

**Exploration, Exploitation and Ambidexterity in the R&D of Pharmaceutical Companies**

by

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**Five key words:** Pharmaceutical R&D, Productivity, Ambidexterity, LOC, MSC**.**

**Purpose:** The purpose of this thesis is to find out what pharmaceutical companies are doing

in exploitation and exploration to improve R&D productivity. This research will also

investigate the implications of management and control theories in combining exploration.

and exploitation in the context of pharmaceutical R&D.

**Methodology:** Multiple case study interviews.

**Theoretical perspectives:** Management Control System (MCS)

Lean Principles, Open innovation, exploration vs exploitation and ambidexterity

**Empirical foundation:** The empirical foundation is based on the information gathered from

interviews. By concluding and analyzing the feedback, we are enabled to combine the empirical

results with management theories to (i) study what different organizations that are involved in pharmaceutical R&D are doing to increase productivity, (ii) investigate the interviewees’ attitudes towards ambidextrous approach and (iii) discuss the possibility, the advantage and practical implication of combining exploration and exploitation.

**Conclusion:** In the case studies we found that big pharmaceutical companies are more ambidextrous while small and medium size organizations lean more to exploration. Also, all organizations in this research acknowledged the importance of being ambidextrous but also argued that only relatively larger organizations can afford the cost of paying dual attention. All interviewees agreed the potential benefit of combining exploitation and exploration and some examples were given. Furthermore, we contribute to the existing research by combining case studies and theories of LOC and MCS, as well as arguing that by utilizing different levers of control rationally, the tensions that result from applying different opposing strategies can be better balanced out in an R&D Pharma environment.

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# 1.Introduction

## 1.1 Background

### 1.1.1 Choice of subject

Productivity has been decreasing in pharmaceutical companies for the past decade (Getz and Kaitin, 2015) and it does not seem that companies are finding solutions to bring back research and development to what it once was in pharmaceuticals. Productivity is decreasing in this area due to a lack of efficiency in the drug discovery phase combined with a decrease in new ideas and innovation (Elmquist and Segrestin, 2007). Attention should be paid to the R&D stage to increase the productivity in pharmaceutical companies.

The R&D departments in pharmaceutical industries are under great pressure to be both cost effective (exploitative) and innovative (explorative), while handling great risk, and constrained resources in a fast-to-market manner (Elmquist and Segrestin, 2007). Consequently, pharmaceutical companies are facing two kinds of challenges now: on one hand, they should reduce wastes and cycle times and also ensure quality in order to cope with the expiring patents (Elmquist and Segrestin, 2007), while on the other hand, they are under constant pressure to develop innovative drugs since the low-hanging fruit is already picked To add to this, the failure rate in pharmaceutical R&D is very high, only 1 in 5000 compounds make it to the last stage in research and development and only few compounds reach the development stage with satisfactory results (Rafols et al., 2014). All of this is forcing pharmaceutical companies to cater for innovation in a faster and more efficient way.

To tackle challenges mentioned above, various management theories as well as techniques were adopted. Most of them are either efficiency enhancement or new idea generation strategies.

### 1.1.2 The Exploitative Strategy: Lean Principles

Though many organizations do not name their efficiency enhancement strategies as lean, they actually share the spirit of lean principles. Lean principles were coined by James P. Wormack and Daniel T. Jones in 1997 (Womack & Jones, 1997). Womack and Jones studied the Toyota Production System (TPS), which includes several production principles, i.e., total production maintenance (TPM), just-in-time (JIT), Kanban (a checklist in production process), value stream mapping and Kaizen (continues improvement). Womack and Jones epitomized the essence of TPS and extended it to a general business level that can be adopted in other manufacturing companies (Thangarajoo and Smith, 2015).

 Lean thinking is concluded to be the way to specify value, line up value creating actions in the best sequence, and conduct these activities without interruption whenever someone requests and performs them more effectively” (Womack & Jones, 1997). The 5 principles of lean thinking are: 1. Define value from the customer perspective, which requires companies to think about who the target consumers are, and value the product as if they are the target consumer. 2. Identify the value streams map. 3. Make the Value flow, which is a principle that aims at managing the remaining value-added activities by reducing production cost, reducing cycle time, and improving efficiency (Landeghem, 2002). 4. Implement pull-based production, which can be viewed as an aspect that makes sure a company sells the product to target consumers whenever the client wants (Womack and Jones 1997). 5. Strive for perfection continuously, a principle that states that companies should open to improvement on a day-to-day basis. One practice of this principle is Kaizen adopted by Toyota.

### 1.1.3 The Exploration Platform: Open innovation

Open Innovation is a new but well-accepted concept to tackle the decreasing trend in new idea generation and now become the typical pattern of innovation in pharmaceutical company. The definition of Open Innovation (OI) was firstly given by Chesbrough (2003). In his book *Open innovation: The new imperative for creating and profiting from technology* Chesbrough stated that OI means that valuable ideas can inflow and outflow from an organization to the entity that has the most value of holding the idea (Chesbrough, 2003). Though the book is commonly regarded as the first book that formally introduced OI, the theory of OI is built on the foundation of many other innovation theories and practices. For example, Spithoven et al. (2013) concluded that OI theory was empowered by the innovation framework developed by Teece (1986) and the idea of absorptive capacity (Cohen & Levinthal, 1990). Chesbrough and Crowther (2006) further developed the initial definition of OI as a tool to use outside resources to boost internal innovation. Put it differently, institutions may use external abilities to strengthen the R&D capacity of their own because open innovation and closed innovation are not mutually exclusive and can have synergies.

