation	Closed-innovation	63.6	70.8	43.8	40.1	34.5
	Semi-opened innovation	29.2	23.2	52.2	53.2	60.1
	Fully-open innovation	7.2	6	4	6.7	5.5
Process innovation	Closed-innovation	56.5	54.8	39.1	38.8	36.8
	Semi-opened innovation	32.3	31.1	54.6	54	53.5
	Fully-open innovation	11.2	14.1	6.3	7.2	9.7

In the pooled sample of different 15474 firms participated in the five waves of CIS, the closed-innovation strategy was highly adopted than semi-opened strategy and fully- opened strategy in both product and innovation, and process innovation until 2009. Up 2009 forward, closed innovation strategy started to continuously decrease where semi-opened innovation strategy starts to get adopted increasingly. Fully-opened innovation strategy did not show a remarkable change over time. in addition, it is obvious that opened strategy is highly adopted in process innovation (solid line) than in product & service innovation.

**Figure 1. The degrees of openness in pooled sample datasets 2007-2015**
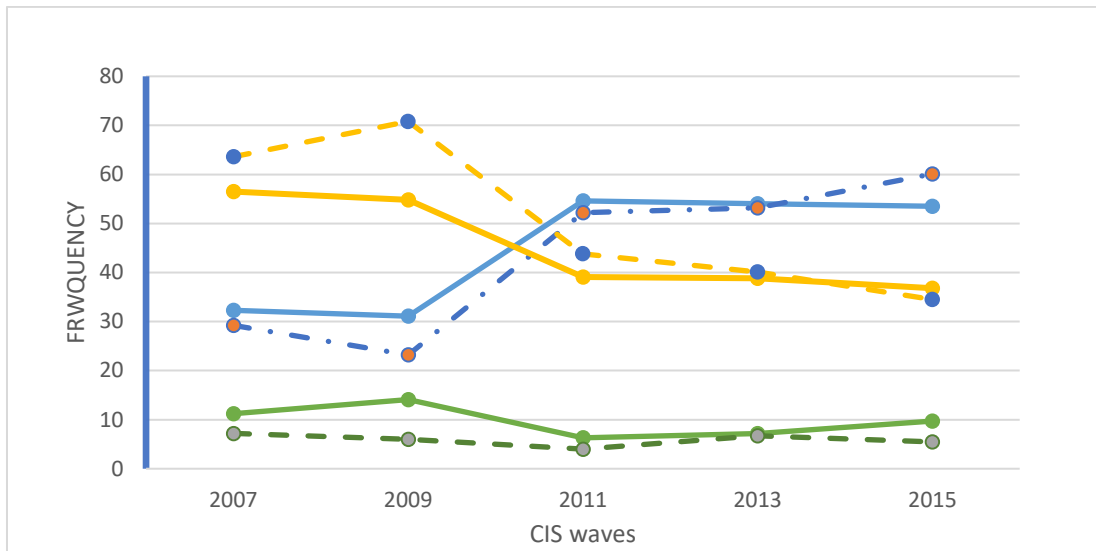
Notes: dashed lines represent product and service innovation, where represents process innovation. the yellow line refers to a closed-innovation strategy, Greenline refers to a full-open innovation strategy, and blue line refers to the semi-open innovation strategy.

The semi-opened innovation strategy is the most commonly adopted strategy after 2009. These results agree with previous studies of Laursen & Salter, 2006 and Barge-gil, 2010 who argued that semi-open innovation strategy is commonly adopted as it enables firms to get the advantage of openness and avoid disadvantages of the fully-opened strategy. Firms may misallocate their attention, bearing unjustified costs, countering a substitution effect, or facing an NIH problem if they highly engaged in a large portfolio of external linkages and collaborations. In general, moving toward adopting a more opened innovation strategy (i.e. semi or full opened strategy) is noticed particularly after 2009. This assures the proposed paradigm shift toward more open innovation. This shift could be explained as a reverberation of the global financial crises that affect negatively on the global economies. The financial crises in 2008 affected negatively on firms' investment in their R&D. Financial crises shocked most of the western economies and generated a high level of stagnant at that time. Managers inside firms' boundaries recognized an unprecedented level of risk if they continued to look inside. Therefore, managers at those firms were enforced to look outside their boundaries to rejuvenate their business activities and restore their innovation capacity through external partnership.

