Technological and non-technological M&A: the effect on innovation and financial performance in the pharmaceutical industry

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Abstract

Large firms in the pharmaceutical industry are forced to adjust strategies in order to maintain firm value as a result of 'productivity gaps' and 'patent cliffs'. We inquire whether different types of M&A's benefit the largest pharma firms in terms of innovation performance and financial performance. More specifically, we divided M&A deals into technological and non-technological M&A deals. Surprisingly, we find that M&A's with acquiring external sources of knowledge as acquisition motive are not able to increase the number of developed drugs, despite an increase in innovation expenditures. In line with our hypotheses, we find weak support that technological M&A deals have a negative effect on short-term financial performance and that non-technological M&A's will benefit the financial performance of large pharma firms in the short-term. Furthermore, we find no support that either technological or non-technological M&A's will benefit the financial performance of firms in the long-term. These results implicate that large pharma firms will not uniformly overcome the difficulties in the pharmaceutical industry by engaging in the analyzed types of M&A's.

Table of contents

1. Introduction

The pharmaceutical industry can be characterized as a highly profitable (Bradfield & El-Sayed, 2009) and innovative industry (Higgins & Rodriquez, 2006). However, the industry is in the last decade confronted with the 'productivity gap'. This phenomenon can be described as a decline in research and development (R&D) output relative to R&D expenditures (Ruffolo, 2006). Despite the increasing expenditures on R&D, the number of new drugs approved remains constant or even declines over time (Ashburn & Thor, 2004). Moreover, the total average developing time of a new drug has increased and the probability that a potential new drug reaches the next phase of the drug development process is decreasing as well (Pammolli, Magazzini, & Riccaboni, 2011). Only 2 of every 10.000 discovered drugs can eventually be sold on the market (European Federation of Pharmaceutical Industries and Association 2017). Following Munos (2009), big pharmaceutical companies have to approve 2 to 3 new drugs per year to reach their growth goals. The development of these drugs comes with significant cost. DiMasi, Grabowski, and Hansen (2016) estimated that the average total R&D cost of a new drug in 2013 is 2870 million dollars, which is a significant increase compared to their estimated total R&D cost of 900 million dollars of a new drug in 2000 (DiMasi, Hansen, & Grabowski, 2003). Figure 1 shows that the analyzed firms in this study have increasing R&D cost, relative to the size of the firm, but a decreasing number of developed drugs since approximately 2005. This could indicate that the analyzed firms in this study are confronted with the challenges mentioned above.

On top of these challenges, firms in the pharmaceutical industry also have to deal with expiring patents of blockbuster drugs (drugs that generate at least one billion dollar revenues annualy), which has a substantial impact on the financial performance of these firms (Fernald, Pennings, Van Den Bosch, Commandeur, & Claassen, 2017) as revenues drop significantly after patent expiration (Berndt, 2001). Therefore, the industry is searching for new opportunities to maintain its innovation and financial performance levels and change their unsustainable business models (Bunnage, 2011). Mergers and acquisitions (M&A) is one possible strategy that firms in the pharmaceutical industry can pursue to reach the increasing critical mass of R&D activities and replenish the product pipeline (Mittra, 2007) to subsequently improve performance. Previous research suggests that firms indeed follow these strategies in response to the aforementioned problems in the industry. For example, Danzon, Esptein, and Nicholson (2007) show that firms are more likely to engage in M&A activity when patents are expiring.

Well-known examples of M&A's in the pharmaceutical industry are the 68 billion dollar acquisition of Wyeth by Pfizer in 2009 (Financial Times, 2009) and the 63 billion dollar acquisition of Monsanto by Bayer in 2016 (Bloomberg, 2018). The number of M&A deals in the pharmaceutical industry has significantly increased the last decades (Bradfield & El-Sayed, 2009; Statista, 2019). What the intentions of these M&A's were and whether they had the desirable result is questionable. M&A's could for example result in undesirable outcomes when firms are not able to successfully integrate acquired operations (Bradfield & El-Sayed, 2009). Following LaMattina, the former president of Pfizer, M&A's are detrimental to innovation in the pharmaceutical industry as a result of the elimination of R&D departments after an acquisition (Herper, 2011).This could negatively affect the performance of the firm and could have undesirable outcomes for society as well.

Previous literature on M&A and innovation show mixed results. Munos (2009) shows that firms involved in M&A activity seem to have worse innovation performance compared to firms that did not. Valentini (2012) inquires the effect of M&A on both patent quality and quantity and finds that M&A has a positive effect on patent output, but decreases patent quality. Cassiman, Colombo, Garrone, and Veugelers (2005) show that the effect of M&A on R&D is dependent on whether the merged firms have complementary or substitutive technologies. Other studies show that M&A both decreased R&D expenditures and R&D productivity (Ornaghi, 2006). More in-depth studies on M&A and innovation performance investigate the relative size of the acquiring firm and the target firm (Ranft & Lord, 2002), the role of absorptive capacity of the acquiring firm (Fernald et al., 2017), the role of acquisition experience (Al-Laham, Schweizer, & Amburgey, 2010), and how knowledge overlap influences post-acquisition performance (Ahuja & Katila, 2001; Cloodt, Hagedoorn, & Van Kranenburg, 2006). Demirbag, Ng, and Tatoglu (2007) studied the effect of M&A on innovation performance in the pharmaceutical industry. They find that firms are not able to improve research productivity by engaging in M&A activities.

Demirbag, Ng, and Tatoglu (2007) investigate in their study the effect of M&A on financial performance as well and find that firms that engage more in M&A activities do not increase profitability relative to firms that do not engage in M&A activities. Multiple studies inquired the effect of mergers on return on assets and show a negative relationship (Meeks, 1977; Mueller, 1980; Dickerson, Gibson, & Tsakalotos, 1997). However, Ramaswamy and Waegelein (2003) find that mergers did significantly increase financial firm performance in the long-term. In general, there is no consensus in the literature whether M&A activities are beneficial for the financial performance of a firm (Hassan, Patro, Tuckman, & Wang, 2007).

Different motives for M&A are established in the economic literature. These motives include the aim to increase short-term performance, the goal to enhance R&D activities, and the intention to increase market power (Chakrabati, Hauschildt, & Süverkrüp, 1994). These theoretical motives are potentially able to justify why firms in the pharmaceutical industry are involved in M&A activities and how the intention of M&A activities affects firm performance (Grabowski & Kyle, 2008). This research will build on these motives to explain the behavior of pharmaceuticals in terms of M&A activity. By looking at different types of M&A, we will explore how these types affect the firm in terms of innovation input and innovation output and how M&A affects financial performance in both the short and the long-term. Specifically, M&A's will be divided into technological M&A and non-technological M&A deals. As previous studies find no unambiguous effect of M&A on both innovation and financial performance, this study will inquire whether motives behind M&A activity give insight into the different findings in the literature.

This study will add to the literature by analyzing innovation performance and financial performance simultaneously. This could possibly increase the efficiency of the estimation if we take the relatedness between the measures of innovation performance and financial performance into account. Furthermore, this study uses a proxy that is expected to be a more appropriate measure of innovation output compared to the number of patents or patent citations, which is predominantly used in the economic literature. Instead, we measure innovation output with the number of new molecular entities (NMEs) and the number of biologic license applications (BLAs).

This study is organized as follows: in chapter two, we will elaborate on the motives for M&A from the literature and link these to technological and non-technological M&A activity to develop the hypotheses. In chapter three, we will describe and justify the data and the methods that will be used. In the fourth chapter, we will state the results and test the hypotheses . In chapter five, we will discuss the results, draw conclusions and explain the limitations of the analysis.

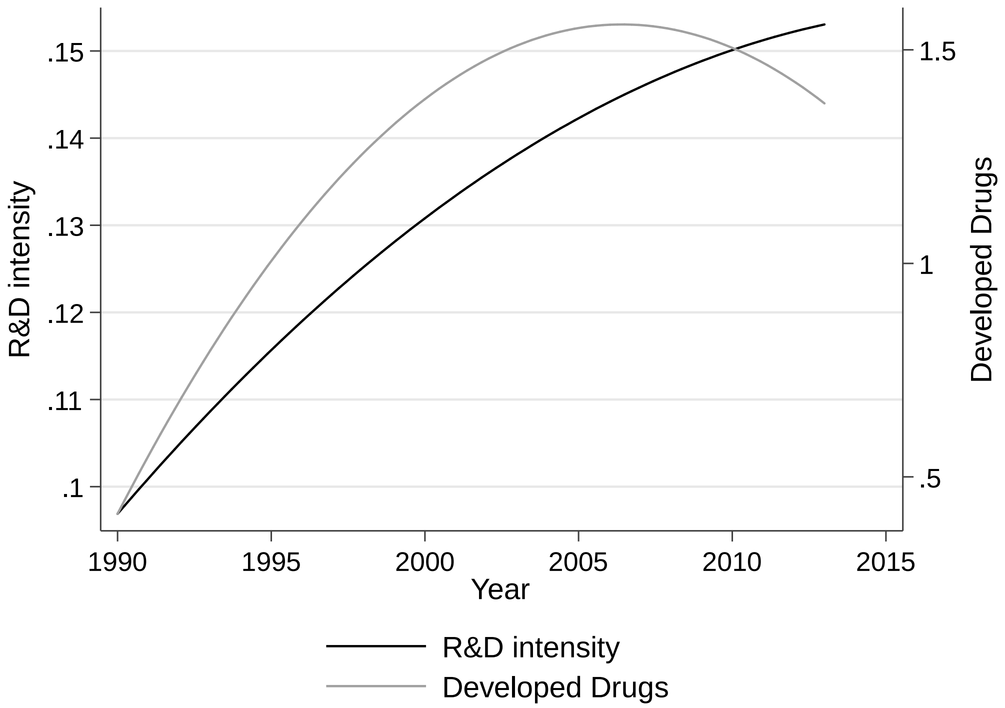

Figure 1. Average of R&D intensity and the number of developed drugs (both new molecular entities and biologic license applications) per firm of the 12 largest pharma firms between 1990 and 2013.

2. Theoretical background and hypotheses

2.1 M&A and innovation performance

2.1.1 Efficiency theory

Some firms engage in M&A activity with the intention to increase the innovative performance of the firm (Sevilir & Tian, 2012). In line with Schumpeter's theory of innovation, we can expect that M&A could lead to new combinations of resources and subsequently, to new innovations (Cassiman, Colombo, Garrone, & Veugelers, 2005). M&A activity is especially in high-tech industries frequently aimed at acquiring external knowledge to improve internal innovation performance (Rossi, Yedidia Tarba, & Raviv, 2013). Duflos and Pfister (2008) find that firms with a lower Tobin's q and decreasing revenues are more likely to be acquirers and firms with radical patents are more likely to be acquired in the pharmaceutical industry. An explanation for this phenomenon is that less innovative firms have the necessity to acquire patents or acquire R&D activities of more innovative firms to enhance their innovation performance. Moreover, Henderson and Cockburn (1994) show that firms in the pharmaceutical industry can profit from external sources of knowledge when they are unable to innovate internally.

Sevilir and Tian (2012) conclude from the model of Aghion and Tirole (1994) that firms that are inefficient in their internal R&D activities, engage in M&A activity to improve efficiency. M&A activities can also be motivated with the aim to acquire a valuable patent when a firm's revenues are dependent on a patent that is expiring. Patent expiration of a blockbuster drug in the pharmaceutical industry is also known as the 'patent cliff' (Munos, 2009). M&A can be used by firms that are heavily dependent on innovations to replenish their R&D output (Mittra, 2007). This is especially applicable to large pharma firms, as these firms are regularly financially dependent on blockbuster drugs (Koenig & Mezick, 2004).