After the introduction of OI definition, the area of OI has attracted many researchers. For example, Trott and Hartmann (2009) examine the six principles proposed by Chesbrough and criticized the open innovation as “putting old one in new bottles' '. By using 305 Belgian manufacturing firms as samples, Faems et al. (2010) studied the cost of OI and found that there was an obvious increase in R&D cost. However, with the rapid expansion of the OI research domain, literature became wide-separate (Gassmann et al., 2010). The early researchers on this topic paid much attention to the questions of “What is OI” and “Why does an organization need OI”. The subsequent research on OI focuses more on the practical level, i.e., the implementation and effect, during the decade of 2010s. Spithoven et al. (2013) analyzed the implementation of OI in small and medium sized enterprises (SME) and found that the effects of OI practices in SMEs are often different from those in large firms and that SMEs were more effective in using different OI practices simultaneously. Four kinds of OI practices were identified by researchers in this decade (Lee et al., 2019). In research by Lee et al (2019), the four different types of OI were: Crowdsourcing OI, Coopetition OI, Science-based OI and Network OI. Also, by using empirical research, Lee et al (2019) found that big firms are more likely to use OI to develop complex projects, even though their own R&D capabilities (represented by the numbers of expert’s teams and laboratories) are relatively strong, while smaller firms are prone to use closed innovation. Bogers et al. (2018) discussed trends, i.e., digital transformation, and challenges in the implementation of OI. Some researchers, i.e., Kratzer et al. (2017), Nestle et al. (2019) and Yun et al. (2020) focused intensively on the innovation culture in an organization, and all found cultures are important in the internalization of external innovation.

## 1.2 Problem Discussion

Considering the challenges in R&D that pharmaceutical companies are facing, it may be necessary for them to pay dual attention to both efficiency enhancement (exploiting their current outcomes and process perfection) and exploration in the R&D process. However, according to some of the previous research, for example, see Sinha (2015) and Johnstone et al. (2011), the needs for explorative and exploitative activities are contradictory. This paper will try to study two major issues: firstly, how should pharmaceutical companies balance and best employ exploration and exploitation, thus achieving productivity improvement. Secondly, what is the role of management and control theories and practice in the process of balancing both.

## 1.3 Purpose and Research Questions

The purpose of this thesis is to find out what pharmaceutical companies are doing regarding exploitation and exploration to improve R&D productivity. This research will also investigate the implication of management and control theories in pharmaceutical R&D.

The research question mainly includes: How is productivity defined in Pharmaceutical companies? What are Pharmaceutical companies doing to implement exploitative strategies to increase efficiency? How are companies increasing the generation of new ideas and innovation through exploration? And finally, how to implement the theory of management control to balance between exploitation and exploration?

# 2. Methodology

## 2.1 Research Design

Our plan is to use multiple case studies to investigate our research questions. Case study is an appropriate research method for this paper for the following reasons. Firstly, according to Scapens (1990) and Yin (2018), case study can provide a perfect opportunity for researchers to have an in-depth knowledge on what the phenomenon is and how this could happen. Consequently, with the help of case study, this research will try to find clearly what firms are doing and the motivation behind their behaviors. Secondly, case study can close the gap between theories and practice. Plenty of research on lean and open innovation are available, however, research on the implementation of lean as well as innovation are rare in the pharmaceutical industry. By using case study, this gap will be hopefully closed. Thirdly, case study is one of the most common research techniques in management accounting domain.

The choice of multiple case studies is since, affected by firm size, market position and corporate culture, companies may show different performance regarding lean and open innovation. Consequently, drawing conclusions by single case study would be biased and is far from convincing (Humphrey and Lee, 2004). To overcome this problem, a multiple case study that collects data from different pharmaceutical companies will be applied. As argued by Yin (2018), multiple case studies provide an opportunity for wider discovery of the reasons behind the phenomenon and also allows researchers to make comparisons across different situations.

The research method should be qualitative because we planned to conduct case studies. Qualitative research, according to Fossey et al. (2002), aims to “address questions concerned with developing an understanding of the meaning and experience dimensions of humans’ lives and social worlds”. Put it differently, a qualitative method is a suitable tool to understand human being’s activities under a given social context. By using qualitative methods and research techniques within the qualitative categories, we can observe and conclude how firms as well as their managers redesign the R&D by adopting lean and open innovation.

Another reason that encourages us to choose qualitative methods is that although previous research on lean or open innovation are sufficient, there are limited case studies regarding the way pharmaceutical companies balance exploitation and exploration. As argued by Merriam and Tisdell (2015), if previous research is limited, a case study that uses a qualitative method would be recommended. By using a qualitative approach, we can observe and investigate how companies in a specific industry improve R&D productivity and combine practice with theories.

Admittedly, the qualitative method has its drawbacks and one that is worth noticing in this research is the outcome of the qualitative method, especially case study using interview, relies heavily on the source (interviewee). For example, in each case study the feedback given by interviewees can be influenced by their previous background and personal preference. We planned to overcome this shortcoming by delivering multiple case studies, including organizations with different characteristics and selecting the interviewees carefully.