(Table 3) The degree of openness based on an unbalanced Panel dataset.

Type of innovation	Degree of openness	Waves of the unbalanced panel between 2017-2015				
		2007	2009	2011	2013	2015
Product innovators	Closed-innovation	63.3	70.6	42.9	40.4	35.9
	Semi-opened innovation	28.2	23.1	52.7	53.5	58.7
	Fully-open innovation	8.5	6.3	4.4	6.1	5.4
Process innovator	Closed-innovation	55.2	53	38.7	37.6	35.7
	Semi-opened innovation	32	32	55.1	54.3	54.6
	Fully-open innovation	12.8	15	6.2	8.1	9.7

Figure.2 Degree of Openness within unbalanced panel dataset
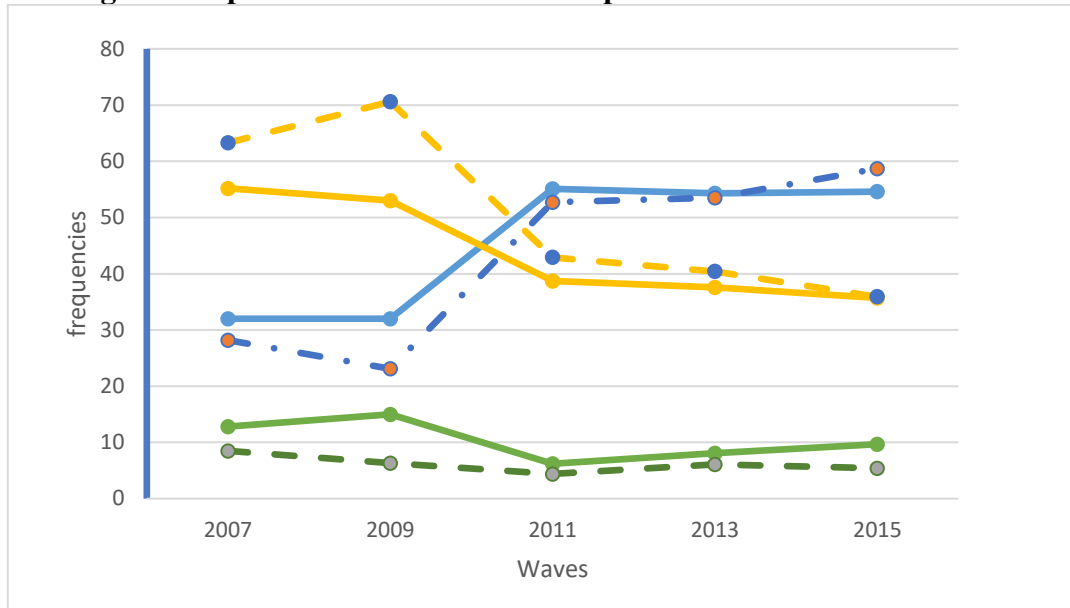
All of these results are also applied to the second two balanced and unbalanced panel datasets where moving toward more opened innovation strategy in form of semi or full open strategies are increasing remarkably after 2009.

Results in table 4 below and figure 3 based on balanced panel data show also that moving toward openness is increasing over time, however for both types of innovations. this shift toward openness remarkably occurs in form of semi-open innovation strategy

Now, the question is do this noticed shifting toward more opened strategy over time is caused by the previous degree of openness (state dependent) or not? In the next section, we try to answer this question based on both unbalanced panel and balanced panel datasets between 2007 and 2017. To do that we will differentiate only between closed innovation strategy and opened an innovation strategy since we need to discover the persistence of openness regardless of the level it takes (i.e. semi or full-opened degree of adoption.

(Table 4) The degree of openness based on a balanced Panel dataset.