Furthermore, M&A could affect innovation performance of a firm when the assets of the acquiring firm and the target firm are complementary (Harrison, Hitt, Hoskisson, & Ireland, 1991). This idea is supported by the model of Rhodes-Kropf and Robinson (2008), who theorize that mergers have better innovative performance if their assets are complementary as a result of synergies. Complementarity of assets could lead to R&D synergies, which in turn contributes to innovation output (Bena & Li, 2014). Similarly, Cassiman and Veugelers (2006) show that firms can increase innovative performance by complementing internal R&D activities with acquiring knowledge externally.

However, M&A's can have a negative impact on innovation performance as well. For example, mergers often reduce the number of researchers relative to the size of the firm, which might result in the loss of valuable knowledge as researchers are the carriers of tacit knowledge (Ornaghi, 2009). Furthermore, innovation performance could suffer from M&A activity due to difficulties in the integration process. These difficulties may occur as a result of a strong cultural distance between the acquiring firm and the target firm (Steigenberger, 2017). Ernst and Vitt (2000) show that innovative performance of the most innovative employees decreases post-acquisition and find that this effect can be explained by cultural differences of the R&D departments of the target firm and the acquiring firm.

2.1.2 Monopoly theory

The economic literature constitutes a long debate on the relationship between market structure and innovation performance. Following Arrow (1962), market competition is a key factor in why firms do innovate. He argues that firms that are a monopolist in their market have fewer incentives to innovate as these firms mainly consider monopoly profits. Arrow shows that monopoly firms innovate less compared to firms in a competitive market as monopoly firms take the cannibalization of their own profits into account, known as the 'replacement effect'. However, Schumpeter (1942) argues that large firms or firms with more market power are pursuing relatively more innovative activities compared to smaller firms in a competitive market. He shows that monopoly firms take the risk of entrants into account, which provides these firms with an incentive to innovate and protect their market share, known as the 'efficiency effect'. Furthermore, large firms are more likely to have the resources to develop innovations.

Blundell, Griffith, and Van Reenen (1999) find empirical evidence that an increase in market share has a positive effect on innovation in the pharmaceutical industry. Furthermore, they show evidence that firms in the pharmaceutical industry benefit more from innovations in terms of market value if their market share is high. Aghion, Bloom, Blundell, Grifith, and Howitt (2005) developed a model to analyze the effect of product market competition on innovation. They show that competition and innovation are inverted U-shape related. Following their reasoning, at high levels of competition the 'Schumpeterian effect' is likely to be more important and at low levels of competition the 'escape-competition effect' is likely to be more important. The latter is considered to be most applicable to the pharmaceutical industry, which is dominated by a few large firms. The 'escape-competition effect' refers to a situation where firms invest more in innovative activities to maintain a competitive advantage in the market.

Following economic theory, it is ambiguous whether M&A's will have a positive or negative effect on innovation performance. On one hand, M&A deals can improve innovation performance as a result of complementarities of assets and synergies between the target firm and the acquiring firm and the incentive to maintain a competitive advantage. On the other hand, M&A deals could be detrimental to the innovative performance of a firm as a result of the loss of tacit knowledge and integration difficulties.

2.2 M&A and financial performance

2.2.1 Efficiency theory

Synergies exist when the value of the merged firm is higher compared to the value of the sum of the separate firms. Trautwein (1990) states three types of synergies that might arise from M&A; financial synergies, operational synergies, and managerial synergies. Firms could profit from financial synergies by reducing their cost of capital. Lewellen (1971) developed the argument that mergers can benefit the firm by acquiring debt capacity or lowering credit risk through diversification to decrease costs of capital. Furthermore, mergers can be driven by tax advantages of M&A (Mittra, 2007). For instance, tax shields and an increased leverage can arise as a result of M&A activities (Jensen & Ruback, 1983). Hayn (1989) shows evidence that tax advantages can account for the short-term financial performance of acquiring firms.

The second type of synergies are operational synergies. These synergies can be achieved when firms increase their scale or scope of their operations. Larger firms benefit from economies of scale as they can spread the fixed cost over a larger output, which increases efficiency. Economies of scale can arise in various activities of the firm. A firm can benefit from this type of synergies by lowering average production cost and increase efficiency in marketing, R&D, sales, and distribution activities. Moreover, M&A's can contribute to economies of scope if the firm increases efficiency by using the same resource inputs for more products. However, Devos, Kadapakkam, and Krishnamurthy (2008) find in their study that operational synergies do not result in higher operating profits.

Managerial synergies are the third type of synergies that can improve efficiency of the firm. Mergers can create value when the acquiring firm replaces the management team of the target firm with relatively more skilled managers of the acquiring firm (Sudarsanam, Holl, & Salami, 1996). By replacing underperforming managers with more skilled managers of the acquiring firm, efficiency is expected to increase. Martin and McConnell (1991) show that takeovers create value by replacing inefficient managers. Similarly, Matsusaka (1993) finds that acquisitions that are driven to exploit managerial synergies do create value. This provides evidence for the managerial synergies hypothesis.

2.2.2. Monopoly theory

Another motive for engaging in M&A activity is imbedded in the monopoly theory. The monopoly theory applies particularly when the target firm is either vertically or horizontally related to the acquiring firm (Sudarsanam et al., 1996). Trautwein (1990) states three possible advantages of how M&A activities that results in more market power increase firm performance. First of all, firms can use M&A to decrease competition and increase prices and revenues, which is known as collusive synergies (Chatterjee, 1986). Secondly, in the case of multi-market contact, an increased market power could benefit the profitability of the firm in other markets as well. Multimarket competition exists when firms compete simultaneously in multiple markets. This could lead to less competitive behavior if these firms are able to identify the benefits of collusive behavior (Strickland, 1985). The third advantage of M&A is the opportunity to prevent market entry of other firms by setting prices sufficiently low (Stigler, 1950). Empirical studies on the effect of M&A on market power and financial returns show mixed results (Devos et al., 2008). Haleblian, Devers, McNamara, Carpenter, and Davison (2009) reviewed the economic literature on M&A and find limited support that firms acquire other firms with the aim to increase market power.

Economic theory provides multiple motivations why firms engage in M&A activities to improve the financial performance of a firm. Firms can improve their efficiency as a result of economies of scale and scope. Furthermore, firms might be able to profit from an increase in market power that result from M&A deals. Despite these predictions of economic theory, many empirical studies find that M&A's did not improve the financial performance of firms in either the long-term or the short-term or did even destroy firm value (Haleblian et al., 2009). This might indicate that managers maximize their own utility at the expense of shareholders as a result of agency problems (Haleblian et al., 2009).

2.3. Technological and non-technological M&A

In this paper, we split M&A activities into two categories; technological and non-technological M&A. We will assume that technological M&A's will predominantly aim at enhancing R&D activities of the firm and at acquiring external sources of knowledge to counter the 'productivity gap' problem and subsequently replenish the R&D pipeline (Higgins & Rodriquez, 2006). On the other hand, we assume that non-technological M&A activities have the goal of achieving synergies and increase market power to enhance firm performance.

Hitt, Hoskisson, and Ireland (1990) theorize that firms might substitute their innovation activities and by acquiring innovation from other firms, as M&A activities are a source of external innovation and as M&A's are likely to decrease the amount of resources that are available for R&D activities. This argument is expected to be valid, despite of an increase of a firm's leverage after an acquisition, as Hall (1989) shows that leverage is negatively related to R&D investments. Moreover, Vyas and Narayanan (2016) argue that firms prefer to invest less in risky R&D activities after an acquisition to limit the risk that is involved with higher debt levels. This argument is expected to hold for both technological and non-technological M&A. Hitt, Hoskisson, Ireland, and Harrison (1991) show empirical evidence that acquisitions have a significant negative impact on innovation input.

Innovation input is expected to decrease more in the case of technological M&A compared to non-technological M&A. This hypothesis is based on the reasoning of Hitt et al. (1990) who argue that managers are risk-averse, which might restrain them from investing in risky R&D projects. Instead, managers could substitute these projects with acquisitions of innovations, which can be seen as less risky compared to internal R&D activities (Hitt, Hoskisson, Johnson, & Moesel, 1996). Technological M&A is a strategy to acquire a portfolio of patents instead of developing patents in-house and is therefore expected to decrease innovation inputs, compared to non-technological M&A. Furthermore, technological M&A is expected to decrease innovation inputs by cutting overlapping R&D activities of the merging firms. This argumentation does not apply to non-technological M&A's as less innovative target firms provide fewer (relevant) R&D activities to the acquiring firm. To conclude, both types of M&A are expected to have a negative effect on innovation input. However, we expect that the effect of technological M&A will be more detrimental to R&D investments compared to non-technological M&A. Therefore, the first hypothesis is:

H1: Technological M&A is negatively related to innovation input, relative to non-technological M&A.

In contrast to the effect of M&A on innovation input, we expect that technological M&A are better able to improve innovation performance, in terms of increasing innovation output of firms in the pharmaceutical industry, compared to non-technological M&A. This hypothesis is supported by Sevilir and Tian (2012) who show that the benefits of M&A on innovation performance increase as the acquired firm becomes more innovative. Acs and Audretsch (1988) find that R&D input and R&D output are positively related. However, we expect that merging firms increase innovation output despite a decreasing innovation input if the target firm provides the acquiring firm with sufficient R&D synergies. Ahuja and Katila (2001) argue that acquisitions can lead to an expanded knowledge base of the acquiring firm in the case the target firm provides sufficient technological inputs. These inputs can result in efficiencies and synergies in the R&D activities of the firm and subsequently increase innovation output. Following Vyas and Narayanan (2016) and Omaghi (2009), R&D synergies exist because of cross-fertilization of ideas between scientists of the acquiring and the target firm.

Non-technological M&A's are expected to provide the acquiring firm with fewer assets to complement R&D activities (Ahuja & Katila, 2001). These acquisitions are expected to provide insufficient R&D synergies to the firm to maintain or improve R&D output levels despite of decreasing R&D expenditures. Furthermore, firms that engage in non-technological M&A typically have other priorities than spurring innovation. Hitt et al. (1990) argue that acquisitions require significant effort from the management team. This could result in a lower commitment of the management of the firm on innovation and managers will consequently provide fewer incentives for their employees to focus on developing innovations (Hitt et al., 1991). This is expected to decrease innovation output. On the other hand, managers are expected to put sufficient effort into innovative activities in the case of technological M&A as spurring innovation has more priority in that case. Therefore, the second hypotheses are:

H2a: Technological M&A is positively related to innovation output.

H2b: Non-technological M&A is negatively related to innovation output.

Non-technological M&A is expected to be mostly driven by efficiency and revenue improving intentions to increase short-term profits. We expect that the effect of non-technological M&A on short-term financial performance are positive as non-technological M&A can provide firms with synergies to decrease costs and can increase market power to increase revenues in the short term. Dimasi, Grabowski, and Vernon (1995) show evidence for economies of scale in the pharmaceutical industry, which supports the argument that firms in the pharmaceutical industry engage in non-technological M&A for financial reasons. Furthermore, non-technological M&A's can be aimed at exploiting tax advantages to increase profits in the short-term. Therefore, non-technological M&A is expected to have a positive effect on short-term financial performance.