## 2.2 Case Selection

The case selection should facilitate the research question and provide information that can contribute to the knowledge gap. Examples that were used in previous research were mainly about the operational and production division of pharmaceutical companies, but less attention was paid to R&D centers like laboratories. Consequently, the managers and researchers in the R&D center of two different pharmaceutical companies were selected and interviewed. To avoid selective bias, we picked two pharmaceutical companies with different situations. Also, since nowadays pharmaceutical companies, regardless of their size, have formed complex innovation collaboration networks with different partners, we did not limit ourselves to only pharmaceutical companies. Two not-for-profit organizations were selected for that they were involved in the R&D chain of pharmaceutical companies. We believed introducing not-for-profit organizations can bring new perspectives to our research, taking into account their important role in R&D.

The company in case A is widely recognized as one of the biggest pharmaceutical companies in the world and has the richest product line among the four selected targets. We selected case A as one of the samples mainly because of its big size and strong R&D ability. We believed a firm like case A with different products may have multiple R&D patterns like integrated innovation and open innovation. According to Alvim-Gaston et al. (2014), it was common that big pharma used integrated innovation in their core business while open innovation was adopted in the field where big pharma’s comparative advantages are relatively weak. Consequently, by using case A as an example we would have a broad picture of in general what pharmaceutical companies are doing in both exploitation and exploration to increase R&D productivity. Furthermore, Case A has adopted lean ever since the 2010s. We believe a relatively long history of lean would be reliable since case A could put lean principles within its own management context.

Company in case B is a private company founded in 2019. It was a relatively smaller company with only a few employees and focused on overcoming the hurdle of targeted intracellular drug delivery. We selected case B mainly for its start-up phrase and relatively small scale. The lean and open innovation in a startup company should be different from those in mutual and large companies like case A and there is a great chance that for SMEs (small and medium sized companies) they use outbound open innovation (selling knowledge to external users) to generate income, which is different from big pharma’s inbound open innovation. By including case B, we may have access to another exploration pattern and also may observe various adaptations of exploitative activities.

 The organization in case C, is a for-profit organization and it is one of the U.S. biggest cancer centers which is affiliated to a university. We believed that incorporating case C is beneficial. Firstly, according to its official website, the organization in case C has already adopted lean and lean-related management principles like lean six sigma in across areas to improve the process throughout the institutions. Secondly, as suggested by literature, one type of open innovation is collaborating with academia like universities. We believe interviewees in case C have much to say about open innovation. Last but not the least, since we already have a sample of a big and comprehensive pharmaceutical company (case A) and a smaller company that focus more on a specific area (case B), we think that incorporating a big but specialized for-profit organization would be valuable to our research.

The organization in case D is a not-for-profit research lab in a hospital of the University of Montreal. The interviewee’s division specializes in genetic disorders. We believed that incorporating a researcher from not-for-profit organization can bring different opinions and perspective to this research regarding the control level and innovation.

## 2.3 Data Collection and Analysis

The pattern of interviews is semi-structured interview. In general, a semi-structured interview means that the interviewers design a few questions ahead of time and bring forward extra questions based on the interviewees’ reaction. A semi-structured has some merits that are important to this research, one of which is that it provides flexibility during the interview (Louise Barriball & While, 1994). We believed that a semi-structured interview could help us to advance the interview by following up various questions based on the interviewee’s response.

Some concerns may appear regarding the semi-structured interview. First, the result of a semi-structured interview may vary from company to company because of the relatively flexible questions. Secondly, giving follow up questions based on interviewees’ response may be challenging. We planned to solve those problems by carefully designing the semi-structured questions to make sure our focus is kept on the R&D productivity and preparing follow up questions in advance. As for the different answers given by interviewees, we regard those differences as reasonable phenomena and would compare them to contribute to the previous research.

Interview guide is important because it provides the framework of data collection. In this thesis most of the data are primary data. According to Schutt (2018), primary data is the unprocessed information that is collected by the primary user. In this research, primary data was obtained through personal interviews with managers, R&D researchers, and experts. The use of primary data can help the authors to have an in-depth knowledge on the implementation of lean, R&D productivity and open innovation in the target firms as well as the managers’ attitudes toward those management techniques. Interview is suitable for collecting primary data of case study because a depth interview may extract information that cannot be obtained through public source (Schutt, 2018).

The execution of the interviews was arranged as follow. Six targets organization, both for-profit and non-for-profit, were decided and the request of interviewees were sent via email. We got four confirmation letters and then designed the interviewee question according to the research purpose. An email that includes the online meeting link and a confirmation of the meeting time would be sent one day before each interview. Some important background information like the clarification of definitions was also sent because managers may address one managerial technique in different terms, for example, open innovation is sometimes referred as crowdsourcing. Making the definition clear would save interview time and accelerate the process.

At the beginning of the interview, we introduced ourselves briefly including the university, intention of research and the use of data. Then we started the interviewee by giving some open questions and let the interviewee ask questions regarding this research as a warm up. The aim of the warm-up section mentioned above is to obtain interviewees’ trust and start the interviewee naturally. In the next stage we brought the questions regarding exploitation and exploration. We also provided follow-up questions based on their response. Throughout the interview we gave positive body language like nodding, smiling and taking notes to encourage interviewees to provide more information. The interviews would be audio-recorded since much attention was paid to the interview and reaction with interviewee so writing down everything is not feasible in this regard and audio recording is useful when we conclude and compare the result of interviews. Also, since people are less sensitive to audio record than to video record, we can avoid steering interviewees. Before we recorded, we asked for permission and promised the confidentiality of the information and claimed that all relevant materials would not be shared with anyone else, to rest assure the managers. After we finished the question session, we gave participants time to ask questions and to add what they would like to.

After each interview the record was listened carefully, and bullet points were summarized to make compression and discussion. Excel was also used to make result comparable and more straightforward. Furthermore, the results were converted into text by directly and indirectly citing the dialogues and interpretation were presented by comparing the results and theories of management control and innovation.

