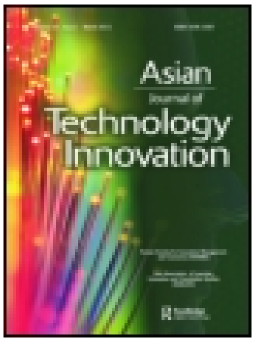

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Unravelling the link between technological M&A and innovation performance using the concept of relative absorptive capacity

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Technological merger and acquisition (M&A) has become an increasingly popular mode of innovation for firms. We investigate the determinants of innovation creation through technological M&As. Based on the concept of relative absorptive capacity, the study examines how the acquiring firm absorbs and assimilates the knowledge of the acquired firm and creates innovation. Specifically, the technological M&As are examined by presenting dyadic perspective variables, including technological similarity and technological digestibility which affect the assimilation, transformation, and exploitation processes of the absorptive capacity. We additionally investigate the role of M&A experience as a moderator of dyadic characteristics and innovation performance of technological M&As. Two hundred and twelve cases of technological M&As in the biopharmaceutical industry from 1993 to 2007 are investigated using zero-inflated negative binomial regression and negative binomial regression. The findings confirm a positive effect of acquiring small firms having a modest level of similar knowledge on post-M&A innovation performance. Moreover, this study highlights the importance of the dyadic perspective in advancing the understanding of technological M&A.

Keywords: technological M&A, relative absorptive capacity, technological similarity, technological digestibility, M&A experience

1. Introduction

Amid constant change and intense competition, firms must constantly keep up with the fast-changing market. Accordingly, rapid technology absorption skills influence the competitiveness of firms; however, firms cannot create knowledge and capabilities for survival and sustainable innovation solely within the organisation (Leonard-Barton 1995; Chesbrough 2003; Keil 2004; Kang and Kang 2009; Kang, Jo, and Kang 2015). In other words, they need to introduce knowledge from external sources. As a result, firms exploit a variety of methods, such as licensing, alliance, joint venture, and merger and acquisition (M&A), to access external knowledge (Lee 2010; Park and Kang 2010; Du, Wu, Lu, and Yu 2013). Among these various collaboration strategies, our research focuses on technological M&A.

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Conducting an M&A with a technological objective implies that the acquiring firm intends to absorb the knowledge of the acquired firm to create innovation and obtain sustainable competitive advantages (Hamel 2000; Ahuja and Katila 2001; Cloodt, Hagedoorn, and Van Kranenburg 2006). According to the findings of the previous technological M&A literature, major factors affecting the subsequent innovation performance include whether or not technological M&A is conducted (Wagner 2011; Valentini 2012), the characteristics of the acquiring firm (Prabhu, Chandy, and Ellis 2005; Desyllas and Hughes 2010), and the characteristics of the acquired firm (Ahuja and Katila 2001; Cloodt et al. 2006; Lin and Jang 2010; Datta and Roumani 2015). The findings of these studies contribute to identifying influential firm-level factors that have an impact on subsequent innovation. However, analyses focusing only on the characteristics of one firm or the M&A deal itself are unable to examine the relative characteristics between the acquiring and acquired firm. It has been argued that the acquiring firm's learning differs between deals because of dyadic characteristics between the acquiring and acquired firm. This is explained in the concept of relative absorptive capacity (Lane and Lubatkin 1998). Recent technological M&A research has put its emphasis on the importance of relative absorptive capacity and started to examine dyadic factors (Bauer and Matzler 2014; Sears and Hoetker 2014). Our study follows this approach and also develops its hypotheses following dyadic perspectives.

Among the various dyadic aspects of firm resources and capabilities of technological M&As, our study focuses on the role of technological similarity and technological digestibility. According to the framework of Zahra and George (2002), acquisition, assimilation, transformation, and exploitation processes are necessary for applying knowledge to innovation. However, prior technological M&A research, which used a dyadic perspective, focused on the acquisition process (Bauer and Matzler 2014; Sears and Hoetker 2014) and did not examine factors which affect the assimilation, transformation, and exploitation processes of the absorptive capacity. Thus, examining the factors which affects these processes is required to better understand the performance differences between technological M&A deals. Our variables, technological similarity and technological digestibility, are representative factors which affect the absorption and integration of knowledge (Kitching 1967; Kogut and Zander 1992; Grant 1996; Ranft and Lord 2002). In addition, we examine the moderating role of M&A experience on the relationship between the dyadic characteristics and the innovation performance of technological M&As. Acquisition-specific capabilities which are accumulated through M&A experiences allow a firm to develop capabilities that strengthen the creation of innovation through the firm's technological M&A strategy.

Our research makes five contributions to unravel the link between technological M&A and innovation performance. First, we link a dyadic perspective with the framework of Zahra and George (2002). Second, we introduce the concept of technological digestibility to the M&A literature. This allows to examine the tacit knowledge aspects in the acquiring and acquired firm. Third, we examine the moderating role of acquisition-specific capabilities. Our findings enable us to investigate the effect of the characteristics of the focal M&A as well as the indirect effect of prior M&A experience. Fourth, we extend the application of the M&A experience from general M&A deals to the ever-increasing domain of technological M&As (Hayward 2002). Fifth, our study highlights that accumulating M&A experience by acquiring small firms is an efficient strategy for creating innovation.

This paper is organised as follows. The first section describes technological M&A and presents the logical background for our hypotheses, linking them to prior research. Section 2 provides details of our employed research model. Using zero-inflated negative binomial regression, we test our hypotheses using data on 212 technological M&A deals of 113 firms in the biopharmaceutical industry from 1993 to 2007. Section 3 presents the result of our empirical analysis, and the final section provides discussions and conclusion.