Type of innovation	Degree of openness	Waves of B. panel sample between 2007 - 2015				
		2007	2009	2011	2013	2015
Product innovators	Closed-innovation	64.3	67.9	45	45	41.1
	Semi-opened innovation	25.3	22.3	49.5	48	55.9
	Fully-open innovation	10.4	9.8	5.5	7	3
Process innovator	Closed-innovation	51.2	56.8	36.2	33.8	37.1
	Semi-opened innovation	30.8	28.4	58.8	57.7	54.3
	Fully-open innovation	18.0	14.8	5.0	8.5	8.6

Figure3. The degree of openness based on a balanced Panel dataset.
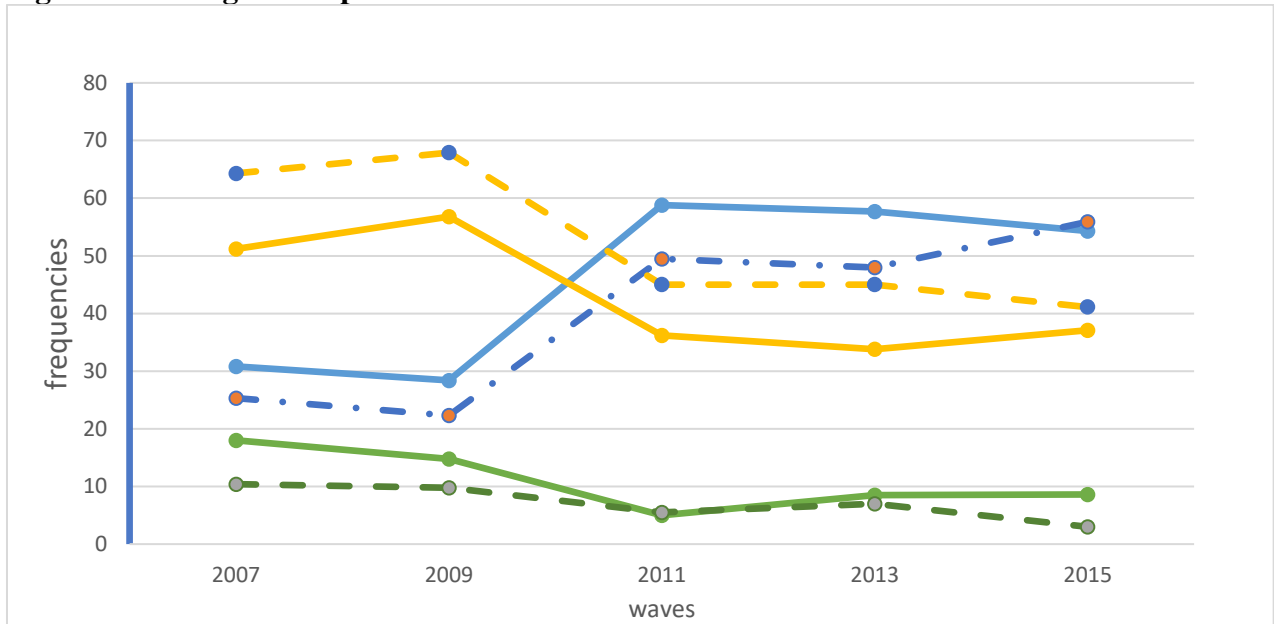
5-2 Is there persistence in firms' open innovation (state- dependency)?

To our knowledge, no previous studies addressed the persistence of openness econometrically. Therefore, in this section, we follow the econometric model of Tavassoli & Karlsson 2015 which created to address the persistence of different types of innovation.

In order to explore whether persistence of openness occurs or not and if yes, how strong is it. we used the transition probabilities matrix (TPM) which reveals information about the probability of transitioning from one state to another. In our case, "state" is the openness status of firms in each period (i.e. open innovation vs closed innovation).