The case studies were conduct by online interview via Zoom and Teams. We believe online interview is appropriate under current situations since many companies, including the companies that interviewees work for, have adopted online working for nearly one year, managers are getting more familiar with online meetings. Conducting online meeting have no obvious negative impact on this research. A merit of online interviews is that interviewees can choose the site to contact us according to their preference. Putting interviewees in a familiar environment can, argued by Gubrium and Holstein (2001), make interviewees feel being respected and encourage them to participate more in the interview.

Apart from primary data collected by interviews, we also used online resources to have a broader understanding of theories including exploration and exploitation activities, lean principle and open innovation, and management control theories. Lund University library database and Google scholar were picked as source of information mainly because of their generality and free access. Firstly, we read the articles that bring forward and develop the theoretical frameworks. Secondly, we sort the available articles by every five years to study the trend and empirical development of the theories. Thirdly, the newest articles were collected, and the research frontier was identified.

## 2.4 Validity and Reliability

We believed this research to be strongly valid for mainly three reasons. First, the external validity was backed by incorporating different interview targets. In this research, various organizations that were involved in pharmaceutical R&D by different ways were investigated to try to capture the complex context of R&D. Besides, the for-profit organizations selected were of different situations: company in case A is one of the largest pharmaceutical companies in the world, company in case B is a start-up with a few employees and company in case c is relatively large. Plus, those three cases have different access to resources and strategies. Secondly, the internal validity was backed by the selection of interviewees: they were all experts in both innovation and division leading, which means the answer they gave was less biased compared with the answer given by solely managers or researchers. Thirdly, some measures were taken to guarantee the research quality. Some of the measures are discussed above. We also sent follow-up emails to request further explanation when necessary.

## 2.5 Limitation

This research is exposed to some limitations. Firstly, the internal validity may be impaired by the fact that the number of interviewees in each case may not be large enough. For each institution one manager participated in this research which means that their answer may focus more on their division rather than the whole company. Though in general the culture and strategies would not vary a lot within the organization, this kind of limitation still exists. Secondly, though interviewees shared general pictures and important information, some examples and empirical materials cannot be presented due to the confidentiality rules regarding intellectual property in pharmaceutical companies, which may potentially undermine the persuasion of case study.

# 3. Literature Review

## 3.1 Defining exploration, exploitation, and ambidexterity

According to Bedford (2015) companies can be divided into explorative, exploitative, and ambidextrous companies. Exploitative companies are the ones that look to refine their strategy and production thus focusing on efficiency and becoming better at what they do. Explorative companies are those that look to generate new ideas and experiment with their strategies for the sake of innovation and discovery. This is what leads to ambidextrous companies or those that balance exploration and exploitation. Ambidextrous firms furthermore are complicated in their structure and ultimate productivity is reached when both differentiation and low-cost goals are balanced rather than engaging in trading off said goals. The strategies and routines of exploration and exploitation are greatly different thus choosing when to be innovative and when to be efficient poses challenges. For being innovative and experimenting requires a certain amount of slack, whether in time or wasting resources the experimentation process requires trial, error, and waste (March et al., 1991). On the other hand, exploitation, or strategies that look for efficiency usually require decreasing waste, inventory as well as decreasing cost. This was further supported by Paul et al. (2010) who not only shows that pharmaceutical companies are ambidextrous in nature and require the increase in both exploration and exploitation for ultimate productivity but also showed the difficulty of increasing these contradictory elements. Paul et al. (2010) defined productivity in R&D in pharmaceutical companies as effectiveness and efficiency. The author furthermore divided these elements into a formula which clearly shows what makes up productivity. In the numerator there is WIP or the number of new inputs and discoveries. TS is the success rate in drug discovery. And V represents the value of the production. In the denominator there is C representing cost and CT representing cycle time. Either increasing numerator or decreasing denominator leads to an increase in productivity. The problem stranded that these factors affect each other either in a complimentary manner or in an adverse one. For example, increasing or decreasing cost alone means a decrease in WIP, for one cannot incur more cost and resources in new discovery. This was furthermore supported by Bedford (2015) who explained that if one focused on exploration without exploitation, one cannot efficiently translate inputs into outputs. March et al. (1991) argued that the pharmaceutical industry was in demand of increased innovation at lower costs but also commented that there are researchers who believed that innovation and enhanced performance were inherently contradictory goals. Researchers even argued that such a balance was not possible, for the point of performance enhancement is to reduce the variation in performance, on the other hand variation is a crucial aspect in innovation. There is much research that discussed how to either increase efficiency or discovery in R&D, but a deeper look was not given to the ambidextrous nature of Pharmaceuticals and how to reach ultimate productivity through balance.

## 3.2 Exploitation in Pharmaceuticals

The first step is to find a process that if implemented does not only affect one element of productivity in R&D such as cost or cycle time alone, but multiple elements simultaneously. According to some research, for instance, Johnstone et al. (2011) and Reinertsen and Shaeffer (2005), lean principles and other related strategies were widely accepted by pharmaceutical companies because those strategies can reduce cycle time, increase success rate, and decrease cost simultaneously. Johnstone et al. (2011) argued that research show the most effect of lean is on cycle times. With such a competitive industry and the pressure of the market to be “the first” cycle time is a leading factor in productivity. The application of lean in R&D reduced cycle time by 50% in some examples and can furthermore lead to less waste between cycles which allowed for better information sharing. According to Johnstone et al. (2011), implementing performance enhancing methods helped in accumulating over 1 Billion in benefits over the years in Lilly, and Covance saved almost 30 million in costs from the implementation of lean and six sigma. Furthermore, implementing lean allows for better and higher quality information sharing between divisions and individuals and can allow individuals to learn from their past mistakes and make better decisions when it comes to lead optimization in drug discovery. This will automatically lead to less attrition rates. An example of how lean can be implemented to increase productivity is the following.