Technological M&A aims at spurring the creation of innovations, which can often not be achieved in the short-term. This is especially applicable to the pharmaceutical industry, where the period from the discovery of a drug till it is launched on the market is 12 to 13 years on average (European Federation of Pharmaceutical Industries and Association, 2017). Furthermore, the period to integrate R&D activities successfully is relatively long (Rossi et al., 2013), which increases costs. Therefore, technological M&A is expected to have a negative effect on short-term profits as a result of integration difficulties. Hence, the third hypotheses are:

H3a: Technological M&A is negatively related to short-term financial performance.

H3b: Non-technological M&A is positively related to short-term financial performance.

Firms that primarily engage in non-technological M&A might in the long-term still be confronted with 'productivity gaps' and 'patent cliffs'. As aforementioned, non-technological M&A is expected to have a negative effect on both innovation input and innovation output. If average R&D costs per new drug continues to rise, this results in a decline in research productivity and subsequently results in a drying drug pipeline. In that case, M&A activities are not be able to improve financial performance in the long-term.

Firms that engage in technological M&A are expected to acquire patents of new blockbuster drugs and improve R&D output. This could provide these firms with a competitive advantage in the long-term. Bloom and Van Reenen (2002) show in their analysis that technological innovations provide firms with growth options. This finding is supported by Artz, Norman, Hatfield, and Cardinal (2010), who show that innovation output is positively related to financial firm performance. Furthermore, DeCarolis and Deeds (1999) find that the number of products in the pipeline of firms in the biotechnology industry is an important indicator of a firm's future profits. This is not surprising as firms in the pharmaceutical industry are expected to be financially dependent on product innovations to create a competitive advantage in the long-term. Therefore, we expect that technological M&A will be a better strategy for pharma firms to improve long-term financial performance compared to non-technological M&A. Hence, the fourth hypothesis is:

H4: Technological M&A is positively related to long-term financial performance, relative to non-technological M&A.

3. Data and methods

3.1 Dataset

This study focusses on the pharmaceutical industry as it is a highly innovative industry that is mainly dependent on its R&D output. Firms in the pharmaceutical industry must either develop innovations themselves or acquire innovations, as imitation is prohibited by strong intellectual property rights (Rapp & Rozek, 1990). Furthermore, M&A activity occurs at a high frequency in the pharmaceutical industry (Hassan et al., 2007) as governments allow for more M&A activity in this industry (Koenig & Mezick, 2004). Therefore, this industry is suitable to analyze how M&A influences innovation performance and financial performance. This study uses data from the twelve largest firms in the pharmaceutical industry, as large pharma firms are particularly involved in M&A. The analyzed firms are Pfizer, Novartis, Roche, Merck & Co, Johnson & Johnson, GlaxoSmithKline, Sanofi, Abbott, AstraZeneca, Bayer, Eli Lilly & Co, and Bristol-Myers Squibb. These firms account for over 60% of total revenues in the pharmaceutical industry (Fernald et al., 2017). GlaxoSmithKline (merger between Glaxo Wellcome and SmithKline Beecham in 2000), Sanofi (merger between Sanofi and Aventis in 2004) and Novartis (merger between Ciba-Geigy and Sandoz in 1996) originate during the analyzed period as a result of a large-scale merger. This causes missing values in the data collection phase and therefore some firm-year combinations of these firms are excluded from the analysis.

The dataset contains data from January 1990 till December 2013. For the financial information on firm level, we use the Datastream databases. Data on all M&A deals are obtained from the ThomsonReuters SDC Platinum database. For this research, only M&A deals where a firm acquired another pharmaceutical firm or an acquisition of a firm in the ‘medical laboratories’, ‘commercial physical and biological research’ or ‘noncommercial research organization’ are taken into consideration. These are expected to be mostly related acquisitions, although acquisitions of, for example, biotech companies are less related to the activities of the large pharmaceutical firms compared to acquisitions within the pharmaceutical industry (Fernald et al., 2017). Only M&A deals where a majority stake is acquired of the target firm are included. Furthermore, only M&A deals with a deal value of 10 million or higher are taken into account, as small acquired firms are expected to have a minimal effect on both innovation and financial performance. In total we analyze 761 M&A deals, of which 516 are technological and 245 are non-technological M&A deals. It is expected that technological M&A deals are more prevalent, as the performance of a firm in the pharmaceutical industry is generally dependent on possessing patents. Therefore, most firms in this industry file patent applications on a regular basis, which results in more technological M&A deals (as a result of the definition of the types of M&A deals, explained in section 3.3.1).

As will be explained in section 3.3.1, we will use patent data of the acquired companies to distinguish between technological M&A and non-technological M&A. This data is collected from the European Patent Office and the United States Patent and Trademark Office Databases. All data on innovations from the analyzed firms in the pharmaceutical industry are obtained from the Center for Drug Evaluation and Research (CDER), the Center for Biologics Evaluation and Research (CBER) and the Food and Drug Administration (FDA) databases.

3.2 Dependent variables

3.2.1 Financial performance

In this paper, we distinguish between short-term and long-term financial performance. Short-term financial performance is proxied with return on assets (ROA). ROA is estimated by the ratio of net income and total assets of a firm. Long-term financial performance is proxied with Tobin’s q. Tobin’s q can be defined as the ratio between the market value of a firm and the replacement costs of the assets of the firm. Tobin’s q is in the literature used as a forward-looking measure of financial firm performance and as an indicator of the growth options of a firm (Bharadwaj, Bharadwaj, & Konsysnki, 1999). Therefore, it is expected that a higher Tobin’s q on average will result in higher long-term profits. Tobin’s q accounts for risk and is less distorted by reporting and tax law distortions compared to accounting-based measures of financial performance (Montgomery & Wernerfelt, 1988). We follow the approach of Chung and Pruitt (1994), who estimates Tobin’s q by:

$$\text{Tobin's q} = \frac{\textit{market value common stock} + \textit{book value preferred stock} + \textit{book value long term debt} + \textit{book value net short term liabilities}}{\textit{book value of assets}}$$

This method obtains similar results as the conventional estimation method for Tobin's q of Lindenberg and Ross (1981) but has less data requirements (Chung & Pruitt, 1994).

3.2.2 Innovation input and output

Innovation input is measured as *R&D intensity*, which is the ratio between total R&D expenditures and sales (Hitt, Hoskisson, Ireland, & Harrison, 1991b). This indicator measures the effort that firms put in R&D activities. Furthermore, it is used as an indicator for innovative competences (Hagedoorn & Cloodt, 2003) or the absorptive capacity of a firm (Fernald et al., 2017). Studies on innovation output performance generally used patent applications or patent citations as a measure of innovation output. However, these proxies are subject to various limitations (Kleinknecht, Van Montfort, & Brouwer, 2002). Therefore, this paper will use a different measure for innovation output performance that is expected to be a more appropriate measure of innovation output. We use the sum of the number of new molecular entities (NMEs*)* from the CDER database and the number of biologic license applications (BLAs) from the CBER database. These measures can be used to proxy the total number of developed drugs by a firm (Munos, 2009). The measure of innovation output is normalized by dividing the number of developed drugs by total sales of the acquiring firm.

3.3 Explanatory variables

3.3.1. Variables of interest

The main explanatory variables in this study are the variables that count the *Number of technological M&A's* and the *Number of non-technological M&A's*. M&A's are considered to be technological if the acquired firm had any positive changes in their patent portfolio in the last 5 years preceding the acquisition (Ahuja & Katila, 2001; Cloodt et al., 2006; Jo, Park, & Kang, 2016). The number of patents of the acquired firm is measured by the number of patent applications. The acquisition of a firm with no patent applications in the 5 years preceding the M&A deal is assumed to be a non-technological acquisition. When only certain assets of a firm are acquired, M&A deals are labeled as technological when the target firm has at least one patent application in the 5 years before the M&A deal and if assets are acquired that are related to innovation, for example R&D activities. Acquisitions of certain assets are labeled as non-technological if the acquired assets are not related to innovation, for example assets related to marketing activities or manufacturing activities. As a robustness check, we will use the number of technological and non-technological acquisitions relative to the size of the firm (measured with the number of employees) as well.

For M&A's to have its full effect on innovation performance it can take multiple years, as both integrating R&D activities and developing new innovations is a relatively slow process. Similar to Fernald et al. (2017) we include a 5-year time lag and create a stock variable for all included independent variables.

3.3.2. Control variables

To control for omitted variable biases we include acquirer characteristics in the analysis that are expected to have an influence on firm performance. First of all, we include *firm size*, which is proxied by the logarithm of the number of employees. Acs and Audretsch (1987) show that firm size has an influence, dependent on the characteristics of the industry, on the innovativeness of a firm. We expect that larger firms have relatively more resources available to invest in R&D activities, which could result in a higher R&D output as R&D input and R&D output are shown to be positively related (Acs & Audretsch, 1988). An increase in firm size could result in agency problems and information asymmetries as well, which may cause problems in incentivizing researchers (Sevilir & Tian, 2012). However, empirical studies generally show that firm size is positively related to innovation performance (Ahuja & Katila, 2001; Cloodt et al., 2006; Sevilir & Tian, 2012). Firm size could harm financial performance as a result of bureaucracy costs. On the other hand, firms can benefit from economies of scale and scope and market power to increase profit. Firm size is correlated with the degree of diversification of the firm as well. Firm diversification is shown in the empirical literature to have a negative effect on financial performance (Hansen & Wernerfelt, 1989).

Secondly, we control for the level of *leverage*, which is estimated by the ratio between total debt and equity. Previous studies find a relationship between leverage and investments and performance of firms (Lang, Ofek, & Stulz, 1995; Aivazian, Ge, & Qiu, 2005). Here we can expect that higher levels of debt relative to total asset will limit the possibilities of a firm to invest, especially in risky R&D activities, which might negatively affect the development of new products. Furthermore, higher debt levels increase the cost of capital of the firm. Therefore, we expect a positive effect of leverage on profits in the short-term.

Thirdly, we control for *firm age* (in years) of the acquiring firm. Firm age could enhance innovative performance if firms develop valuable capabilities over time (Coad, Segarra, & Teruel, 2016). Previous research shows mixed results on the effect of firm age on a firm's financial performance (Loderer & Waelchli, 2010; Coad, Segarra, & Teruel, 2013). For instance, Huergo and Jaumandreu (2004) and Balasubramanian and Lee (2008) find, in contrast to Coad et al. (2016), a negative effect of firm age on innovation performance. This could be a result of structural inertia, which is related to firm age (Ilaboya & Ohiokha, 2016). To control for time trends, we include *year dummies* in all models. One potential trend that could affect performance is the decrease in R&D efficiency over the last decades (Jo et al., 2016). Furthermore, we include *firm dummies* to control for firm-specific fixed effects.