To constitute the matrix, we use a discrete-time Markov chain. A discrete-time Markov chain is a sequence of random variables X_1, X_2, X_n, with the Markov property; namely that the probability of moving to the next state depends only upon the present state and not on the sequence of events that preceded it.

$$\text{TPM} \quad = \quad \begin{bmatrix} P11, P12, P13, \ldots \ldots P1d \\ P21, P22, P23, \ldots \ldots P2D \\ \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \\ \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \\ Pd1, Pd2, Pd3, \ldots \ldots Pdd \end{bmatrix} \quad (1)$$

Where

$$p_{ij} = P (X_t = j/X_{t-1} = i) \quad (2)$$

where p_{ij} measure the probability of moving from state i to state j in one period for the vector X. Finally, X consists of two variables measuring different types of open innovation (i.e. $X1$ is Product& service and $X2$ is process innovation. This TPM provides useful information for analyzing persistence since it measures the probability that a firm goes from one state to another while moving from one period to another period in time(Tavassoli & Karlsson 2015).

p_{ij} are unknown parameters in our case and they can be calculated by maximum likelihood. It can be shown that the estimated parameters of pij equal to $Pij = \frac{nij}{ni}$, where n_{ij} the number of observed transitions from state i to state j, and n_i is the total number of state i. In context the of open innovation persistence, it is shown that persistency can exist in two forms of weak or strong (Roper and Hewitt-Dundas, 2008). A strong open innovation persistency if the sum of

diagonal elements of the matrix TPM (p_{ij}, *if i = j*) is equal or bigger than 100% probability and all cells of the diagonal of the matrix TPM equal to or higher than 50%. A weak open innovation persistency appears if the sum of diagonal elements of the matrix TPM (p_{ij}, if *i = j*) is equal or bigger than 100% probability but not all cells of the diagonal of the matrix are equal to or higher than 50%. Using TPM, one can also calculate the unconditional state dependence (USD) as follows:

$$USD = p_{jj} - p_{ij} = P\ (X_t = j/X_{t-1} = j) - P\ (X_t = j/X_{t-1} = i) \qquad (3)$$

where *j refers* to open innovation state and *i* refers to closed innovation state. USD is measured as percentage point (hereafter PP) and shows how much of the probability of being applying open innovation in year *t (Y_t= j)* can be explained by the difference between adopting open innovation strategy *(X_t−1= j)* versus adopting closed innovation strategy *(Y_{t-1}= i)* in year t – 1. USD is unconditional because it does not condition the state dependency on any other observed or unobserved characteristics of the firm. Which means that persistence might appear but the reason behind persistence could be the previous degree of openness or another unobserved variable. In this case, more research is required to address also those unobserved factors and estimate the conditional state dependence persistence. Table 5 reports the estimated parameters of the transition probabilities matrix as well as USD by using both balanced and unbalanced panel datasets. Results show a general weak pattern of the persistence of adopting an open innovation strategy in both product and service, and process innovation. This pattern is weak since not all the diagonal elements are usually equal to or higher than 50%. Openness persistence is relatively the same in both unbalanced and balanced panel data. Therefore, we will discuss only balanced-panel data where 397 firms participated consecutively in all waves.

In product and service innovation, 40.20% of firms that applied open innovation in year *t* continued to practice open innovation activities in the subsequent year t+*1*, while 59.8% stopped their engagement. In contrast, only 9.5 of firms that adopted closed innovation at year *t* are able to practice open innovation at year *t+1*, where 90.6 continued to be closed innovator. In another word, the probability of being an adopting open innovation strategy in year *t + 1* was about 30.85 PP higher for firms that adopted opened innovation strategy than those who adopted a closed innovation strategy in year *t*. This ensures postulation that the early adopters of openness are able to practice open innovation than the later adopters. Which in return reflects on their ability to introduce new innovative product and services. More research is required to measure innovation performance of both early and later adopters of open innovation.

Table 5. Unconditional State persistence of openness over waves

Type	Openness status time (t)	unbalanced panel			balanced. panel		
		Openness status t+1		USD (PP)	Openness status t+1		USD (PP)
		Closed	Opened		Closed	Opened	
Product& service innovation	Closed innovation	88.7	11.3	32.6	90.6	9.35	30.85
	Opened innovation	56.1	43.9		59.8	40.20	
Processes innovation	Closed innovation	98.8	10.2	28.2	91.9	8.12	28.68
	Opened innovation	61.6	38.4		63.2	36.80	

The table reports the estimated parameters of transition probabilities matrices. Innovations status are the "state", which can be CLOSED or OPENED innovation, The sum of the rows in each matrix equals to 100%, The table also reports the USD (unconditional state dependence), as the percentage points (PP), which shows how much of

the probability of adopting open innovation strategy in year t can be explained by the difference between being closed innovative versus being open innovative in year t − 1, t = 2009, 2011, 2013, , and 2015.