2. Theoretical background and hypotheses

2.1. *Technological M&A and recent trends*

The pattern of recently concluded M&As is different from that of the past. Generally, M&As are undertaken for purposes such as increasing market share, building economies of scale and scope, accessing new markets, and diversification (Trautwein 1990; Berkovitch and Narayanan 1993; Chakrabarti, Hauschildt, and Süverkrüp 1994; Hagedoorn and Sadowski 1999). For example, Google's acquisition of Youtube and Facebook's acquisition of Instagram are examples of M&As pursuing conventional objectives. Different from these non-technological M&As, firms pursue technological M&As to intensify their research and development capabilities by absorbing the knowledge of the acquired firm and create innovation which could not have been generated by using only their own resources (Ahuja and Katila 2001). Google's acquisition of Android, Titan Aerospace, and Nest Labs as well as Apple's acquisition of Siri are examples of such technological M&As. The M&A literature review performed by Rossi, Tarba, and Raviv (2013) found that acquiring the technologies of the target firm was a major motive of M&A in the biotechnology, ICT, electronics, and telecommunications industries and that the number of technological M&A deals is constantly increasing. However, a lot of research points out that so far that insufficient attention has been given to technological M&As (Wagner 2011; Valentini 2012; Rossi et al. 2013; Bena and Li 2014; Bauer and Matzler 2014; Lodh and Battaggion 2014; Datta and Roumani 2015). Our study aims to increase the understanding of technological M&As by examining factors that influence the subsequent innovation performance of technological M&A deals.

Non-technological M&A deals are excluded from the final sample of our study, because they do not affect the creation of innovation (Ahuja and Katila 2001; Cloodt et al. 2006). We identify technological M&A according to the definition provided by Ahuja and Katila (2001) who conducted a leading study on technological M&A. They classified a M&A deal as technological if the acquired firm had at least one patent granted in the five-year period preceding the M&A or non-technological otherwise.

2.2. *Prior research on technological M&As and innovation performance*

The extant literature on the relationship between technological M&A and innovation performance focused on examining factors which affect innovation after the technological M&A and can be categorised depending on the subject of analysis. First, prior studies have shown that the technological M&A deal itself has an effect on subsequent innovation (Wagner 2011; Valentini 2012). These studies see technological M&A as the process of bringing external knowledge into the acquiring firm. Accordingly, their view is that conducting technological M&A provides novel knowledge to the acquiring firm and helps to create innovation. Second, several scholars argue that the characteristics of the knowledge base of the acquiring firm are central to creating innovation. For instance, Prabhu et al. (2005) investigated the effects of knowledge breadth and depth of the acquiring firm and Desyllas and Hughes (2010) examined the role of the knowledge base size on the innovation performance. Other studies have analysed the effects of the acquired firm's knowledge characteristics on subsequent innovation (Ahuja and Katila 2001; Cloodt et al. 2006; Lin and Jang 2010; Datta and Roumani 2015). For example, Datta and Roumani (2015) argue that the size, radicalness, and emphasis of the acquired firm's knowledge base have effects on the innovation performance. The above studies contribute to technological M&A literature by recognising technological M&A as a way of transferring knowledge and by examining the effects of firm-level knowledge factors. However, according to the relative absorptive capacity theory of Lane and Lubatkin (1998), it is ascertained that the absorptive capacity of a firm changes depending on its partner. In the M&A context, the different relative absorptive capacity explains the difference in the outcome of M&As with different targets. In addition, previous literature discussed that the innovation performance of a firm engaging in external technology sourcing is influenced by the relative knowledge base characteristics (Lane and Lubatkin 1998; Zahra and George 2002) and relative capability differences in terms of the organisation perspective (Lichtenthaler 2008). Therefore, adopting a dyadic perspective on technological M&A research increases our understanding of technological M&A.

Accordingly, some literature on technological M&A adopted a dyadic perspective to investigate the determinants of creating innovation (Bauer and Matzler 2014; Sears and Hoetker 2014). For example, Sears and Hoetker (2014) elucidate that the acquiring firm learns more from the acquired firm when the knowledge overlap is low. The basis for this argument is the assumption that a large amount of new knowledge of the target firm allows the acquirer firm to create more innovation. However, according to the absorptive capacity reconceptualization of Zahra and George (2002), acquisition, assimilation, transformation, and exploitation processes are required to apply knowledge to innovation. To advance the understanding of prior research which focused on the examination of the effects of a large amount of new knowledge acquisition, investigating the factors which affect the assimilation, transformation, and exploitation processes is necessary. Our variables, technological similarity and technological digestibility, are important factors that affect the absorption and integration of knowledge via the assimilation, transformation, and exploitation processes (Kitching 1967; Kogut and Zander 1992; Grant 1996; Ranft and Lord 2002). Also, the concept of technological digestibility, which has been already adopted in other collaboration strategy literature such as alliances, allows to examine the tacit knowledge aspects in the acquiring and acquired firm. Our research is the first one to apply the concept of technological digestibility to the technological M&A research.

Moreover, while previous research has tested the direct effect of M&A experience on post-M&A performance, the moderation effect of M&A experience on the impact of dyadic perspective factors is examined. The investigation of the moderating role of M&A experience allows to exemplify how the accumulated knowledge of utilising the acquired resource through technological M&As affects the effects of dyadic perspective factors on the assimilation, transformation, and exploitation process in the course of creating innovation.

2.3. *Dyadic perspectives on the innovation performance of technological M&A*

2.3.1. *Technological similarity*

Knowledge attributes of both the acquiring and acquired firms influence the degree of absorption and integration of the acquired knowledge. In particular, the knowledge similarity between the two firms has a close relationship with the relative absorptive capacity of the acquiring firm.

Similar technological knowledge implies that both firms share a similar language and recognition structure, which facilitates the transfer of explicit and tacit knowledge (Cohen and Levinthal 1989; Lane and Lubatkin 1998). Thus, technological knowledge similarity with the acquired firm helps the acquiring firm absorb more knowledge.

Furthermore, according to Kogut and Zander (1992) and Grant (1996), similar knowledge supports the integration of knowledge of both the acquiring and acquired firms. Absorbing knowledge is not enough to create innovation; instead, absorptive capacity is necessary for integrating and assimilating knowledge (Cohen and Levinthal 1990). Therefore, similar technological knowledge allows the acquiring firm to better utilise its relative absorptive capacity and create subsequent innovation (Lane and Lubatkin 1998).

On the contrary, if the acquiring firm and the acquired firm have dissimilar knowledge bases, a gap in the R&D method or routine of innovation between the two firms occurs (Kogut and Zander

1992). Even though the acquired firm has valuable knowledge, the dissimilarity disrupts the knowledge transfer, and the acquiring firm will find it difficult to absorb the acquired knowledge (Mowery, Oxley, and Silverman 1998). In turn, difficulty in knowledge transfer would hinder knowledge integration of the acquiring and the acquired firm, negatively affecting the creation of innovation.