3.4 Methodology

For the analysis, we consider multiple models to analyze the 12 large pharma firms in the period 1990-2013. First of all, we consider the random effects (RE) and fixed effects (FE) panel models. Choosing between these models is a trade-off between consistency and efficiency of the estimation. To test which of these models is more appropriate a Hausman test (Hausman, 1978) can be used. A Hausman test indicates whether a RE model is consistent and more efficient compared to a FE estimation. However, we report both RE and FE models for the sake of reliability. We estimate the following FE and RE regressions with subscript *i* to identify the firm and subscript *t* to identify the time period and ε to represent the error term:

$$Financial\ performance_{it} = \beta_0 + \beta_1\,(\text{Number of technological M\&A's})_{it} + \beta_2\,(\text{Number of nontechnological M\&A's})_{it} + f(\text{Control variables})_{it} + \varepsilon_{it}$$

$$Innovation\ performance_{it} = \beta_0 + \beta_1\,(\text{Number of technological M\&A's})_{i(t-t-5)} + \beta_2\,(\text{Number of nontechnological M\&A})_{i(t-t-5)} + f(\text{Control variables})_{i(t-t-5)} + \varepsilon_{it}$$

This study uses multiple dependent variables that are possibly related to each other. Therefore, a seemingly unrelated regression (SUR) is considered as well. This method could be more efficient when estimating multiple regression equations that seem to be unrelated, but in fact are related (Beasley, 2008), and is therefore expected to be useful for the analysis. We apply the SUR estimation developed by Zellner (1962). A SUR initially estimates separate equations for the different regressors with ordinary least squares (OLS). The correlations within observations between the error terms of the set of equations are used to correct the second step which is estimated by a generalized least squares (GLS) estimator. This method is appropriate in case of unbalanced panel data with a small number of observations over a long time period (Greene, 2003). As we analyze only 12 firms over a 23-year period, these assumptions are likely to hold. The SUR is preferred compared to multiple regular pooled OLS estimations, as it also takes the correlation between the equations within observations into account. Similar to a RE estimation, the pooled OLS estimation could suffer from a heterogeneity bias. Therefore, comparing the SUR and RE estimations with the FE estimation can be used to indicate whether time-invariant unobserved heterogeneity results in biased estimates in the former models. However, as the SUR estimation does not take the panel structure of the data and the individual heterogeneity into account, this could lead to a biased estimate. To account for serial correlation of the standard errors we estimated all SUR models with standard errors clustered on firm level.

The SUR estimator could be more efficient if there is correlation between the error terms of the equations. This could be the case when there are common omitted variables in the equations. When the error terms of the equations are uncorrelated, the SUR estimation is similar to a regular OLS estimator (when using the same independent variables in all equations) and other models might be more efficient. We will estimate a four-equation SUR model using innovation input, innovation output, short-term financial performance and long-term financial performance as dependent variables. We estimate the following system of equations:

$$y_{ijt} = X_{ijt}\beta_{ij} + \varepsilon_{ijt}$$

Where *y* is the dependent variable of equation *i* of firm *j* in time *t*. *X* includes all independent variables, which may vary across equations. ε represents the error term. To test whether the SUR estimation is useful, we perform a Breusch-Pagan test. This test will identify whether the correlation between the error terms of the equations is significant.

To test whether technological M&A is positively or negatively related to performance relative to non-technological M&A (hypothesis 1 and hypothesis 4) we use a two-tailed Wald test to test whether the variables are significantly different from each other. The relative differences between the coefficients of the regressions and the outcomes of the Wald tests will be used to test the hypothesis 1 and hypothesis 4.

4. Results

4.1 Descriptive statistics

Table 1 shows the descriptive statistics of all explanatory variables used for the analysis on the firm-year level. This table includes the absolute value of drugs (the sum of NME's and BLA's) and the absolute number of (non)technological M&A's to simplify the interpretation of these variables. The dataset contains 270 firm-year combinations for most variables, except for *Long-term financial performance* and *Firm size* due to missing values of Tobin's q and the number of employees. As expected, the pharmaceutical industry is a relatively R&D-intensive sector. Firms invest on average 13.3% of their revenues in R&D activities. The firms develop on average 1.004 NME's and 0.281 BLA's per year. In total, the observed firms developed 271 NME's and 76 BLA's in the analyzed period. The descriptive statistics show that M&A activities are regularly observed as well. Firms engage on average in 1.689 technological M&A's and 0.833 non-technological M&A's per year. Most large pharma firms are profitable in the analyzed period as the ROA is 11.2% on average. Furthermore, the average Tobin's q is amply above one. This suggests that growth options for the large pharma firms are relatively high.

Table 1. Descriptive statistics of variables

Variable	Mean	Std.Dev.	Min	Max
Innovation input	.133	.045	.051	.496
Innovation output	1.285	1.57	0	11
Short-term financial performance	.112	.058	-.071	.254
Long-term financial performance	3.507	2.084	.799	10.736
Number of technological M&A's	1.689	1.649	0	8
Number of non-technological M&A's	.833	1.113	0	6
Size	74510.16	32710.24	1160	171000
Firm age	100.556	29.65	23	154
Leverage	.636	.231	.09	.998

Notes - Size and Firm age are log transformations.

Table 2 shows the correlations between the variables used for the analysis. A high correlation between variables results in multicollinearity problems. The relatively low correlations suggest that multicollinearity problems are not likely to arise. The correlation between *Firm size* and the *Number of technological M&A's* might suggests that larger firms engage more in technological-related M&A activities. Furthermore, the correlation between *Number of technological M&A's* and *Number of non-technological M&A's* might suggests that firms engage in both types of M&A. Table A1 consists of the variance inflation factor scores. The variance inflation factor scores confirm that no multicollinearity problems occur as all VIF scores are relatively low and under the widely used critical values of 5 or 10. The highest score is 1.255, which suggest that the analyzed variables are, at most, moderately correlated.

Table 2. Correlation matrix

	(1)	(2)	(3)	(4)	(5)
(1) Number of technological M&A's	1.000				
(2) Number of non-technological M&A's	0.326	1.000			
(3) Firm size	0.208	-0.021	1.000		
(4) Leverage	-0.183	-0.178	0.024	1.000	
(5) Firm Age	-0.177	-0.310	0.269	0.232	1.000

4.2 Panel models

In this section we will show the main results for the hypotheses. First of all, we show the results for the effect of technological and non-technological M&A on innovation performance to test hypothesis 1, hypothesis 2a and hypothesis 2b. Next, we display the results of the effect of technological and non-technological M&A on financial performance to test hypothesis 3a, Hypothesis 3b and Hypothesis 4. In the last part we estimate the effect of M&A on both innovation performance and financial performance simultaneously using a SUR estimation as complementary evidence for all hypotheses. In addition, we will do the same estimation using the number of technological and non-technological M&A's relative to the size of the firm. Furthermore, we will do an additional analysis to test the robustness of our results of the effect of M&A on long-term financial performance.

Through the different models we find some similarities regarding the effects of the control variables. Most models show that *size* is significantly and negatively related to innovation output. This result gives some indication that larger firms are less innovative compared to smaller firms, which might indicate that larger firms are confronted with agency problems. Furthermore, *firm age* has a positive and significant effect on innovation output in most models, indicating that older firms are more innovative. This finding might indicate that large pharmaceutical firms do not suffer from structural inertia and provides some evidence for 'learning effects' in the pharmaceutical industry.

4.2.1 Innovation performance

Table 3 displays the results of the RE and FE estimations concerning the effect of technological and non-technological M&A on innovation input and innovation output. The RE and FE estimations give similar results for all variables. Therefore, the RE estimations are considered to be consistent and more efficient compared to the FE estimations. Columns 1 to 4 show the results when using the absolute number of M&A's. Column 1 and 2 show the effect of M&A on innovation input. The *Number of technological M&A's* has a positive effect on innovation input, this effect is significant at the 5% level. The effect of the *Number of non-technological M&A's* on innovation input is insignificant at all levels. Column 3 and 4 show the effect of M&A on innovation output. The *Number of technological M&A's* has an insignificant effect on innovation output. The effect of *Number of non-technological M&A's* is negative and significant at the 5% level.

Columns 5 to 8 show the results when using the number of M&A's relative to the size of the firm. Column 5 and 6 display similar results compared to the estimation when using the absolute number of M&A's. The *Relative number of technological M&A's* is positively related to innovation input and this effect is significant at the 5% level. The effect of *Relative number of non-technological M&A's* is again insignificant at all levels. The effect of the relative number of M&A's on innovation output, displayed in Column 7 and 8, changed compared to the effect when using the absolute measure. The effect of *Relative number of non-technological M&A's* turns insignificant. However, the effect of *Relative number of technological M&A's* remains insignificant.

Table 3. Random effects and fixed effects estimates on the effect of M&A on innovation performance

Column Variables	(1) Innovation input (RE)	(2) Innovation input (FE)	(3) Innovation output (RE)	(4) Innovation output (FE)
Number of technological M&A's	0.00308** (0.00154)	0.00308* (0.00149)	-2.38e-09 (1.45e-09)	-2.38e-09 (1.45e-09)
Number of non-technological M&A's	-0.000898 (0.00166)	-0.000898 (0.00161)	-3.31e-09** (1.68e-09)	-3.31e-09** (1.68e-09)
Size	-0.0133** (0.00665)	-0.0133* (0.00645)	-2.71e-08*** (6.66e-09)	-2.71e-08*** (6.66e-09)
Firm Age	-0.0257 (0.0438)	-0.0257 (0.0425)	1.96e-07*** (5.70e-08)	1.96e-07*** (5.70e-08)
Leverage	-0.0125 (0.00823)	-0.0125 (0.00798)	-1.67e-08 (1.14e-08)	-1.67e-08 (1.14e-08)
Year Dummies	INCLUDED	INCLUDED	INCLUDED	INCLUDED
Firm Dummies	INCLUDED	-	INCLUDED	-
Constant	1.819* (1.001)	1.797* (0.922)	-3.82e-06*** (1.40e-06)	-3.82e-06*** (1.40e-06)
Observations	207	207	207	207
R-squared		0.474		0.321
Number of firms	12	12	12	12
Column Variables	(5) Innovation input (RE)	(6) Innovation input (FE)	(7) Innovation output (RE)	(8) Innovation output (FE)
Relative number of technological M&A's	187.9** (75.07)	187.9** (72.77)	-7.60e-05 (0.000109)	-7.60e-05 (0.000106)
Relative number of non-technological M&A's	-118.9 (73.16)	-118.9 (70.93)	4.27e-05 (0.000102)	4.27e-05 (9.87e-05)
Size	-0.00460 (0.00449)	-0.00460 (0.00435)	-2.86e-08*** (6.60e-09)	-2.86e-08*** (6.40e-09)
Firm Age	0.00866 (0.0333)	0.00866 (0.0322)	1.34e-07** (6.31e-08)	1.34e-07* (6.13e-08)
Leverage	-0.00931 (0.00827)	-0.00931 (0.00802)	-1.68e-08 (1.28e-08)	-1.68e-08 (1.24e-08)
Year Dummies	INCLUDED	INCLUDED	INCLUDED	INCLUDED
Firm Dummies	INCLUDED	-	INCLUDED	-
Constant	0.237 (0.785)	0.243 (0.730)	-1.91e-06 (1.63e-06)	-1.70e-06 (1.52e-06)
Observations	207	207	207	207
R-squared		0.703		0.315
Number of firms	12	12	12	12

Notes – All independent variables are stock variables of a 5-year lag. Year dummies included in all regressions. Firm dummies only included in RE models. Standard errors are clustered at firm level and reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1

4.2.2 Financial performance

Table 4 shows the results of the RE and FE estimations of the effect of technological and non-technological M&A on both short-term and long-term financial performance. Again, the RE estimations are considered to be consistent and more efficient compared to the FE estimations. Columns 1 to 4 show the results when using the absolute number of M&A's. Column 1 and 2 show that the *Number of technological M&A's* has a negative and significant effect (at the 5% level) on short-term financial performance. The effect of the *Number of non-technological M&A's* is insignificant at all levels. Column 3 and 4 indicate that more technological M&A's will negatively affect long-term financial performance. This effect is significant at the 5% significance level. The effect of *Number of non-technological M&A's* is insignificant at all levels.