In process innovation, 36.80 of firms that applied open innovation in year *t* continued to practice open innovation activities in the subsequent year t+*1*, while 63.2% stopped their engagement. In contrast, only 8.12 of firms that adopted closed innovation at year *t* are able to practice open innovation at year *t+1*, where 91.9 continued to be closed innovator. In another word, the probability of being an adopting open innovation strategy in year *t + 1* was about 28.68 PP higher for opened innovators than closed innovators in year t. This also means that applying open innovation practices to innovate new processes is easier and more likely for the earlier adopter of open innovation model.In sum, results indicate that semi-open innovation strategy is commonly adopted for b9oth types of innovation, and persistence of openness is relatively the same since the unconditional state dependency of openness in both are 28.68, 30.85 respectively.

Discussion and Conclusion

In the last decade, open innovation has prevailed as a dominant innovation strategy within innovation management scope. Chesbrough,2003 has defined it as purposeful inflows and outflows of knowledge over firms' boundaries. From that time forward, open innovation grabbed the attention of scholars from different disciplines. A majority of previous literature underscored the positive impact of open innovation on firms' innovation performance. However, adopting an open innovation strategy required a prerequisite to grain the benefits of openness. These prerequisites extent from individual's competencies to the organizational and managerial arrangement. For instance, firms that invest in their internal R&D and innovation activities has been proved to success in adopting and benefiting from open innovation. Open innovation literature, however, gave scant attention to the impact of the previous degree of openness on openness persistent in the future. Open innovation literature also mostly relied on qualitative cases studies or cross-section data to propose the growing shift toward open innovation paradigm. We, therefore, do not understand the dynamic of openness due to the shortage of longitudinal studies the following open innovation phenomenon for a time period. In this paper filled out this gap by addressing the dynamic of openness in two aspects. Firstly, is there a paradigm shift toward more open innovation and if which form does it take? Secondly, does openness behaviour persists over time, if yes, how strong is this persistence?

To do that, we used a panel data of German enterprises that consecutively participated in CIS between 2007 and 2015. Firstly, the main results approved the suggested theoretical shift from closed innovation towards the adoption of more opened innovation strategy after 2009. These changes might occur as a reverberation of global financial crises 2008- 2009. In order to give alive for their innovation activities after the crises, firms decided to look outside their boundaries and search broadly for potential collaborations. Managers also experienced an unprecedented level of risk which pushed them to go beyond their traditional status and call for more collaborative innovation activities to share the risk.

Secondly, the openness of innovation is showed a degree of persistence and state dependent on the previous degree of openness. Results stated that firms that adopted an open innovation strategy have a higher probability to practice more open innovation strategy than firms that were closed innovators at the same time. This suggested state dependent persistence of openness explains the openness of innovation as an organizational learning process. Firms that adopt open innovation earlier have a chance to learn how to manage external collaboration successfully. They gain advantages of openness, obtain more experience, and accumulating more knowledge that facilitates the adoption of openness than the later adopters. From this lens, the openness of the innovation process is not that strategy which firms can apply successfully when they need, instead, it is a long process of learning and evolving. This learning starts by

intuition and skills on an individual level until it being institutionalized in forms of routines, rules and procedures on the organizational level.

On a practical level, these results alarm that successful adoption of open innovation is not only a matter of structural factors such firm size, industry sector & R&D intensity, instead, but it is also a matter of learning how to practice a successful open innovation strategy over time. Due to the growing orientation towards more opened and nested business environment, big data era, and diffusion of knowledge through a wide spectrum of sources, firm that decided to start earlier in adopting open innovation strategy will be able in to cope with these expected fast and dynamic changes in the future. This will rent those firms a strategic competitive advantage over their rivals regarding how to benefit from online communities, individual innovators, startups and entrepreneurs. Firms that still looking inside their boundaries and depend only their internal capabilities, will face more challenges in the future to adopt open innovation strategy more than firms that recognized this reality earlier.

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