While increasing technological similarity makes the integration easier, it might have a detrimental effect of the actual innovation outcome. A large overlap of knowledge might not provide sufficiently new knowledge and not 'serve as the basis for absorbing additional stimuli and information from the external environment' (Ahuja and Katila 2001).

In conclusion, technological similarity between the acquiring and the acquired firms affects an M&A's subsequent innovation performance (Lubatkin 1983; Singh and Montgomery 1987; Lane and Lubatkin 1998). Different levels of similarity of the technological knowledge between the acquiring and acquired firm have positive or negative effects on the acquiring firm's innovation performance. Hence, the following hypothesis is proposed:

> Hypothesis 1: In technological M&As, the technological similarity has an inverted U-shape relationship with the acquiring firm's subsequent innovation performance.

2.3.2. *Technological digestibility*

Technological digestibility, first introduced by Hennart (1988), implies that the knowledge size difference between firms affects the degree of knowledge absorption between them. In the M&A context, technological digestibility can lead to difficulties when the acquired firm has a relatively larger knowledge base compared with the acquiring firm. However, a large knowledge base of the acquired firm might also have positive effects through broadening the knowledge of the acquiring firm. Consequently, some firms prefer the acquired firm to have a large knowledge base, because more knowledge leads to more innovation (Cloodt et al. 2006). In other words, a trade-off is observed in the relative size of knowledge base and innovation performance. Therefore, a closer look into whether a relatively large or small knowledge base of the acquired firm is better for innovation is warranted.

Generally, the integration of the knowledge of the acquired and acquiring firms is easier if the relative size of the knowledge base of the acquiring firm is small (Ranft and Lord 2002; Cloodt, et al. 2006). In turn, because the acquiring firm could digest more of the acquired knowledge, a positive effect on subsequent innovation can be expected. Conversely, if the acquired firm's knowledge base is relatively large compared to that of the acquiring firm, the number and complexities of new procedures, routines, and relationships required to integrate and digest the knowledge of the acquired firm also increase (Carayannopoulos and Auster 2010). Therefore, when the relative size of the knowledge base compared with the acquiring firm is large, the acquiring firm requires more time, energy, and resources to absorb the knowledge of the acquired firm, negatively influencing the creation of innovation (Kitching 1967; Cloodt et al. 2006; Paruchuri, Nerkar, and Hambrick 2006).

The relative size of the knowledge base in technological M&As has already been considered in the study of Ahuja and Katila (2001). Their focus, however, was different from the technological digestibility in our study. Ahuja and Katila (2001) employed the ratio of the acquiring and acquired firms' patents as the measure for the relative size of the acquired firm's knowledge base. However, as patents are explicit knowledge repositories and do not represent tacit knowledge, a more suitable way of comparing the actual repositories of knowledge and technology of the firms is required. According to Paruchuri et al. (2006), employees are repositories of knowledge and technology of the firm, and Argote and Ingram (2000) see employees as the most powerful reservoir of knowledge, because of their explicit and tacit knowledge. Therefore, technological digestibility, that is, the ratio of employees between the acquiring and acquired firms, is a suitable concept to estimate the relative knowledge base.

In conclusion, if the acquired firm possesses a relatively large knowledge base, the acquiring firm gains access to a large amount of knowledge but would have difficulty in digesting, that is, transferring, integrating, and applying it towards innovative outcomes. Therefore, for an efficient innovation outcome, the acquiring firm is required to choose its M&A targets based on the measure of digestibility. Accordingly, the following hypothesis is presented:

Hypothesis 2: In technological M&As, the greater the technological digestibility, the greater will be the subsequent innovation performance of the acquiring firm.

2.4. *The influence of M&A experience on the subsequent innovation performance*

2.4.1. *The direct effects of M&A experience*

The subsequent innovation performance of the acquiring firm can be affected by the dyadic knowledge characteristics but also by acquisition-specific capability. In other words, all other factors being equal, firms that have more prior M&A experience will exhibit a better innovation performance.

Acquisition-specific capabilities from accumulated M&A experience provide knowledge that improves M&A performance (Hitt, Harrison, and Ireland 2001; Laamanen and Keil 2008; Trichterborn, zu Knyphausen-Aufseß, and Schweizer 2015). When the two organisations interact, conflict inevitably occurs. Acquisition-specific capability facilitates the management of such conflicts. According to the dominant general management logic of Prahalad and Bettis (1986), acquisition-specific capability helps the acquiring firm learn to integrate and reduce the conflict of organisations. Acquisition-specific capability gained through prior M&A experience also provides a learning mechanism that facilitates the effective capture, absorption, and integration of knowledge (Hayward 2002). Therefore, M&A experience positively affects the creation of innovation. Accordingly, the following hypothesis can be stated:

Hypothesis 3: In technological M&As, greater M&A experience of the acquiring firm leads to a greater subsequent innovation performance.

2.4.2. *The moderating role of M&A experience*

Besides the direct effect on subsequent innovation performance, M&A experience can also intensify the relationship between the dyadic characteristics and innovation performance. M&A experience is a factor related to the facilitation of knowledge absorption and integration (Hayward 2002). In other words, M&A experience helps reduce conflict as the acquiring and acquired firms integrate and cooperate, effectively serving as a catalyst.

For technological M&A, prior experience can help the acquiring firm create innovation, because it affects the flow of technological knowledge to the acquiring firm. The direct effect of M&A experience on innovation is examined in Hypothesis 3. Hypothesis 4, meanwhile, examines the moderating role of M&A experience. The baseline hypotheses are that technological similarity and technological digestibility have a relationship with the acquiring firm's subsequent innovation performance. Acquisition-specific capability gained through prior M&A experience can intensify this relationship by facilitating the transfer and integration of knowledge from the acquired firm. Therefore:

Hypothesis 4a: In technological M&As, increasing M&A experience of the acquiring firm strengthens the relationship between technological similarity and subsequent innovation performance.