Columns 5 to 8 show the results when using the number of M&A's relative to the size of the firm. The effect of the *Relative number of technological M&A's* on short-term financial performance is again negative and significant (at the 1% level). The coefficient of *Relative number of non-technological M&A's* is contradicting compared to the absolute measure of this variable. The effect is positive and significant at the 5% level. The results on long-term financial performance, shown in Column 7 and 8, are contradicting as well. Although the effect of the *Relative number of technological M&A's* is again negative, the effect is insignificant. The *Relative number of non-technological M&A's* is again insignificant at all levels.

Table 4. Random effects and fixed effects estimates on the effect of M&A on financial performance

Column Variables	(1) Short-term performance (RE)	(2) Short-term performance (FE)	(3) Long-term performance (RE)	(4) Long-term performance (FE)
Number of technological M&A's	-0.00433**	-0.00433**	-0.119**	-0.119**
	(0.00175)	(0.00171)	(0.0470)	(0.0459)
Number of non-technological M&A's	0.00391 (0.00312)	0.00391 (0.00305)	-0.0316 (0.0659)	-0.0316 (0.0643)
Size	-0.000483	-0.000483	0.226	0.226
	(0.0214)	(0.0209)	(0.575)	(0.561)
Firm Age	-0.0533	-0.0533	-9.610	-9.610
	(0.207)	(0.203)	(7.310)	(7.134)
Leverage	-0.0601*	-0.0601*	-0.674	-0.674
	(0.0324)	(0.0316)	(1.387)	(1.354)
Year Dummies	INCLUDED	INCLUDED	INCLUDED	INCLUDED
Firm Dummies	INCLUDED	-	INCLUDED	-
Constant	1.710*	1.694*	-3.74e-06***	-3.45e-06**
	(0.965)	(0.889)	(1.41e-06)	(1.31e-06)
Observations	267	267	267	267
R-squared		0.474		0.321
Number of firms	12	12	12	12
Column Variables	(5) Short-term performance (RE)	(6) Short-term performance (FE)	(7) Long-term performance (RE)	(8) Long-term performance (FE)
Relative number of technological M&A's	-271.6*** (70.58)	-271.6*** (68.93)	-3.887 (2.873)	-3.887 (2.804)
Relative number of non-technological M&A's	250.3*** (90.31)	250.3** (88.19)	3.303 (2.879)	3.303 (2.809)
Size	-0.0153	-0.0153	-0.0655	-0.0655
	(0.0385)	(0.0376)	(0.996)	(0.972)
Firm Age	-0.0216	-0.0216	-9.400	-9.400
	(0.226)	(0.220)	(8.080)	(7.885)
Leverage	-0.0610*	-0.0610*	-0.675	-0.675
	(0.0313)	(0.0306)	(1.396)	(1.363)
Year Dummies	INCLUDED	INCLUDED	INCLUDED	INCLUDED
Firm Dummies	INCLUDED	-	INCLUDED	-
Constant	0.237	0.243	-1.91e-06	-1.70e-06
	(0.785)	(0.730)	(1.63e-06)	(1.52e-06)
Observations	267	267	267	267
R-squared		0.703		0.315
Number of firms	12	12	12	12

Notes – Year dummies included in all regressions. Firm dummies only included in RE models. Standard errors are clustered at firm level and reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1

4.2.3 SUR estimation

Before analyzing the results of the SUR models, we performed a Breusch-Pagan test of independence to identify whether significant correlation exists between the error terms of the equations. The results, reported in Table A2 and Table A3, show that the correlation between the error terms is significant, implying that the SUR estimations are possibly more efficient compared to the regular RE estimations. The strongest correlation is between short-term and long-term financial performance, indicating that the financial performance of a firm in the short-term is a good indicator of the performance of a firm in the long-term. Surprisingly, there is only a very small correlation between innovation input and innovation output. This is in line with the 'productivity gap' phenomenon, as more expenditures on R&D seem to not result in more developed drugs. Furthermore, innovation output seems to be weakly correlated to long-term financial performance.

Table 5 shows the results after the SUR estimation, using the absolute number of M&A deals. The effect of the *Number of technological M&A's* on innovation input (Column 1) is in accordance with the previous findings. More technological M&A's deals are related to more investments in R&D activities. Similar to previous results, *Number of non-technological M&A's* has an insignificant effect on innovation input. Column 2 shows the effects of M&A on innovation output. Both the *Number of technological M&A's* and the *Number of non-technological M&A's* are negatively related to innovation output (significant at 5% level). Column 3 shows the effects on short-term financial performance. In contrast to previous results, the *Number of technological M&A's* is insignificantly related to short-term financial performance. The effect of the *Number of non-technological M&A's* is marginally significant. Column 4 shows the effect on long-term financial performance. The *Number of technological M&A's* has a negative and marginally significant effect on the financial performance of a firm in the long-term. The *Number of non-technological M&A's* has an insignificant effect on the long-term financial performance of the analyzed firms.

Table 5. Seemingly unrelated regression on both innovation and financial performance with absolute number of M&A deals

Column Variables	(1) Innovation input	(2) Innovation output	(3) Short-term performance	(4) Long-term performance
Number of technological M&A's	.0021122** (.0009154)	-1.90e-09** (9.40e-10)	-.0024103 (.0020365)	-.083535* (.0468402)
Number of non-technological M&A's	-.0004696 (.0015788)	-3.39e-09** (1.50e-09)	.0050302* (.0027417)	.0669714 (.0811325)
Size	-.0131675** (.0059339)	-2.61e-08*** (5.95e-09)	.0172613 (.0297931)	.5382493 (.8739633)
Firm Age	-.019728 (.0400806)	1.88e-07*** (4.91e-08)	-.0755666 (.3547838)	-20.00951 (13.0123)
Leverage	-.0149284* (.0078908)	-1.61e-08 (1.03e-08)	-.0087437 (.0317363)	.3493044 (1.126378)
Year Dummies	INCLUDED	INCLUDED	INCLUDED	INCLUDED
Firm Dummies	INCLUDED	INCLUDED	INCLUDED	INCLUDED
Constant	1.652959* (.9273589)	-3.65e-06*** (1.21e-06)	.3006027 (1.7046)	94.20467 (61.51837)
Observations	207	207	207	207
R-squared	0.7178	0.3844	0.4112	0.7261
Number of firms	12	12	12	12

Notes – Year and firm dummies included in all regressions. Standard errors are clustered at firm level and reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 6 shows the results after the SUR estimation, using the number of M&A deals relative to the size of the firm. The results of the *Relative number of technological M&A's* on innovation inputs (Column 1) are corresponding with the previous findings. The *Relative number of technological M&A's* has a positive and significant effect (at the 1% level) on innovation inputs. However, the effect of *Relative number of non-technological M&A's* on expenditures on innovation is in contrast to all previous findings. The *Relative number of non-technological M&A's* has a negative and significant (at the 5% level) effect on innovation input. Column 2 shows the results on innovation output. Both the *Relative number of technological M&A's* and the *Relative number of non-technological M&A's* have an insignificant effect on innovation output, which is in line with previous findings. The effects of M&A's on short-term financial performance are displayed in Column 3. The *Relative number of technological M&A's* negative effect on the financial performance in the short-term, however, this effect is only significant at the 10% level. The effect of the *Relative number of non-technological M&A's* is positive and significant at the 5% level. Column 4 shows the effect on long-term financial performance. Similar to the previous findings, the *Relative number of technological M&A's* has a negative and marginally significant effect on long-term financial performance. The *Relative number of non-technological M&A's* has an insignificant effect on the financial performance of firms in the long-term, which is in line with the previous results.

Table 6. Seemingly unrelated regression on both innovation and financial performance (number of M&A deals relative to size)

Column Variables	(1) Innovation input	(2) Innovation output	(3) Short-term performance	(4) Long-term performance
Relative number of technological M&A's	188.9296*** (59.40471)	-.0000922 (.0001034)	-223.1825* (130.9847)	-5286.296* (2827.56)
Relative number of non-technological M&A's	-119.6079** (59.08192)	.0000563 (.0000947)	486.6734** (237.8339)	4665.683 (8659.843)
Size	-.0043242 (.0043208)	-2.84e-08*** (5.80e-09)	.0105928 (.0318868)	.3393823 (.9237979)
Firm Age	.0065064 (.0313022)	1.31e-07** (5.48e-08)	.0689416 (.3700787)	-19.6912 (13.33466)
Leverage	-.0090131 (.0080106)	-1.84e-08* (1.11e-08)	-.0150884 (.0339694)	.2202988 (1.139932)
Year Dummies	INCLUDED	INCLUDED	INCLUDED	INCLUDED
Firm Dummies	INCLUDED	INCLUDED	INCLUDED	INCLUDED
Constant	.2803032 (.7247683)	-1.84e-06 (1.44e-06)	.348589 (1.744196)	94.96147 (62.48059)
Observations	207	207	207	207
R-squared	0.8409	0.3787	0.4180	0.7257
Number of firms	12	12	12	12

Notes –Year and firm dummies included in all regressions. Standard errors are clustered at firm level and reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1

4.2.4 Hypothesis testing

All results of the different estimation techniques and different variable choices are summarized in Table 7. Table 8 consist of all Wald tests to test hypothesis 1 and hypothesis 4. Following hypothesis 1, technological M&A is negatively related to innovation input, relative to non-technological M&A. In all regression models, we find results that indicate the opposite effect. Technological M&A is positively related to innovation input and non-technological M&A is insignificantly related to innovation input. Moreover, the Wald test on the relative number of M&A's show that the *Relative number of technological M&A's* and *Relative number of non-technological M&A's* are significantly different, indicating the converse of hypothesis 1. Therefore, we find no support for hypothesis 1.

Following hypothesis 2a and 2b, technological M&A is positively related to innovation output and non-technological M&A is negatively related to innovation output. We find that the absolute number of technological M&A's has a negative effect on innovation output and the relative number of technological M&A's has an insignificant effect. Therefore, we find no support for hypothesis 2a. For non-technological M&A, we find significant negative effects on innovation for the absolute number of M&A's. Therefore, we find weak evidence to support hypothesis 2b.

Following hypothesis 3a and 3b, technological M&A's are negatively related to short-term financial performance and non-technological M&A's are positively related to short-term financial performance. For the regular RE models we find a negative effect of technological M&A on short-term financial performance, providing evidence for hypothesis 3a. However, when taking the correlation between the different equations into account, we only find insignificant or marginally significant results. Therefore, we only find weak support for hypothesis 3a. For hypothesis 3b, we find support that the *Relative number of non-technological M&A's* have a positive effect on the financial performance of a firm in the short-term.

Following hypothesis 4, technological M&A is positively related to long-term financial performance relative to non-technological M&A. However, we show in all models that technological M&A has a larger negative effect on long-term performance compared to non-technological M&A. Furthermore, most Wald tests indicate that the effects of technological M&A and non-technological M&A are not significantly different. Therefore, we find no evidence to support hypothesis 4.