Although a lot of technology has been introduced in recent years to enhance and optimize the process of drug discovery such as high throughput screening and high throughput chemical synthesis, productivity is decreasing in research and development in pharmaceutical companies. This is due to the naturally iterative process (design, synthesize, test and redesign) of drug discovery. This cycle has not been shortened with this technology. But Weller et al. (2006) showed that integrating lean principles mostly present in the manufacturing industry could lead to lead optimization of drug discovery and the reduction of the cycle time. Moreover, Reinertsen and Shaeffer (2005) explained that the main reason for the decrease in productivity in pharmaceuticals is the high failure rates, and the implementation of manufacturing principles such as lean principles can enhance the knowledge gained from lead optimization and increase candidate success rates. The process of lead optimization regardless of complexity shares multiple points of value in common and the implementation of lean can increase these points and deliver the products as quickly and as completely as possible to the customer while being cost efficient and applicable in financially constrained companies.

It is first important to describe in a short manner the process of drug discovery to understand how lean can intervene to make it more efficient. According to Reinertsen and Shaeffer (2005) The first part is lead discovery, which is generating multiple lead compounds through synthesizing individual organic compounds to create a diverse structural library. This library consists of multiple compounds some of which will be considered for optimization, hence lead optimization acting as the building blocks for the drug. The second part is lead optimization which consists of choosing the preferred compounds. Although lead discovery consists of 1,000-10,000 compounds, lead optimization consists of only 20-200 compounds. Reinertsen and Shaeffer (2005) explain that lead optimization is dependent on multiple iterations and the efficiency of drug discovery is dependent on reducing or making each iterative more productive. Parallel array synthesis which is testing multiple compounds per cycle rather than the traditional individual compound has been testing over the years, but it is leading to less productivity and more time due to having to synthesize an entire library. Lean principle can here be introduced to reduce said synthesis cycle time and make parallel array synthesis more viable. This is seconded by Petrillo (2007) who explains that increasing the synthesis rate without changing the cycle time. Shortening the cycle time means that the newly synthesized compounds will in contrast benefit from the previous iteration and become up to date from a design perspective.

According to the case study implemented by Reinertsen and Shaeffer (2005), value stream analysis is implemented in the synthesis process which determined which steps were nor value adding steps. This mostly includes waiting time for deliveries such as reagents to come to the lab and in batch wise steps where each batch must wait for the preceding one to be completed to move on. Moreover, non-value adds steps also included repetition of procedures due to error. Due to the practices and structure of the pharmaceutical and chemical industry, it is impossible to incorporate the pull system from the manufacturing industry to reduce or eliminate the waiting time to pick and receive the reagents from the vendor. Therefore, in the process of eliminating nonvalue adding steps the author provided scientists with data rich and accurate reagents selection tools. Moreover, the author worked with the vendors to create a readily available collection of 2,000 reagents which can be accessed almost immediately when needed. Furthermore, agreements have been made with bigger vendors for real time access to reagent inventory. In this way scientists can choose which reagents are most suitable and viable and can be delivered with the most speed. This coupled with the new technology of automated pre-weighted and custom packages this reduces the time wasted in reagent building and delivery. Furthermore, an integrated team was implemented in the discovery process which reduced unnecessary iterative processes as well as placing shared instruments and tools in a single lab which is aligned throughout the whole process and providing the workers with schedules which show when a specific shared instrument is used by who during a specific time. This reduces the time wasted for scientists to wait for shared tools to become available.

The pharmaceutical industry can furthermore use production levelling from the manufacturing industry. Manufacturing companies produce much waste from manufacturing large quantities at the same time. This is the same case in pharmaceuticals in the case of batches when very large libraries are synthesized at single time resulting in work in progress and extra inventory. Thus, one should break down the batches into smaller one that can be processed overnight unattended by workers (Reinertsen and Shaeffer, 2005). The application of these steps reduced the cycle time from 8 to under 2 weeks, hence meeting the requirement of viable and successful array synthesis where the cycle is the same as the traditional synthesis.