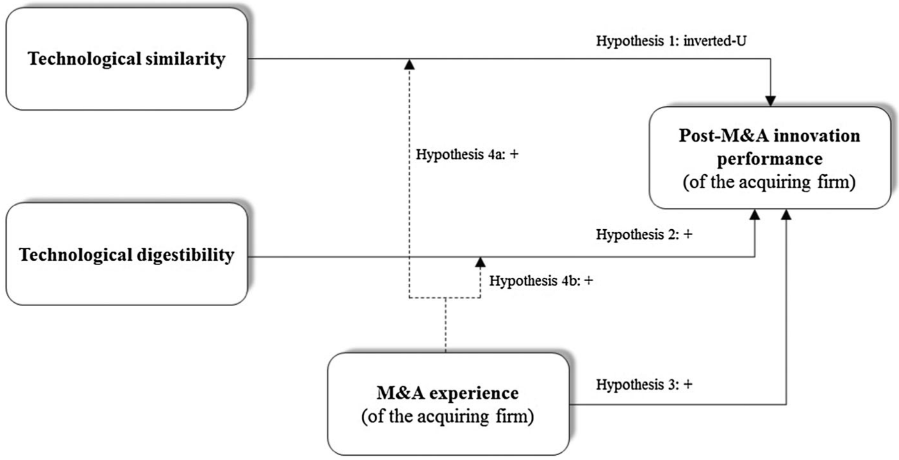

Figure 1: Research model conceptualisation and hypotheses.

> Hypothesis 4b: In technological M&As, increasing M&A experience of the acquiring firm strengthens the relationship between technological digestibility and subsequent innovation performance.

Figure 1 shows a conceptual diagram of the research model summarising our hypotheses.

3. Methodology

3.1. *Data and sample*

Our hypotheses were empirically tested on a dataset containing data of 212 technological M&A deals of biopharmaceutical firms in a range of countries including amongst others the United States, Germany, Japan, and India. The biopharmaceutical industry was chosen for several reasons. First, this industry encourages patenting activity, thus allowing a more precise estimation of firms' innovation capability. Second, the industry can be divided into several sub-industries representing distinct types of knowledge, thus, allowing diverse analysis to be undertaken within a single industry (Carayannopoulos and Auster 2010). In addition, knowledge in the biopharmaceutical industry is tacit rather than explicit (Al-Laham and Amburgey 2005) and uncertainty is high; thus, firms usually conduct M&A to increase their innovation capability and continually keep up with the market (Higgins and Rodriguez 2006). For these reasons, the biopharmaceutical industry provides a good context for the study of technological M&As.

We collected data on 1133 M&A deals from the SDC Platinum M&A database. The SDC Platinum M&A database provides acquisition deal data in the biopharmaceutical industry. These 1133 M&A deals occurred from 1993 to 2007. We also obtained data on United States patent applications and granted patent of the acquiring and acquired firms from 1990 to 2010 through USPTO and, in accordance with Ahuja and Katila (2001), only considered technological M&A deals in which the acquired firm had been granted at least one patent in the 5 years preceding the M&A. The United States represents the biggest technological market in the world, and as such, this is where the highest number of patent litigations has been recorded. Thus, United States patents were used in our study because both United States and foreign companies usually apply for United States patents in order to be protected from patent infringement (Albert, Avery, Narin, and McAllister 1991). In addition, Dosi, Pavitt, and Soete (1990) provide evidence that a United States patent is a good measure of the innovative performance of foreign firms. After examining the patents of the firms in our sample, the firms' financial data from 1990 to 2010 were obtained through the Datastream database. After excluding technological M&A deals with missing data, the final dataset used for our empirical analysis contained 212 technological M&A deals conducted from 1993 to 2007 by 113 firms.

3.2. *Dependent variable*

3.2.1. *Innovation performance*

The goal of this paper is to examine the impact of technological M&A on the subsequent innovation performance of the acquiring firm. Thus, the dependent variable is the subsequent innovation performance of the acquiring firm following the M&A deal.

According to prior research, innovation output is directly related to the number of patents a firm has generated (Ahuja 2000; Owen-Smith and Powell 2004; Rothaermel and Hess 2007); thus, the dependent variable is measured by the difference in the number of US patent applications which resulted in granted patents before and after the M&A for each acquiring firm (Ernst and Vitt 2000). When using patent data, the selection of a suitable time frame for the analysis is an important issue. Generally, the technology covered by a patent loses most of its value within 5 years (van de Vrande, Vanhaverbeke, and Duysters 2009). Thus, 5 years after the acquisition, the impact of knowledge from the acquired firm is imperceptible. While the speed of technology transition in a technologically advanced industry such as the biopharmaceutical industry is very fast, a time lag occurs between knowledge absorption and the actual patent application (Rothaermel and Hess 2007). Therefore, the post-M&A patent count for the dependent variable is based on the patents of the acquiring firm applied for 1–3 years after the acquisition. Similarly, a time period of 1–3 years before the acquisition is used to count the pre-M&A patents. Due to the fact that no appropriate methodologies to deal with non-negative count values exist, we converted all negative values of our dependent variable to zero.

3.3. *Independent variables*

3.3.1. *Technological similarity*

The study compares the patent classes present in the patent portfolios of the acquiring and acquired firms to measure the technological similarity (Carayannopoulos and Auster 2010). When both firms hold patents in similar patent classes, the technological similarity between the acquiring and acquired firms is considered to be high. Specifically, the following formula has been employed to calculate this overlap:

$$\text{Technological similarity} = \frac{\mathrm{PC}_{i,t} \cap \mathrm{PC}_{j,t}}{\mathrm{PC}_{i,t} + \mathrm{PC}_{j,t} - (\mathrm{PC}_{i,t} \cap \mathrm{PC}_{t,j})} \quad (1)$$

where $\mathrm{PC}_{i,t}$ and $\mathrm{PC}_{j,t}$ are the patent class of the acquiring and acquired firms in the 3 years preceding the M&A at time *t*, respectively. Thus, the variable technological similarity ranges from zero to one, wherein zero implies that the acquiring and acquired firms share no technological background at all, and one implies that the acquired firm has exactly the same technological background as the acquiring firm.

3.3.2. *Technological digestibility*

Hennart (1988), the progenitor of technological digestibility, measured technological digestibility using the ratio of the number of employees of the acquired and acquiring firms. In our study, the variable was operationalised following this definition as well. As mentioned previously, employees are repositories of knowledge and technology of the firm; thus, this variable is a suitable way to reflect the relative knowledge base of a firm. More specifically:

$$\text{Technological digestibility} = \frac{\text{Number of employees of the acquired firm in the M\&A deal year}}{\text{Number of employees of the acquiring firm in the M\&A deal year}} \quad (2)$$

By the definition of this variable, a higher value of technological digestibility makes it more difficult for the acquiring firm to capture and apply the target firm's knowledge. Given that the influence of this variable on the regression results and the intuitive understanding of its notion are opposite, careful interpretation of the results is needed.