Table 7. Summary of the results of the random effects and seemingly unrelated regression models

Dependent variable		Absolute number of M&A's (RE)	Number of M&A's relative to size (RE)	Absolute number of M&A's (SUR)	Number of M&A's relative to size (SUR)
Innovation input	Technological	+(**)	+(**)	+(**)	+(***)
	Non-Technological	+/-	+/-	+/-	-(**)
Innovation output	Technological	-(**)	+/-	-(**)	+/-
	Non-Technological	-(**)	+/-	-(**)	+/-
Short-term financial performance	Technological	-(**)	-(***)	+/-	-(*)
	Non-Technological	+/-	+(**)	+(*)	+(**)
Long-term financial performance	Technological	-(**)	+/-	-(*)	-(*)
	Non-Technological	+/-	+/-	+/-	+/-

Notes- +/- indicates an insignificant effect. *** p<0.01, ** p<0.05, * p<0.1

Table 8. Wald tests (number of technological M&A's = number of non-technological M&A's)

Model	Absolute number of M&A's (RE)	Number of M&A's relative to size (RE)	Absolute number of M&A's (SUR)	Number of M&A's relative to size (SUR)
Innovation input (hypothesis 1)	Chi-squared: 3.26 P-value: 0.0710	Chi-squared: 4.29 P-value: 0.0383	Chi-squared: 2.37 P-value: 0.1241	Chi-squared: 6.80 P-value: 0.0091
Long-term financial performance (hypothesis 4)	Chi-squared: 1.46 P-value: 0.2264	Chi-squared: 1.58 P-value: 0.2083	Chi-squared: 3.36 P-value: 0.0669	Chi-squared: 1.64 P-value: 0.2009

4.2.5 Robustness check

Initially we used Tobin's q to proxy the financial performance of a firm in the long-term. Though, Tobin's q is estimated using the market value of a firm, which could lead to a biased estimate. Previous research shows that firms overpay for target firms as a result of managerial overconfidence (Malmendier & Tate, 2008). Overconfident or overoptimistic managers can be described as managers who "overestimate the returns to their investment projects" (Malmendier & Tate, 2005, p. 2662). As a result, overconfident managers could overestimate the positive effect of a M&A deal on firm performance and hence overbid for the target firm. Subsequently, the market value of the firm declines as a result of these value-destroying investments. A decline in market value of a firm decreases Tobin's q in the current period, however, in the long-term the M&A deal could still create value.

This is expected to have the most impact on technological M&A's as the returns of innovations can be highly uncertain. The returns of non-technological M&A deals are expected to be less volatile, compared to technological M&A deals. More uncertainty can result in a larger overestimation. This could result in deflated values of Tobin's q, especially for firms that engage more in technological M&A's. Therefore, we will estimate the effect of M&A's on long-term financial performance using a different proxy. We will use ROA as the dependent variable and include a 5-year time lag of this variable (similar results are obtained using a 4-year and a 6-year time lag) to measure the effect of M&A deals on performance over a longer period. We create a stock variable for all included independent variables as well.

Table A4 shows the FE and RE models using the absolute and relative number of acquisitions. Similar to previous results, we find that technological M&A deals have an insignificant or negative effect on long-term firm performance. Surprisingly we find that non-technological M&A deals have a positive effect on long-term financial performance. Therefore, we find again no evidence to support hypothesis 4. Table A5 and Table A6 show the SUR estimations using the absolute and relative number of acquisitions. Again, the effect of non-technological M&A on long-term financial performance is positive compared to technological M&A, however, all effects of both types of M&A on financial performance are insignificant. In conclusion, we find similar results compared to our main analysis, indicating that our results are not biased as a result of using Tobin's q as a proxy for long-term financial performance.

5. Conclusion and discussion

Our study investigates the effect of M&A on innovation performance and financial performance in the context of large pharma firms. Similar to Ahuja and Katila (2001) and Cloodt et al. (2006) we divide M&A in technological M&A and non-technological M&A. Remarkably, we find that technological M&A deals do increase investments in R&D activities relative to non-technological M&A deals, however, this does not consistently result in more developed drugs. Moreover, the analysis shows some evidence that technological M&A deals negatively affect financial performance in the short-term. Furthermore, technological M&A deals are not likely to benefit the long-term financial performance of large pharma firms, relative to non-technological M&A's.

The positive impact of technological M&A on investments in R&D activities relative to non-technological M&A is to some extent inconsistent with economic theory, as we expected that firms would substitute internal R&D activities with external sources of innovation. This surprising finding can be explained in multiple ways. First of all, firms might increase innovation inputs when acquiring external sources of knowledge to increase their absorptive capacity. Absorptive capacity can be described as the capability of the firm to exploit external sources of innovation (Cohen & Levinthal, 1990). Firms might be able to identify the need to increase their ability to absorb the knowledge of the target firm. This is in line with Caloghirou, Kastelli, and Tsakanikas (2004) who find empirical evidence that an increased absorptive capacity enhances the ability of a firm to utilize external sources of knowledge in order to increase innovative performance. Secondly, firms might use external sources of innovation to complement their own innovation activities rather than to substitute them. For instance, Cassiman and Veugelers (2006) show that firms can improve innovative performance by combining internal and external innovation activities.

Despite the increase in effort in R&D activities, we show that firms that engage more in technological M&A's are not able to increase innovation output, which provides support for the 'productivity gap' phenomenon in the pharmaceutical industry. Multiple studies inquired the effect of knowledge overlap between the target firm and the acquired firm on post-M&A innovation performance. These studies regularly show that overlap between the knowledge of the target firm and the acquiring firm is curvilinear related to the innovation performance of the acquiring firm (Ahuja & Katila, 2001; Cloodt et al., 2006; Valentini & Dawson, 2010). This implicates that too little overlap between the knowledge bases provides limited benefits to innovation performance of the acquiring firm. This could harm the post-M&A performance of firms, especially in the case of acquisitions of firms in the biotechnology industry where knowledge is very specific and complex (Decarolis & Deeds, 1999). Al-Laham et al. (2010) argue that this specific kind of knowledge is less likely to benefit other firms than the innovator itself as the options for cross-fertilization are limited. Furthermore, firms that engage in M&A (both technological and non-technological M&A) might encounter problems when integrating R&D activities. Steigenberger (2017) argues that the productivity of R&D departments decreases as a result of integration of R&D activities. However, Puranam, Singh, and Zollo (2006) show that the decrease in innovation output after a technology acquisition will recuperate over time. Therefore, it is possible that technological M&A's do create value in a longer period than analyzed in this study.

We find some evidence that technological M&A deals will have a negative effect and non-technological M&A deals will have a positive effect on profits in the short-term, which is in line with the hypotheses. The negative effect of technological M&A on short-term financial performance can be due to integration costs of integrating R&D activities of the target firm and the acquiring firm. Furthermore, firms who engaged more in technological M&A invested more in R&D activities as well, which reduces short-term profits. Firms that engage more in non-technological M&A might encounter integration problems as well, but the negative effects on profits are possibly mitigated by, for example, tax advantages and an increase in revenues as a result of an increase in market power.

Both technological and non-technological M&A seem to have an insignificant effect on long-term financial performance. Given the results of technological M&A on innovation output, this is not a surprising result. Acquisitions with acquiring external sources of knowledge as acquisition motive seem to have an insignificant effect on the development of new drugs. As the rate of development of new (blockbuster) drugs is expected to be an important indicator of long-term financial performance of firms in the pharmaceutical industry, both technological and non-technological M&A's are not expected to benefit the firm in the long-term.

These results raise questions whether large pharma firms can use M&A as a strategy to overcome a decreasing research productivity to maintain firm value in both the short and the long-term. The results indicate that both analyzed types of M&A will not uniformly benefit firms in the pharmaceutical industry. Firms should especially be cautious when engaging in M&A activities that are motivated to enhance innovation, as these M&A deals seem to aggravate the 'productivity gap' and seem to be detrimental to firm performance rather than beneficial. However, we do not imply that firms should not engage in either technological or non-technological M&A. For example, it could be the case that M&A's do benefit innovation performance when firms acquire former alliance partners (Al-Laham et al., 2010). A more in-depth analysis of the heterogeneity of technological and non-technological M&A's could assess whether some M&A deals are more beneficial than others.

5.1 Limitations and future research

Although we control for as many relevant firm characteristics as possible it could be the case that some confounding variables are still omitted. Ornaghi (2009) argues that the decision to engage in M&A is endogenous, as it is dependent on the characteristics of the firm. This argument can applied to the different types of M&A as well, as the decision of firms to engage to a certain extent in either technological or non-technological M&A can be endogenous. For example, firms that are unable to innovate internally might be more likely to engage in technological M&A. Future studies could try to address this possible issue by incorporating instrumental variable estimations or matching techniques. Danzon et al. (2017) use propensity score matching to solve the problem of selection bias in their study on the effect of M&A in the pharmaceutical industry. They find in their matching procedure that firms that engaged in M&A have more expiring patents compared to firms that do not engage in M&A. This raises some concerns about the results obtained in this study.

A second possible limitation of our study is the measure of long-term financial performance, Tobin's q. First of all, we use an approximation of Tobin's q to limit the data requirements. Although this proxy has a significant correlation with the regular estimation of Tobin's q, it is not a perfect measure. Furthermore, Dybvig and Warachka (2015) argue theoretically and show empirical evidence that the effect of firm performance on Tobin's q is ambiguous. However, we obtained similar results in the robustness check using a different proxy of long-term financial performance.

Another suggestion for future research is a different measure of technological and non-technological M&A. We define M&A's as technological if the acquired firm has at least one patent application 5 years preceding the merger. However, this measure is subject to a number of limitations. A M&A deal that is labeled as technological M&A in this study could be a non-technological M&A in reality. This is for example the case when a firm is acquired that has a patent application 5 years preceding the merger, but is mainly acquired with the intention to benefit from economies of scale in manufacturing activities. A more in-depth case study could look at the motivations of the top-management team to label M&A activities. For instance, a questionnaire could be used to gather information about the intentions of the management and link these intentions to either technological or non-technological M&A or even more specific categories of M&A activities. Furthermore, it should be mentioned that firms can acquire a firm with intentions that are linked to both technological and non-technological M&A.

The results of this study should be extrapolated with caution. This study analyzes the effect of M&A in a very specific context; large firms in the pharmaceutical industry. These results might for example not hold in low-tech industries, but more interestingly these results might also not hold in other high-tech industry. Bower (2001) argues that integration problems are more prevalent in the pharmaceutical industry compared to the IT industry. This could be a result of the high specificity of knowledge in the pharmaceutical industry, which could complicate the integration process of R&D activities. Future re

References

Acs, Z. J., & Audretsch, D. B. (1987). Innovation, market structure, and firm size. *The review of Economics and Statistics*, 567-574.

Acs, Z. J., & Audretsch, D. B. (1988). Innovation in large and small firms: an empirical analysis. *The American economic review*, 678-690.

Aghion, P., Bloom, N., Blundell, R., Griffith, R., & Howitt, P. (2005). Competition and innovation: An inverted-U relationship. *The Quarterly Journal of Economics*, *120*(2), 701-728.

Aghion, P., & Tirole, J. (1994). Opening the black box of innovation. *European Economic Review*, *38*(3-4), 701-710.

Ahuja, G., & Katila, R. (2001). Technological acquisitions and the innovation performance of acquiring firms: A longitudinal study. *Strategic management journal*, *22*(3), 197-220.

Aivazian, V. A., Ge, Y., & Qiu, J. (2005). The impact of leverage on firm investment: Canadian evidence. *Journal of corporate finance*, *11*(1-2), 277-291.

Al-Laham, A., Schweizer, L., & Amburgey, T. L. (2010). Dating before marriage? Analyzing the influence of pre-acquisition experience and target familiarity on acquisition success in the “M&A as R&D” type of acquisition. *Scandinavian Journal of Management*, *26*(1), 25-37.

Arrow, K. J. (1962). Economic welfare and the allocation of resources for invention. In *The Rate and Direction of Inventive Activity* (pp. 609-626*)*. Princeton: Princeton University Press.

Artz, K. W., Norman, P. M., Hatfield, D. E., & Cardinal, L. B. (2010). A longitudinal study of the impact of R&D, patents, and product innovation on firm performance. *Journal of product innovation management*, *27*(5), 725-740.