## 3.3 Exploration in Pharmaceuticals

The second part of productivity in R&D in pharmaceuticals is exploration. This strategy focuses on exploration, differentiation, and innovation. Unlike exploitation which is focused on predictable results, exploration may result in uncertain and volatile effects. Exploration furthermore allows for the convergence of individual and organizational beliefs which in turn allows for company growth and knowledge sharing as well as creativity and new discovery, which is essential from competitive advantage in a competitive industry such as the pharmaceutical one. As mentioned previously, open innovation (OI) currently is welcomed by pharmaceutical companies because it can increase the productivity of R&D. Traditional integrated innovation is becoming less and less productive since the complexity of R&D is increasing and firms are becoming more focused on specific areas, whereas breakthroughs in new products and new ideas needs the comprehensive adoption of knowledge (Chesbrough and Appleyard, 2007). Open innovation can boost the R&D outcome for mainly two reasons: firstly, OI can absorb knowledge outside the institution thus create new ideas, and secondly, the OI process can increase the ability to identify, develop and commercialize new opportunities, which is referred as absorptive capacity. Mounting research are proving that open innovation can generate new ideas, products, and know-how. Before the formal introduction of the OI concept, Powell et al. (1996) argued that the breath of access to external innovation incentives is beneficial to firms’ innovation. To support this idea, West and Bogers (2011) suggested a positive correlation between the linkage with external innovation partners and the improved innovation performance by identifying and assessing the four-phases model (obtaining, integrating, and commercializing) of inbound (the inflow of knowledge) open innovation. Regarding the form of OI, Keil et al. (2008) suggested that different innovative collaboration, i.e., joint venture, CVC investment, all can increase the output of innovations. Almirall and Casadesus-Masanell (2010) argued that OI can increase the amount of new ideas because in OI process, different idea suppliers are engaged in R&D paths that are different from what they are used to and thus provided an opportunity to discover the hidden idea that cannot be found under their old R&D style. They also argued that OI is a platform to combine different product features to encourage new products and prototypes. Also, Laursen and Salter (2004) claimed that in the OI process, the presence of other stakeholders, i.e., suppliers, and universities and customers, can also enhance the output of innovation. By using the company's data and survey, some researchers proved the second advantage of OI in the process of increasing productivity: the benefit of absorptive capacity. Vanhaverbeke et al. (2008) analyzed the linkage between OI and absorptive capacity and argued from organization learning perspective that companies engage in OI can benefit from not only the introduction of new ideas but also the transfer, diffusion and internalize of innovative culture and strategy, which are all within the absorptive capacity domain. Spithoven et al. (2010) suggested that absorptive capacity is one of the preconditions of utilizing OI and can also be strengthened by the OI process, and that absorptive capacity can facilitate companies’ ability to identify and commercialize valuable opportunities, no matter external and internal, to achieve competitive advantage. Absorptive capacity can also enhance the knowledge management ability, which benefits the R&D productivity in the process of knowledge exploration, retention, and exploitation (Lichtenthaler and Lichtenthaler, 2009). Similarly, King and Lakhani (2011) discussed the OI and absorptive capacity in the software industry and suggested that the experience in previous adoption of external knowledge resources would benefit the subsequent process. Apart from generating new ideas and the benefits that derived from absorptive capacity, some research show that OI can also increase the R&D productivity in other aspects. For example, OI has been found to accelerate the time-to-market process and provide more flexibility in launching processes (Chesbrough, 2004). OI can also reduce innovation risk by reducing bottleneck (Vanhaverbeke and Cloodt, 2006), acquiring the first mover advantage by knowing the technological trend, achieving risk sharing and having flexibility to exit (Vanhaverbeke et al., 2008).

Researchers in pharmaceutical industries also paid much attention to Open Innovation since pharmaceutical companies face the same, if not even higher level of uncertainty compared with other manufacturing industries. As a matter of fact, the practice of OI in the pharmaceutical industry dates much farther. Roijakkers and Hagedoorn (2006) observed a steady increase in the number of firms that use either contractual or equity collaborations to deliver joint R&D ever since 1975. According to Barnes et al. (2009), the complex market requirement and the high level of uncertainty in R&D process push bio-pharmaceutical companies, especially large firms, to form “technological alliance”. Other explanations of why pharmaceutical companies adopt the prototype of OI are the limited venture capital in the capital market and the increased complexity in R&D process (Roijakkers and Hagedoorn, 2006). One example of the early adoption of OI was that in the beginning of 20th century, Eli Lilly established the first internet problem solving platform to connect firms with potential solution providers (Hunter & Stephens, 2010). By using panel study, Chiaroni et al. (2009) firstly assessed the extent and the determinants of the adoption and implementation of OI, specifically in the pharmaceutical industry. They also discuss the different OI tools. Hunter and Stephens (2010) in their research argued that the integrated R&D process is less efficient and unsustainable, and brought the question of whether OI is a suitable way for big pharma. They regarded OI as a valuable R&D model for big pharma since it provided flexibility and helps the company keep up with the rapid change of environment. Munos (2010) argued that although OI may be one of the possible solutions to drug R&D, it should be implemented with cautions, especially taking cultural, scientific, and other factors into consideration. By using firm data of the top 20 bio-pharmaceutical companies from 2000-20007 together with interview, Bianchi et al. (2011) identified two major changes in the open innovation (technological collaborations) process: (i) firms were involving more and more partners outside their core area and (ii) alliance were becoming more and more important in the R&D process. Eaton (2011) suggested that the performance of drug companies cannot meet funders’ expectations and also discussed the feasibility of OI in Non-Pharmaceutical companies. In contrast to Lee et al (2019), the research of Michelino et al. (2015a) showed that OI was very pervasive in smaller and younger firms however the OI often showed negative performance.  Michelino et al. (2015b) also investigated the relationship between OI and company internal R&D and financial performance. Schuhmacher et al. (2013) identified four types of open innovation: knowledge creation, knowledge integration, knowledge translation and knowledge leverage. They also find that there was no superior OI type, pharmaceutical companies should design the model according to its own features. Alvim-Gaston et al. (2014) studied the Lilly Open Innovation Drug Discovery (OIDD) platform and illustrate how OIDD may facilitate the process of new product development. Also, the Grants4Targets (G4T) were studied, and researchers find that G4T was successful in promoting OI, i.e., identifying promising animal tests and getting access to academia. In response, the performance of pharmaceutical companies in the research increases (Dorsch et al., 2015). By using 630 annual reports of 126 targeted companies as samples, Michelino et al. (2015a) suggested a model for measuring the openness degree of bio-pharmaceutical companies. Michelino et al. (2015a) also found a negative correlation between openness and firm age. Wikhamn et al. (2016) delivered 104 surveys to small and medium size enterprises in Sweden to detect how widespread the notion of OI in the bio-pharmaceutical industry. The result of this research showed that only very few companies in response have adopted the OI concept. Wikhamn et al. (2016) also argued a positive correlation between the OI and entrepreneurship. Michelino et al. (2017) provided a framework to evaluate the openness in start-ups and found that companies with high levels of industrial specialization tend to form technological collaboration more. By using 701 U.S. pharmaceutical companies, Shin et al. (2018) found that both inbound and outbound open innovation can improve the efficiency of R&D process thus boosting enterprise value. Schuhmacher et al. (2018) argued that enterprises should develop their absorptive capacities to identify external resources as well as design the company's structure to fully utilize open innovation. Nilsson and Minssen (2018) pointed out that a common understanding of the expectations is one of the keys to implement OI successfully and build a five-level model to reduce the complexity in negotiation. Thompson and Bentzien (2020) concludes the adoption of OI and future directions.