3.3.3. *M&A experience*

The independent variable M&A experience was examined in two ways, namely, in terms of its direct impact and its moderating impact on the relationships of the dyadic variables. M&A experience was measured by the number of M&A deals of the acquiring firm preceding the M&A deal being examined. In the research, hypotheses for the moderation effect were verified by multiplying the dyadic independent variables by M&A experience, a common method of verifying the moderation effect. Specifically, (technological similarity × M&A experience) and (technological digestibility × M&A experience) were tested.

3.4. *Control variables*

Three variables were used to help control alternative explanations of the subsequent M&A innovative performance of the acquiring firm. A study by Cohen and Levinthal (1990) indicated the relationship between absorptive capacity and the creation of innovation. R&D intensity was chosen as the control variable for the study because absorptive capacity could be intensified by accumulated technological knowledge and investment in technological capability (Cohen and Levinthal 1990). R&D intensity was measured by the R&D expenditure over sales in the year of the M&A deal. In addition, the effect of a R&D paradigm shift in the biopharmaceutical industry was controlled. After the year 2000, the average R&D expenditure in the biopharmaceutical industry increased by 14%, but the success rate of clinical demonstrations decreased from 20% to 8%. This indicates that a paradigm shift in the industry took place around the year 2000, as productivity of R&D in the biopharmaceutical industry rapidly decreased. Thus, we introduced a dummy variable in which M&A deals before the year 2000 are coded as 0, while M&A deals after the year 2000 are coded as 1. Furthermore, although foreign and United States firms applied for patents in the United States to guarantee protection from patent infringement, the nationalities of the firms were controlled, because national differences of the firms could affect their innovation performance. Thus, using another dummy variable, United States firms were coded as 1, while non-United States firms were coded as 0.

3.5. *Empirical model specification*

The dependent variable of the study is a countable variable, and as a result, ordinary least square regression models could not be employed in the research. Generally, when the dependent variable is a countable variable, such as a number of events in a certain period, Poisson regression is used

Table 1: Descriptive statistics and correlations among the variables.

Variable	1	2	3	4	5	6	7	Mean	SD
R&D intensity	1.00							1.3472	6.7716
Nation	−0.058	1.00						0.6669	0.4713
R&D paradigm shift	0.037	0.069	1.00					0.7972	0.4030
Technological similarity	−0.048	0.008	−0.059	1.00				0.4353	0.2698
Technological digestibility	0.010	0.125	0.064	0.047	1.00			0.1159	0.2215
M&A experience	−0.098	0.100	−0.014	−0.027	−0.131	1.00		2.3113	2.9940
Innovation performance	−0.044	−0.239	−0.050	0.199	−0.127	0.237	1.00	17.2830	45.9885

(Hausman, Hall, and Griliches 1984). However, Poisson regression can be employed only when the mean of the variable is the same as the variance of the variable. Table 1 shows that the mean and variance of the dependent variable are quite different. Thus, Poisson regression could not be employed. Generally when the variable is countable and shows over-dispersion, negative binomial regression is employed. However, the dependent variable of this study has 92 zero values out of a total of 212 values. Thus, the use of ordinary generalised linear models would make the model lose its reliability. For this reason, we employed zero-inflated negative binomial regression to verify the proposed hypotheses (Greene 1994). We also implemented a Vuong test to evaluate the suitability of zero-inflated negative binomial regression over negative binomial regression. In the Vuong test, the z-statistic shows whether the zero-inflated negative binomial is a better choice than the negative binomial regression (Long 1997). The result of the Vuong test showed that the *p*-value is .0000 which implies that zero-inflated negative binomial regression should be used.

4. Results

Table 1 presents the correlation and descriptive statistics for the variables included in the analysis. All variables in our hypotheses have an appropriate correlation value below 0.3.

Low correlation between the variables implies that the models have a very low possibility of multicollinearity. However, as the presence of multicollinearity would cause serious problems, we conducted a variance inflation factor (VIF) test. If the value of VIF is above 10 or value of tolerance, which is one over the value of VIF or less than 0.1, multicollinearity is very likely (Myers 1990). According to the results presented in Table 2, we rule out the possibility of multicollinearity in our models.

Table 2: Results of the VIF test.

Variable	VIF	1/VIF
R&D intensity	1.02	0.9839
Nation	1.04	0.9638
R&D paradigm shift	1.01	0.9865
Technological similarity	1.01	0.9909
Technological digestibility	1.04	0.9583
M&A experience	1.04	0.9599
Mean VIF	1.03	

Table 3 presents the results for all models using zero-inflated negative binomial regression. Model 1 reflects the effect of only the control variables. As indicated in Model 1, R&D intensity and Nationality have a strong relationship with innovation performance, but the effects from the R&D paradigm shift do not show any statistical significance. It implies that the paradigm shift seen in the biopharmaceutical industry did by itself not affect the firms' innovation productivity. Models 2–5 show the same results for the control variables. Model 2 shows the result of the direct independent variables, and Models 3–4 show the results of the direct independent variables and moderator variables. Finally, in Model 5 the full model, containing all variables used in our analysis, is presented.

Hypothesis 1 argues that the technological similarity and innovation performance have an inverted U-shape relationship. In Table 3, the coefficient for technological similarity did not demonstrate any statistical significant result and thus Hypothesis 1 could not be verified. While the results in Table 3 did not provide a significant result, we find empirical evidence to support Hypothesis 1 in the results of the additional sensitivity tests, which is discussed in Section 4.1. In our Hypothesis 2, a positive relationship between the technological digestibility of the acquiring firm and the subsequent innovation performance has been proposed. We find strong empirical evidence to support Hypothesis 2. As stated in the description of the independent variables, a negative coefficient of technological digestibility does not imply a negative impact of technological digestibility. According to Hennart (1988), in the definition of technological digestibility, the

Table 3: Zero-inflated negative binomial regression results for innovation performance (Type I in Table 5).