Ashburn, T. T., & Thor, K. B. (2004). Drug repositioning: identifying and developing new uses for existing drugs. *Nature reviews Drug discovery*, *3*(8), 673.

Balasubramanian, N., & Lee, J. (2008). Firm age and innovation. *Industrial and Corporate Change*, *17*(5), 1019-1047.

Beasley, T. M. (2008). Seemingly unrelated regression (SUR) models as a solution to path analytic models with correlated errors. *Multiple linear regression viewpoints*, *34*(1), 1-7.

Bena, J., & Li, K. (2014). Corporate innovations and mergers and acquisitions. *The Journal of Finance*, *69*(5), 1923-1960.

Berndt, E. R. (2001). The US pharmaceutical industry: why major growth in times of cost containment?. *Health Affairs*, *20*(2), 100-114.

Bharadwaj, A. S., Bharadwaj, S. G., & Konsynski, B. R. (1999). Information technology effects on firm performance as measured by Tobin's q. *Management science*, *45*(7), 1008-1024.

Bloom, N., & Van Reenen, J. (2002). Patents, real options and firm performance. *The Economic Journal*, *112*(478), C97-C116.

Bloomberg (2018). *Bayer closes Monsanto deal to cap $63 billion transformation.* Retrieved from: https://www.bloomberg.com/news/articles/2018-06-07/bayer-closes-monsanto-deal-to-cap-63-billion-transformation

Blundell, R., Griffith, R., & Reenen, J. V. (1995). Dynamic count data models of technological innovation. *The Economic Journal*, *105*(429), 333-344.

Bower, J. L. (2001). Not all M&As are alike: And that matters. *Harvard Business Review, 79(3), 93-101*

Bradfield, R., & El-Sayed, H. (2009). Four scenarios for the future of the pharmaceutical industry. *Technology Analysis & Strategic Management*, *21*(2), 195-212.

Bunnage, M. E. (2011). Getting pharmaceutical R&D back on target. *Nature chemical biology*, *7*(6), 335

Caloghirou, Y., Kastelli, I., & Tsakanikas, A. (2004). Internal capabilities and external knowledge sources: complements or substitutes for innovative performance?. *Technovation*, *24*(1), 29-39.

Cassiman, B., & Veugelers, R. (2006). In search of complementarity in innovation strategy: Internal R&D and external knowledge acquisition. *Management science*, *52*(1), 68-82.

Cassiman, B., Colombo, M. G., Garrone, P., & Veugelers, R. (2005). The impact of M&A on the R&D process: An empirical analysis of the role of technological-and market-relatedness. *Research Policy*, *34*(2), 195-220.

Chakrabarti, A., Hauschildt, J., & Süverkrüp, C. (1994). Does it pay to acquire technological firms?. *R&D Management*, *24*(1), 047-056.

Chatterjee, S. (1986). Types of synergy and economic value: The impact of acquisitions on merging and rival firms. *Strategic management journal*, *7*(2), 119-139.

Chung, K. H., & Pruitt, S. W. (1994). A simple approximation of Tobin's q. *Financial management*, 70-74.

Cloodt, M., Hagedoorn, J., & Van Kranenburg, H. (2006). Mergers and acquisitions: Their effect on the innovative performance of companies in high-tech industries. *Research policy*, *35*(5), 642-654.

Coad, A., Segarra, A., & Teruel, M. (2013). Like milk or wine: Does firm performance improve with age?. *Structural Change and Economic Dynamics*, *24*, 173-189.

Coad, A., Segarra, A., & Teruel, M. (2016). Innovation and firm growth: Does firm age play a role?. *Research Policy*, *45*(2), 387-400.

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative science quarterly*, *35*(1), 128-152.

Danzon, P. M., Epstein, A., & Nicholson, S. (2007). Mergers and acquisitions in the pharmaceutical and biotech industries. *Managerial and Decision Economics*, *28*(4-5), 307-328.

DeCarolis, D. M., & Deeds, D. L. (1999). The impact of stocks and flows of organizational knowledge on firm performance: An empirical investigation of the biotechnology industry. *Strategic management journal*, *20*(10), 953-968.

Devos, E., Kadapakkam, P. R., & Krishnamurthy, S. (2008). How do mergers create value? A comparison of taxes, market power, and efficiency improvements as explanations for synergies. *The Review of Financial Studies*, *22*(3), 1179-1211.

Demirbag, M., Ng, C. K., & Tatoglu, E. (2007). Performance of mergers and acquisitions in the pharmaceutical industry: a comparative perspective. *Multinational Business Review*, *15*(2), 41-62.

Dickerson, A. P., Gibson, H. D., & Tsakalotos, E. (1997). The impact of acquisitions on company performance: Evidence from a large panel of UK firms. *Oxford economic papers*, *49*(3), 344-361.

DiMasi, J. A., Hansen, R. W., & Grabowski, H. G. (2003). The price of innovation: new estimates of drug development costs. *Journal of health economics*, *22*(2), 151-185.

DiMasi, J. A., Grabowski, H. G., & Hansen, R. W. (2016). Innovation in the pharmaceutical industry: new estimates of R&D costs. *Journal of health economics*, *47*, 20-33.

DiMasi, J. A., Grabowski, H. G., & Vernon, J. (1995). R&D costs, innovative output and firm size in the pharmaceutical industry. *International Journal of the Economics of Business*, *2*(2), 201-219.

Duflos, G., & Pfister, E. (2008). Searching for innovations? The technological determinants of acquisitions in the pharmaceutical industry.

Dybvig, P. H., & Warachka, M. (2015). Tobin's q does not measure firm performance: Theory, empirics, and alternatives. *Empirics, and Alternatives (March 5, 2015)*.

Ernst, H., & Vitt, J. (2000). The influence of corporate acquisitions on the behaviour of key inventors. *R&D Management*, *30*(2), 105-120.

European Federation of Pharmaceutical Industries and Associations. (2017). *The pharmaceutical industry in figures*. Brussels, Belgium: European Federation of Pharmaceutical Industries and Associations.

Fernald, K. D. S., Pennings, H. P. G., Van Den Bosch, J. F., Commandeur, H. R., & Claassen, E. (2017). The moderating role of absorptive capacity and the differential effects of acquisitions and alliances on Big Pharma firms' innovation performance. *PloS one*, *12*(2), e0172488.

Financial Times. (2009). *Pfizer seals $68bn Wyeth purchase.* Retrieved from: https://www.ft.com/content/411b988c-eb2c-11dd-bb6e-0000779fd2ac

Grabowski, H., & Kyle, M. (2008). 11. Mergers and alliances in pharmaceuticals: effects on innovation and R&D productivity. *The economics of corporate governance and mergers*, 262.

Greene, W. (2003). Econometrics. *Various Editions*.

Hagedoorn, J., & Cloodt, M. (2003). Measuring innovative performance: is there an advantage in using multiple indicators?. *Research policy*, *32*(8), 1365-1379.

Haleblian, J., Devers, C. E., McNamara, G., Carpenter, M. A., & Davison, R. B. (2009). Taking stock of what we know about mergers and acquisitions: A review and research agenda. *Journal of management*, *35*(3), 469-502.

Hall, B. H. (1989). *The impact of corporate restructuring on industrial research and development* (No. w3216). National Bureau of Economic Research.

Hansen, G. S., & Wernerfelt, B. (1989). Determinants of firm performance: The relative importance of economic and organizational factors. *Strategic management journal*, *10*(5), 399-411

Harrison, J. S., Hitt, M. A., Hoskisson, R. E., & Ireland, R. D. (1991). Synergies and post-acquisition performance: Differences versus similarities in resource allocations. *Journal of management*, *17*(1), 173-190.

Hassan, M., Patro, D. K., Tuckman, H., & Wang, X. (2007). Do mergers and acquisitions create shareholder wealth in the pharmaceutical industry?. *International Journal of Pharmaceutical and Healthcare Marketing*, *1*(1), 58-78.

Hausman, J. A. (1978). Specification tests in econometrics. *Econometrica: Journal of the econometric society*, 1251-1271.

Hayn, C. (1989). Tax attributes as determinants of shareholder gains in corporate acquisitions. *Journal of Financial Economics*, *23*(1), 121-153.

Henderson, R., & Cockburn, I. (1994). Measuring competence? Exploring firm effects in pharmaceutical research. *Strategic management journal*, *15*(S1), 63-84.

Herper, M. (2011, August). Former Pfizer Research Chief Says Pharmaceutical Mergers Cripple Science. *Forbes*. Retrieved from https://www.forbes.com/sites/matthewherper/2011/08/01/former-pfizer-research-chief-says-pharmaceutical-mergers-cripple-science/#4f6e0f7c20c3

Higgins, M. J., & Rodriguez, D. (2006). The outsourcing of R&D through acquisitions in the pharmaceutical industry. *Journal of financial economics*, *80*(2), 351-383.

Hitt, M. A., Hoskisson, R. E., & Ireland, R. D. (1990). Mergers and acquisitions and managerial commitment to innovation in M-form firms. *Strategic Management Journal*, 29-47.

Hitt, M. A., Hoskisson, R. E., Ireland, R. D., & Harrison, J. S. (1991). Effects of acquisitions on R&D inputs and outputs. *Academy of Management journal*, *34*(3), 693-706.

Hitt, M. A., Hoskisson, R. E., Ireland, R. D., & Harrison, J. S. (1991b). Are acquisitions a poison pill for innovation?. *Academy of Management Perspectives*, *5*(4), 22-34.

Hitt, M. A., Hoskisson, R. E., Johnson, R. A., & Moesel, D. D. (1996). The market for corporate control and firm innovation. *Academy of management journal*, *39*(5), 1084-1119.

Huergo, E., & Jaumandreu, J. (2004). How does probability of innovation change with firm age?. *Small Business Economics*, *22*(3-4), 193-207.

Ilaboya, O. J., & Ohiokha, I. F. (2016). Firm age, size and profitability dynamics: a test of learning by doing and structural inertia hypotheses. *Business and Management Research*, *5*(1), 29-39.

James, A. D. (2002). The strategic management of mergers and acquisitions in the pharmaceutical industry: Developing a resource-based perspective. *Technology Analysis & Strategic Management*, *14*(3), 299-313.

Jensen, M. C., & Ruback, R. S. (1983). The market for corporate control: The scientific evidence. *Journal of Financial economics*, *11*(1-4), 5-50.

Jo, G. S., Park, G., & Kang, J. (2016). Unravelling the link between technological M&A and innovation performance using the concept of relative absorptive capacity. *Asian Journal of Technology Innovation*, *24*(1), 55-76.

Kleinknecht, A., Van Montfort, K., & Brouwer, E. (2002). The non-trivial choice between innovation indicators. *Economics of Innovation and new technology*, *11*(2), 109-121.

Koenig, M. E., & Mezick, E. M. (2004). Impact of mergers & acquisitions on research productivity within the pharmaceutical industry. *Scientometrics*, *59*(1), 157-169.

Lang, L., Ofek, E., & Stulz, R. (1996). Leverage, investment, and firm growth. *Journal of financial Economics*, *40*(1), 3-29.

Lewellen, W. G. (1971). A pure financial rationale for the conglomerate merger. *The journal of Finance*, *26*(2), 521-537.

Lindenberg, E. B., & Ross, S. A. (1981). Tobin's q ratio and industrial organization. *Journal of business*, 1-32.

Lockett, A., Wiklund, J., Davidsson, P., & Girma, S. (2011). Organic and acquisitive growth: Re-examining, testing and extending Penrose's growth theory. *Journal of management studies*, *48*(1), 48-74.