## 3.4 How to balance exploration and exploitation.

As an ambidextrous industry, pharmaceutical companies must focus on both exploitation and exploration equally. Choosing to focus on exploitation on account of exploration means that the company will only focus on short term gains and lack the vision to be competitive in an industry where the amount of discovery and idea generation is decreasing every year. This is supported by Johnstone et al. (2011) who argued that performance enhancement and discovery share many resources so focusing on decreasing cycle time and increasing success rate for example means that variation in performance must decrease. This leaded to a decrease in innovation. Focusing on exploration on the other hand will lead to the lack of the ability to get the idea to a finished product and hence the consumer. One can argue that companies must then decide if exploration or exploitation is more important for productivity or plays a greater role. The problem is that pharmaceutical companies are lacking on both ends. As described in the previous chapter companies need more innovation at a lower cost and attrition. When the companies focus mostly on partnerships, joint ventures, and other collaborations to a high extent, they will have difficulty in managing all the complex aspects and divisions. A focus on becoming too exploitative means that the companies are not answering the questions of expiring patents from the 1980s and the need for new drugs. Although research seems to be divided in this aspect where some argue for increased innovation and an open science program, while others call for leaner procedures there is rising evidence that lean could not only allow for innovation but might be complementary as well. The answer might be not to look at exploitation or lean in this case and open innovation as completely adverse forces where one must choose one or the other but to take the benefits and elements of lean as an infrastructure or base for improving open innovation. One must accept that pushing exploitation or exploration could lead to negative effects in the other one and try to mitigate these effects rather than eradicate them. According to Johnstone et al. (2011), innovation was neither constrained nor pushed by process improvement, rather it was affected by the choices one makes during the process. Lean can help find the root of problems which stimulates better idea creation and decision making. It can put powerful tools in the hand of the right individuals and provides the autonomy for said individuals to tackle problems. Most importantly innovation cannot be fostered by a single person. Lean can here help as it breaks down the silo structure in operations and motivates information sharing between groups and individuals and promotes cross sharing and training (Johnstone et al., 2011). This is essential for innovation which requires group effort. Standardization is often looked upon as anti-innovation but can be used as a platform to boost innovation. Since standardizing practices makes it easier to recognize innovation goals and get the product to the final stages. Standardization should not be a set of rules, but rather a guideline which is flexible and promotes best practices and advancing employees. When lean and standardization is looked upon in this manner R&D goals such as lead optimization in drug discovery becomes clearer and one can separate unwanted and wanted variation. Not all variation is slack and bad for performance enhancement, and not all variation is useful for innovation and discovery (Johnstone et al., 2011). Hence unwanted and wanted variation must be separated and lean can reduce unwanted variation. This though does not mean that wanted variation is always beneficial. From the exploitation point of view performance enhancement requires the reduction of all variation to the bare minimum but this is an example of striking a balance which fits between lean and open innovation and is mitigated through the proper implementation of both. With that said one must acknowledge the fact that these are merely suggestions and although they seem logical and have the structure of the proper advancement of ambidexterity, there are few implementations of these suggestions in real life and the full effect is unknown. Bedford (2015) introduced the idea of levers of control (LOC) in an organization. The four levers are belief, boundaries, diagnostic and interactive control system. Each lever represents an action that if triggered will have a positive or negative effect on organization. Unlike explorative or exploitative companies, ambidextrous organizations must utilize multiple levers simultaneously to increase productivity. Bedford (2015) argued that diagnostic and interactive control systems have a positive effect on performance in hybrid companies. Diagnostic systems bring to the managers attention mistakes made in implementation of strategy and variance in work. Interactive control systems are those that promote information sharing, cross division training and interaction. This goes hand in hand with Johnstone et al. (2011) argument that lean, and standardization can push innovation by promoting quality interaction and teamwork and reducing unwanted variance in R&D. Contrary to popular belief boundaries do not have to limit innovation but can be implemented in a way that narrows innovation to fit organizational values and goals. Hence reducing unwanted variance and promoting teamwork, which is in turn essential for innovation.