Dependent variable: innovation performance	Model 1 Coefficient (SE)	Model 2 Coefficient (SE)	Model 3 Coefficient (SE)	Model 4 Coefficient (SE)	Model 5 Coefficient (SE)
Control variables					
R&D intensity	−0.0370**	−0.0281**	−0.0281**	−0.0288**	−0.0288**
	(0.0117)	(0.0113)	(0.0113)	(0.0113)	(0.0113)
Nation	−0.7626**	−0.9947***	−0.9943***	−1.0463***	−1.0458***
	(0.2558)	(0.2233)	(0.2234)	(0.2242)	(0.2243)
R&D paradigm shift	−0.2493	−0.0493	−0.0534	−0.1486	−0.1509
	(0.3243)	(0.2941)	(0.2948)	(0.2999)	(0.3004)
Independent variables					
Technological similarity		1.1656	1.1099	1.1117	1.0727
		(1.6267)	(1.6462)	(1.6259)	(1.6439)
Technological similarity squared		−0.0622	−0.0644	−0.0557	−0.0586
		(1.5053)	(1.5041)	(1.4990)	(1.4982)
Technological digestibility		−1.5171***	−1.5122***	−1.0363**	−1.0348*
		(0.4498)	(0.4505)	(0.5713)	(0.5718)
M&A experience		0.1190***	0.1092**	0.1210***	0.1138**
		(0.0304)	(0.0527)	(0.0308)	(0.0536)
Technological similarity × M&A experience			0.0227		0.0168
			(0.1024)		(0.1045)
Technological digestibility × M&A experience				−0.3748	−0.3723
				(0.2787)	(0.2789)
N (Zero obs)	212(120)	212(120)	212(120)	212(120)	212(120)
Log likelihood	−417.5717	−397.2102	−397.1855	−396.3764	−396.3634
LR χ^2	15.35	56.07	56.12	57.74	57.77
Regression *p*-value	.0003	.0000	.0000	.0000	.0000

$^{*}p < .10$.
$^{**}p < .05$.
$^{***}p < .01$.

number of employees of the acquired firm in the M&A year is in the numerator, and so a negative coefficient of the variable represents a positive relationship between technological digestibility and subsequent innovation performance. The M&A experience of the acquiring firm was also expected to lead to an increased innovation performance. The coefficients of M&A experience in all models are positive and significant, thus strongly supporting Hypothesis 3.

However, the interaction effects between M&A experience and the two dyadic variables are not statistically significant, thereby providing no support for Hypotheses 4a and 4b. A reason for why the moderation effects show insignificant results although the direct effect of M&A on subsequent innovation performance is strongly supported is given as follows. Haleblian and Finkelstein (1999) state that differences in M&A experience research results are caused by studies that do not classify prior M&A experience as similar or dissimilar with the M&A deal investigated. On a slightly similar note, in testing the moderation effect with the learning effect of the technological variables, a more detailed classification of M&A experience is required. Specifically, classifying M&A experience as technological or non-technological M&A experience would help to identify the interaction effects. Therefore, we expect follow-up studies to investigate the moderating role of M&A experience using a more fine-grained approach.

4.1. *Sensitivity analysis*

To improve the robustness of our test results and conclude whether Hypothesis 1 is supported or not, our study conducted seven sensitivity analysis with various test setting.

First, we changed the measurement of the dependent variable. Besides the employed change in patenting activities, there are various other measurements of innovation performance. One of the most frequently used measurements is the number of US patent applications which resulted in granted patents for each acquiring firm (Ahuja 2000; Ahuja and Katila 2001; Owen-Smith and Powell 2004; Puranam and Srikanth 2007; Rothaermel and Hess 2007). We adopted this as the measurement of the dependent variable and performed additional analyses. The change of measurement gave rise to a change of the distribution of the dependent variable. The new dependent variable shows over-dispersion, but does not contain as many zero values as the original dependent variable. Accordingly, we changed the analysis model to negative binomial regression. As a result, we found support for Hypothesis 1 and further support for the other findings of our study. Table 4 shows the results of the sensitivity analysis by changing the measurement of innovation performance and using negative binomial regression.

Second, we diversified the measurement of technological similarity by analysing the number of the overlapped patent classes. Previous literature has adopted the overlap of the patent classes to measure technological similarity, because the patent class represents the technological characteristics of the patent and there is a strong possibility that patents with similar technologies are classified within the same class (e.g. Hagedoorn and Duysters, 2002; Schildt, Keil, and Maula, 2012). The results from this sensitivity analysis are summarised as Type III test in Table 5.

Third, we changed the measurement of M&A experience to a dummy variable. While the prior measurement represents the extent of M&A experience, the new measurement would simply show whether the acquiring firm has previous M&A experience or not. We found that most of the test results exhibit the same pattern as before. The results are summarised as Type IV test in Table 5.

Fourth, we conducted additional sensitivity analysis using combinations of new measurements of technological similarity, M&A experience, and innovation performance. Interestingly, the results of Type VIII test support Hypothesis 4a: the positive moderation effect of M&A experience on the relationship between technological similarity and subsequent innovation performance. Thus, in spite of the limitation that a number of tests did not demonstrate significant

Table 4: Negative binomial regression results for innovation performance (Type II in Table 5).

Dependent variable: innovation performance	Model 1 Coefficient (SE)	Model 2 Coefficient (SE)	Model 3 Coefficient (SE)	Model 4 Coefficient (SE)	Model 5 Coefficient (SE)
Control variables					
R&D intensity	−0.0400***	−0.0356**	−0.0356**	−0.0366**	−0.0366**
	(0.0122)	(0.0121)	(0.0121)	(0.0121)	(0.0121)
Nation	−0.0148	−0.1055	−0.1061	−0.1538	−0.1533
	(0.2373)	(0.2273)	(0.2272)	(0.2294)	(0.2294)
R&D paradigm shift	−0.8008**	−0.7148**	−0.7165**	−0.7850**	−0.7852**
	(0.2745)	(0.2604)	(0.2604)	(0.2667)	(0.2667)
Independent variables					
Technological similarity		3.5845**	3.6640**	3.5447**	3.5779**
		(1.6003)	(1.6485)	(1.5983)	(1.6476)
Technological similarity squared		−2.6157*	−2.6311*	−2.5529*	−2.5587*
		(1.5071)	(1.5099)	(1.5094)	(1.5115)
Technological digestibility		−2.3430***	−2.3385***	−1.8009***	−1.8031***
		(0.5191)	(0.5205)	(0.7075)	(0.7081)
M&A experience		0.1224***	0.1338**	0.1281***	0.1329*
		(0.0400)	(0.0707)	(0.0413)	(0.0720)
Technological similarity × M&A experience			−0.0271		−0.0117
			(0.1380)		(0.1432)
Technological digestibility × M&A experience				−0.3805	−0.3781
				(0.3311)	(0.3327)
N	212	212	212	212	212
Log likelihood	−1070.1021	−1050.3850	−1050.3659	−1049.7308	−1049.7274
Pseudo R^2	0.0019	0.0252	0.0253	0.0258	0.0258
LR χ^2	14.96	54.39	55.43	55.70	55.70
Regression p-value	0.0019	0.0000	0.0000	0.0000	0.0000

*$p < .10$.
**$p < .05$.
***$p < .01$.

results on Hypothesis 4a, we can argue that the empirical results show support for the existence of a positive moderation effects of M&A experience.