Loderer, C. F., & Waelchli, U. (2010). Firm age and performance. *Available at SSRN 1342248*.

Malmendier, U., & Tate, G. (2005). CEO overconfidence and corporate investment. *The journal of finance*, *60*(6), 2661-2700.

Malmendier, U., & Tate, G. (2008). Who makes acquisitions? CEO overconfidence and the market's reaction. *Journal of financial Economics*, *89*(1), 20-43.

Martin, K. J., & McConnell, J. J. (1991). Corporate performance, corporate takeovers, and management turnover. *The Journal of Finance*, *46*(2), 671-687.

Matsusaka, J. G. (1993). Takeover motives during the conglomerate merger wave. *The RAND Journal of Economics*, 357-379.

Mittra, J. (2007). Life science innovation and the restructuring of the pharmaceutical industry: Merger, acquisition and strategic alliance behaviour of large firms. *Technology Analysis & Strategic Management*, *19*(3), 279-301.

Montgomery, C. A., & Wernerfelt, B. (1988). Diversification, Ricardian rents, and Tobin's q. *The Rand journal of economics*, 623-632.

Mueller, D. (1980). *The Determinants and Effects of Mergers.* Cambridge, Oelgeschlager

Munos, B. (2009). Lessons from 60 years of pharmaceutical innovation. Nature reviews Drug discovery, 8(12), 959.

Nguyen, M., & Nguyen, H. (2010). *Stata Module: Estimates of System of Regression Equations with Unbalanced Panel Data and Random Effects*. Working Paper.

Ornaghi, C. (2006). Mergers and innovation: the case of the pharmaceutical industry.

Ornaghi, C. (2009). Mergers and innovation in big pharma. *International journal of industrial organization*, *27*(1), 70-79.

Pammolli, F., Magazzini, L., & Riccaboni, M. (2011). The productivity crisis in pharmaceutical R&D. *Nature reviews Drug discovery*, *10*(6), 428.

Puranam, P., Singh, H., & Zollo, M. (2006). Organizing for innovation: Managing the coordination-autonomy dilemma in technology acquisitions. *Academy of Management journal, 49*(2), 263-280.

Ramaswamy, K. P., & Waegelein, J. F. (2003). Firm financial performance following mergers. *Review of Quantitative Finance and Accounting*, *20*(2), 115-126.

Ranft, A. L., & Lord, M. D. (2002). Acquiring new technologies and capabilities: A grounded model of acquisition implementation. *Organization science*, *13*(4), 420-441.

Rapp, R. T., & Rozek, R. P. (1990). Benefits and costs of intellectual property protection in developing countries. *Journal of world trade*, *24*(5), 75-102.

Rhodes-Kropf, M., & Robinson, D. T. (2008). The market for mergers and the boundaries of the firm. *The Journal of Finance*, *63*(3), 1169-1211.

Rossi, M., Yedidia Tarba, S., & Raviv, A. (2013). Mergers and acquisitions in the hightech industry: a literature review. *International Journal of Organizational Analysis*, *21*(1), 66-82.

Ruffolo, R. R. (2006). Why has R&D productivity declined in the pharmaceutical industry?. *Expert opinion on drug discovery*, *1*(2), 99-102.

Schumpeter, J. (1942). Creative destruction. *Capitalism, socialism and democracy*, *825*, 82-85.

Sears, J., & Hoetker, G. (2014). Technological overlap, technological capabilities, and resource recombination in technological acquisitions. *Strategic Management Journal*, *35*(1), 48-67.

Sevilir, M., & Tian, X. (2012). Acquiring innovation. In *AFA 2012 Chicago Meetings Paper*.

Shin, S. R., Han, J., Marhold, K., & Kang, J. (2017). Reconfiguring the firm's core technological portfolio through open innovation: focusing on technological M&A. *Journal of Knowledge Management*, *21*(3), 571-591.

Statista (2019). *Number of pharmaceutical merger and acquisition deals worldwide from 2004 to 2014.* Retrieved from: https://www.statista.com/statistics/314605/global-pharmaceutical-merger-and-acquisition-deals/

Steigenberger, N. (2017). The challenge of integration: A review of the M&A integration literature. *International Journal of Management Reviews*, *19*(4), 408-431.

Stigler, G. J. (1950). Monopoly and oligopoly by merger. *The American Economic Review*, 23-34.

Strickland, A. D. (1985), Conglomerate mergers, mutual forbearance behavior and price competition. *Managerial and Decision Economics, 6*(3), 153-159.

Sudarsanam, S., Holl, P., & Salami, A. (1996). Shareholder wealth gains in mergers: effect of synergy and ownership structure. *Journal of Business Finance & Accounting*, *23*(5-6), 673-698.

Trichterborn, A., Zu Knyphausen-Aufseß, D., & Schweizer, L. (2016). How to improve acquisition performance: The role of a dedicated M&A function, M&A learning process, and M&A capability. *Strategic Management Journal*, *37*(4), 763-773.

Valentini, G., & Dawson, A. (2010). Beyond knowledge bases: Towards a better understanding of the effects of M&A on technological performance. In *Advances in Mergers and Acquisitions* (pp. 177-197). Emerald Group Publishing Limited.

Valentini, G. (2012). Measuring the effect of M&A on patenting quantity and quality. *Strategic Management Journal*, *33*(3), 336-346.

Vyas, V., & Narayanan, K. (2016). Does M&A matter for R&D? Evidence from the pharmaceutical sector in India. In *Technology*(pp. 89-109). Springer, Singapore.

Zellner, A. (1962). An efficient method of estimating seemingly unrelated regressions and tests for aggregation bias. *Journal of the American statistical Association*, *57*(298), 348-368.

Appendix A

Table A1. Variance inflation factor

	VIF	1/VIF
Firm Age	1.255	.797
Number of technological M&A's	1.224	.817
Number of non-technological M&A's	1.189	.841
Size	1.165	.859
Leverage	1.092	.916
Mean VIF	1.185	.

Table A2. Correlation matrix of residuals from the SUR estimation, using absolute number of acquisitions

	(1)	(2)	(3)	(4)
(1) Innovation input	1.000			
(2) Innovation output	0.0228	1.000		
(3) Short-term financial performance	-0.022	-0.0638	1.000	
(4) Long-term financial performance	0.0429	-0.0193	0.5432	1.000

Notes - Breusch-Pagan test of independence: Chi-square= 66.983, p-value=0.000

Table A3. Correlation matrix of residuals from the SUR estimation, using relative number of acquisitions

	(1)	(2)	(3)	(4)
(1) Innovation input	1.000			
(2) Innovation output	-0.0599	1.000		
(3) Short-term financial performance	-0.1220	-0.0314	1.000	
(4) Long-term financial performance	-0.0924	0.0187	0.5433	1.000

Notes - Breusch-Pagan test of independence: Chi-square= 62.486, p-value=0.000

Table A4. Random effects and fixed effects estimates on the effect of M&A on long-term financial performance (measured with stock variable of ROA)

Column	(1)	(2)
Variables	Long-term financial performance (RE)	Long-term financial performance (FE)
Number of technological M&A’s	-0.00215	-0.00215
	(0.00169)	(0.00163)
Number of non-technological M&A’s	0.00375**	0.00375**
	(0.00156)	(0.00151)
Size	0.00534	0.00534
	(0.00500)	(0.00484)
Firm Age	-0.0245	-0.0245
	(0.0521)	(0.0504)
Leverage	-0.0195	-0.0195
	(0.0134)	(0.0129)
Year Dummies	INCLUDED	INCLUDED
Firm Dummies	INCLUDED	-
Constant	0.667	0.583
	(1.552)	(1.439)
Observations	207	207
R-squared		0.235
Number of firms	12	12
Column	(3)	(4)
Variables	Long-term financial performance (RE)	Long-term financial performance (FE)
Relative number of technological M&A’s	-216.1***	-216.1**
	(81.27)	(78.79)
Relative number of non-technological M&A’s	186.2**	186.2**
	(84.13)	(81.56)
Size	0.00179	0.00179
	(0.00480)	(0.00466)
Firm Age	-0.0194	-0.0194
	(0.0583)	(0.0565)
Leverage	-0.0207*	-0.0207*
	(0.0117)	(0.0113)
Year Dummies	INCLUDED	INCLUDED
Firm Dummies	INCLUDED	-
Constant	0.339	0.264
	(1.700)	(1.581)
Observations	207	207
R-squared		0.251
Number of firms	12	12

Notes – All independent variables are stock variables of a 5-year lag. Year dummies included in all regressions. Firm dummies only included in RE models. Standard errors are clustered at firm level and reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table A5. SUR estimates on the effect of the absolute number of M&A's on long-term financial performance (measured with stock variable of ROA)

Column Variables	(1) Innovation input	(2) Innovation output	(3) Short-term financial performance	(4) Long-term financial performance
Number of technological M&A's	.0028671** (.0012297)	-2.57e-09* (1.33e-09)	-.0004485 (.001883)	-.0037258 (.0301184)
Number of non-technological M&A's	-.0006767 (.0015588)	-3.11e-09** (1.53e-09)	.003995 (.0029248)	.0363492 (.051127)
Size	-.0126749** (.0058517)	-2.65e-08*** (6.22e-09)	-.0017867 (.0236939)	-.1440088 (.193237)
Firm Age	-.027451 (.0401506)	1.95e-07*** (5.24e-08)	.0316263 (.3109001)	-1.262558 (1.952509)
Leverage	-.0135322* (.0081932)	-1.77e-08 (9.94e-09)	-.0253554 (.0201003)	-.2242237 (.3114333)
Year Dummies	INCLUDED	INCLUDED	INCLUDED	INCLUDED
Firm Dummies	INCLUDED	INCLUDED	INCLUDED	INCLUDED
Constant	1.837452** (.9275141)	-3.81e-06*** (1.27e-06)	-.0008072 (1.566541)	50.40079 (52.26841)
Observations	207	207	207	207
R-squared	0.7218	0.3853	0.4069	0.7321
Number of firms	12	12	12	12

Notes – Year and firm dummies included in all regressions. Standard errors are clustered at firm level and reported in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table A6. SUR estimates on the effect of the relative number of M&A's on long-term financial performance (measured with stock variable of ROA)

Column Variables	(1) Innovation input	(2) Innovation output	(3) Short-term performance	(4) Long-term performance
Relative number of technological M&A's	187.7171*** (58.56599)	-.0000972 (.0001043)	-153.4899 (127.1762)	-1630.182 (2949.993)
Relative number of non-technological M&A's	-118.7858** (58.00719)	.000061 (.0000959)	379.0655 (260.0416)	1268.534 (3014.086)
Size	-.0045954 (.0040918)	-2.82e-08*** (5.89e-09)	-.0100769 (.028117)	-.2233894 (.1962164)
Firm Age	.0086333 (.029919)	1.30e-07** (5.97e-08)	.0450587 (.3162403)	-.9724426 (1.93339)
Leverage	-.0093231 (.0079817)	-1.87e-08* (1.09e-08)	-.0289594 (.022001)	-.2610733 (.2720489)
Year Dummies	INCLUDED	INCLUDED	INCLUDED	INCLUDED
Firm Dummies	INCLUDED	INCLUDED	INCLUDED	INCLUDED
Constant	.2380987 (.704311)	-1.82e-06 (1.55e-06)	.0276032 (1.564082)	47.48742 (52.73471)
Observations	207	207	207	207
R-squared	0.8409	0.3787	0.4135	0.7386
Number of firms	12	12	12	12

Notes –Year and firm dummies included in all regressions. Standard errors are clustered at firm level and reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1