Table 5 presents the test results of our eight difference settings: 1) Type I used the same baseline definitions and methodology as the settings of Table 3; 2) Type II changed the measurement of innovation performance to the number of patents and employed negative binomial regression as reported in Table 4; 3) Type III used the alternative measurement of technological similarity of the number of overlapped patent classes; 4) in Type IV, M&A experience was measured using a dummy variable; 5) Type V changed the methodology to negative binomial regression and used different measurements for technological similarity and innovation performance; 6) Type VI changed the methodology to negative binomial regression and used different measurements for M&A experience and innovation performance; 7) Type VII used alternative measurements for technological similarity and M&A experience; and 8) Type VIII adopted alternative measurements for technological similarity, M&A experience and innovation performance and employed negative binomial regression.

In summary, the results of our empirical study show an inverted U-shape relationship between technological similarity and innovation performance. Because a research paper, in general, concludes the support of its hypotheses with one or two tests, the significant results of four tests

Table 5: Sensitivity analysis results.

Test type	Variable name	Model 1	Model 2	Model 3	Model 4	Model 5
Type I (same as Table 3)	Technological similarity		x	x	x	x
	Technological similarity squared		x	x	x	x
• Baseline definitions and methodology	Technological digestibility		***	***	**	*
	M&A experience		***	**	***	**
	Technological similarity × M&A experience			x		x
	Technological digestibility × M&A experience				x	x
Type II (same as Table 4)	Technological similarity		**	**	**	**
	Technological similarity squared		*	*	*	*
• Innovation performance:	Technological digestibility		***	***	***	***
number of patents	M&A experience		***	**	***	*
• Negative binomial regression	Technological similarity × M&A experience			x		x
	Technological digestibility × M&A experience				x	x
Type III	Technological similarity		**	**	**	**
	Technological similarity squared		x	x	x	x
• Technological similarity:	Technological digestibility		***	***	**	**
the number of overlapped patent class	M&A experience		***	**	***	**
• No methodology change	Technological similarity × M&A experience			x		x
	Technological digestibility × M&A experience				x	x
Type IV	Technological similarity		x	x	x	x
	Technological similarity squared		x	x	x	x
• M&A experience:	Technological digestibility		***	***	***	***
M&A experience dummy	M&A experience		**	x	*	x
• No methodology change	Technological similarity × M&A experience			x		x
	Technological digestibility × M&A experience				x	x

(*Continued*)

Table 5: Continued.

Test type	Variable name	Model 1	Model 2	Model 3	Model 4	Model 5
Type V	Technological similarity		***	***	***	***
	Technological similarity squared		***	**	**	**
• Technological similarity:	Technological digestibility		***	***	***	***
number of overlapped patent class	M&A experience		***	**	***	**
• Innovation performance:	Technological similarity × M&A experience			x		x
number of patents	Technological digestibility × M&A experience				x	x
• Negative binomial regression						
Type VI	Technological similarity		**	**	**	**
	Technological similarity squared		*	*	*	*
• M&A experience:	Technological digestibility		***	***	***	***
M&A experience dummy	M&A experience		***	x	**	x
• Innovation performance:	Technological similarity × M&A experience			x		x
number of patents	Technological digestibility × M&A experience				x	x
• Negative binomial regression						
Type VII	Technological similarity		**	**	**	**
	Technological similarity squared		x	x	x	x
• Technological similarity:	Technological digestibility		***	***	***	***
number of overlapped patent class	M&A experience		**	*	*	x
• M&A experience:	Technological similarity × M&A experience					x
M&A experience dummy	Technological digestibility × M&A experience			x	x	x
• No methodology change						

(*Continued*)

Table 5: Continued.

Test type	Variable name	Model 1	Model 2	Model 3	Model 4	Model 5
Type VIII	Technological similarity		***	***	***	***
• Technological similarity: number of overlapped patent class	Technological similarity squared		***	***	***	**
• M&A experience: M&A experience dummy	Technological digestibility		***	***	***	***
• Innovation performance: number of patents	M&A experience		***	***	***	***
• Negative binomial regression	Technological similarity × M&A experience			x		*
	Technological digestibility × M&A experience				x	x

Notes: For readability, we report significant test results with *(asterisk) and did not include the test results of control variables. Asterisks *, ** and *** show the significance levels of *$p < .10$, **$p < .05$, and ***$p < .01$, respectively, and the support of the suggested direction in hypotheses. Marked 'X' means no significant result. The definitions of Models 1–5 follow the definitions of Models 1–5 in Table 3.

would be an evidence of hypothesis verification. In other words, in spite of the limitation which shows inconsistent results on the inverted U-shape relationship, we can argue that the inverted U-shape relationship in Hypothesis 1 is supported because multiple tests show the significant results on the inverted U-shape relationship. Technological digestibility is also related significantly to high innovation performance in accordance with the results. Dyadic determinants can be viewed as important elements, since both dyadic characteristics in the research show a strong significance. In addition, the hypothesis on the positive relationship between the M&A experience and subsequent innovation performance is supported. However, the results suggest that the M&A experience as a moderator is mostly not significant.

5. Conclusion and implications

Since the 1990s, the number of technological M&A has substantially increased (Cassiman and Colombo 2006). Firms, especially those in technologically advanced industries, have recently conducted numerous M&As to profit from the resulting technology acquisition and absorption (Bower 2001). However, relatively insufficient academic attention has been given to technological M&A (Wagner 2011; Valentini 2012; Rossi et al. 2013; Bauer and Matzler 2014; Bena and Li 2014; Lodh and Battaggion 2014; Datta and Roumani 2015). Therefore, we examine factors that affect subsequent technological M&A innovation performance to help fill this research gap.

Our findings provide managerial implications to those considering technological M&As. First, the empirical results confirm that the similar knowledge between the acquiring and acquired firm has both an advantage and a disadvantage on post-M&A innovation performance. In terms of the acquisition process part of absorptive capacity, an increase in technological similarity reduces the quantity of acquired new knowledge and gives rise to a decrease in post-M&A innovation. However, in terms of the assimilation, transformation, and exploitation processes of absorptive capacity, a similar technological base provides a similar language and recognition structure which help the absorption and integration of the acquired knowledge. Therefore, the acquiring firm needs to select a M&A target which is similar enough to learn from each other, but dissimilar enough to provide new knowledge to generate new innovation.

Second, we identify the positive effects of acquiring small firms on post-M&A innovation performance. The significant effect of technological digestibility found in our study shows the advantage of acquiring small firms. Moreover, using the concept of technological digestibility, our research explains the tendency of large firms conducting technological M&As to acquire technologies of smaller firms.

Third, the positive role of the M&A experience in contributing to the creation of innovation has been identified. Acquiring small, but innovative firms not only provides technological knowledge for generating innovation but also managerial knowledge which helps to reduce conflicts and better acquire knowledge during future M&A deals, which becomes even more important witnessing the current wave of M&As, which is mainly driven by technological M&As.

Fourth, our finding reveals that the acquisition-specific capability through accumulated M&A experience has not only direct effects but also indirect effects on post-M&A innovation. Although only one test demonstrated the supporting result of the moderation effect of M&A experience, our finding suggests that it is important for firms to keep conducting technological M&As to fully utilise the positive effects of determinants, such as technological similarity and technological digestibility, on innovation performance in the next technological M&A.

Our study makes a number of contributions to the research and understanding of technological M&As. First, the framework of Zahra and George (2002) is adopted to a dyadic perspective research to overcome the limitations of previous literature which put their focus only on the acquisition process. Our study focuses on the examination of dyadic perspective factors which affect the assimilation, transformation, and exploitation process of the acquired knowledge.

Second, adoption of the concept of technological digestibility to the technological M&A literature for the first time enables us to compare the tacit knowledge between the acquiring and acquired firm. The knowledge transfer between the acquiring firm and acquired firm is difficult, because of the often tacit nature of knowledge (Szulanski 1996; Cavusgil, Calantone, and Zhao 2003; Cummings and Teng 2003). Accordingly, comparing tacit knowledge between two firms contributes to increasing our understanding of knowledge transfer, absorption, and integration between firms. By adopting the concept of technological digestibility, we were able to examine the tacit knowledge aspects intrinsic in human resources. We broaden the application of the concept of technological digestibility, which has been already adopted in other collaboration strategy literature such as alliances, to the research on technological M&As. In fact, recently the term 'acquihiring' emerged in the business world and shows the increasing importance of human resources in obtaining external technologies and capabilities.

Third, the interaction effects between factors are identified by analysing the moderating role of acquisition-specific capabilities. An increase in acquisition-specific capabilities through a series of M&As gives rise to the accumulation of more knowledge of how to exploit the acquired knowledge. Our study investigated the effects of M&A experience which is one of the most important factors which affect both post-M&A innovation and dyadic perspective factors simultaneously. Through this approach, we are able to understand how the experience gained through previous M&As affects the performance of focal M&A directly and indirectly.

Fourth, while the investigation of the effects of M&A experience on subsequent performance was mainly conducted using samples of general M&A deals (Hayward 2002), we investigate the effects of M&A experience in the ever-increasing domain of technological M&As. A firm that uses a technological M&A strategy tends to conduct multiple M&As rather than only one M&A. Firms in our research sample conducted an average of 2.31 technological M&A deals. Accordingly, the examination of M&A experience in the context of technological M&As is necessary to understand post-M&A innovation performance.

Fifth, our study finds that accumulating M&A experience through acquiring comparatively small firms is efficient for creating innovation. Our research proved the positive effects of technological digestibility and M&A experience. It implies that acquiring small firms and conducting multiple M&As are beneficial to create innovation in the present and subsequent M&As. To summarise these findings, in terms of technological digestibility, M&As with small firms show an improved performance. Moreover, because the acquisition of small firms is less burdensome than that of larger firms, it allows the acquirer to use the remaining resources to conduct other M&As to acquire new knowledge and gain further M&A experience. According to the results of our empirical analysis, the M&A experience has both a positive direct effect as well as a moderating effect. Thus, the M&A experience through multiple acquisition of small firms allows the acquiring firm to create more innovation.

Our study has some limitations that we hope future research in the field will help to address. First, the biopharmaceutical industry could have been divided into several technology subcategories, each exhibiting distinct characteristics related to knowledge and capabilities (Carayannopoulos and Auster 2010). This would enable researchers to examine the various attributes from many angles, although using a single industry could still be problematic. Thus, additional work is needed to apply the findings of our study to other industries. Second, while some tests support the hypothesis of an inverted U-shape relationship between technological similarity and post-M&A innovation performance, the results were not consistent over all tests. To demonstrate and improve the robustness of our test results, our study employed diverse measurements of the dependent variable and independent variables. Accordingly, the number of tests considerably increased and 4 out of total 8 tests show significant results. However, to increase the validity of the results, another measurement of technological similarity could be employed. We followed prior literature in adopting the patent class to measure technological similarity (e.g. Sampson 2007; Makri, Hitt, and Lane 2010); however, other literature has used the patent citation information between the acquiring and acquired firm (Sears and Hoetker 2014). Although our research is not able to employ such a measurement because of insufficient data, future research can address this issue by adopting patent citation data to measure technological similarity. Third, since the effects of M&A experience as a moderator in the research model is verified only in one test, its role should be examined in other settings. For instance, as our study observes M&A from a dyadic perspective, M&A experience could also take a dyadic point of view, which could give rise to new implications. Specifically, in the case of the acquiring firm having prior collaboration experiences with the acquired firm such as through licensing, alliance, and joint venture deals, those experiences might positively moderate the relationships between technological similarity, technological digestibility, and subsequent M&A innovation performance. Therefore, further research on the innovation performance of technological M&A in other settings is needed.

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