The importance of ambidexterity is furthermore supported by O'reilly and Tushman (2013) who emphasized the importance of a hybrid structure to secure the long-term survival and profitability of a company. Exploitation aims to secure the viability of the company now, and exploration secures the future viability of the company. A company should innovate and explore to adapt to change and competitors while also investing in efficiency to reduce variability. The question remains of how and when to implement ambidexterity in a company. (O'reilly and Tushman, 2013) similarly, to (Haustein et al. 2014) argue that bigger firms with more resources are better suited to balance between exploration and exploitation than smaller and more resource starved firms. Moreover, O'reilly and Tushman (2013) argue that external collaborations such as open innovation not only helps in exploration but also helps in the implementation of exploitation and balancing both aspects. This is based on multiple studies, one of which studies 325 biotech firms. Interestingly this goes against the literature review which identifies open innovation as a purely explorative action. In addition, the author argues that lean or Toyota principles not only focus on exploitation by making processes more efficient but are also a building block and infrastructure for ambidexterity. Lean principles encourage communication, and constantly changing jobs encourages creativity. This is important for lean, especially in pharmaceuticals it is looked upon to reduce cycle times and increase success rate, but not considered to increase idea creation and help increase drug discovery. This shows that both open innovation and lean principles can be considered complementary hybrid methods in which balance can be achieved between exploration and exploitation. With that said, according to O'reilly & Tushman (2013) this is considered contextual ambidexterity and not simultaneous ambidexterity where the company aims to be explorative and exploitative at the same time, but only considered innovation as a part of consequence of efficiency. This is what we hope to explore in our case studies. Simultaneous ambidexterity according to O'reilly and Tushman (2013) differed from contextual in that it consists of different units and divisions in a company each pursuing either exploration and exploitation and connected by values and company culture and beliefs. These said divisions have their own processes and goals. Such a structure requires a strong management that can balance the counter effects that might result when pursuing said structures simultaneously. This goes hand in hand with Simon's levers of control which argue that opposite effects might rise when pursuing said structure, which should be properly controlled and balanced. On the other hand, sequential ambidexterity or pursuing either exploration or exploitation depending on market condition according to O'reilly and Tushman, (2013) is furthermore prevalent, but prevalent research on the effects and how said structure is implemented is scarce. In addition, according to O'reilly and Tushman (2013), structure was more popular in small service industries with little technological complexity. Our case studies will help us find a clear answer to how pharmaceutical industries balance exploration and exploitation.

## 3.5 Management control systems and ambidexterity

Past studies had analyzed the effect of a single management control system (MSC) on multiple contingencies or multiple MCS or a single contingency and have found that focusing on performance enhancement adversely affects innovative companies. The consensus is that focusing on efficiency adversely affects innovation, but the study by Haustein et al. (2014) showed otherwise and open a discussion for a setting which allows exploration and exploitation to work in harmony. Haustein et al (2014) framework used multiple MCS which were tools used by management to increase control and efficiency, and studies the effect on 11 contingencies. Namely External, organizational, and innovation of said innovative firm company. Haustein et al. (2014) argued that MCS should not be standard across industries and companies, for MCS used in noon innovative companies will produce an adverse effect if used in high tech and explorative companies. Therefore, MCS should be configured and adapted to suit each type of company. According to Haustein et al. (2014), external contingencies which were of relevance to MCS tools were environmental contingencies. Said contingencies represented uncertainty and differentiation such as activities in R&D. This was also of utmost importance to pharmaceutical companies which suffer on both ends of being explorative and innovative as well as efficient in drug discovery. Personnel, action, and result control all have a benefit in environmental uncertainty according to the author and can reduce uncertainty. In addition, in a decentralized structure which is best suited for a complex and innovative firm according to Haustein et al. (2014) one part of organizational characteristics is technological complexity. Using standard administrative and financial control is adversely related to performance of high tech and complex companies, therefore control by management should be adapted to the specific nature of said company. Another aspect of organizational characteristics which can also be argued for pharmaceutical companies is firm size. Haustein et al. (2014) argued that larger firms with more activities, personnel and communication can benefit more from direct methods of control such as result and action control rather than indirect methods such as promotions. One can see this as large firms become more exploitative and standardizing processes and procedures relative to smaller firms.  Most importantly the level of innovativeness is an important contingent factor for MCS according to Haustein et al. (2014). interestingly innovativeness or the ability of the company to discover and develop new ideas, which in pharmaceutical R&D would be drug discovery tend sway more in terms of direct and indirect MCS. This according to Haustein et al. (2014) depended on whether the focus of the company lies more in computational or technical complexity for example, where computational required action control and technical requires result control. This shows that standardization in terms of MCS across all companies and industries regardless of their nature is unadvisable. This furthermore showed that although direct exploitative methods of control can be implemented in innovative companies and have complementary effects on external and some organizational contingencies, the innovative capability of said company will tend to decrease. With that said, large companies with more resources can better apply direct management control systems in a careful manner to innovation, for they have the resources, manpower and technological strength to balance or mitigate the adverse effect on innovativeness. This is not the case with smaller companies. This is supported by Bedford (2015) and Simon's levers of control. Even if two levers are activated at the same time, one focusing on exploration while the other focuses on exploitation and resulting in contrary effects, companies could accept these effects rather than must pick one side. Companies can then try to mitigate and balance side effects.

While prior research studied and analyzed the effect of management control systems on variations of innovation, and while the consensus is that companies would rather specialize in exploration or exploitation, the effect and combination of MCS on firms that are ambidextrous or the firms that implement exploitation and exploration simultaneously has not been thoroughly analyzed according to Bedford (2015). Furthermore, innovation has been perceived as a monolith or rather a single process, or entity rather than a mix of different processes, which in return require different modes of processes to control and balance efficiently. The study by Bedford (2015) is of particular importance for it tackles Simons levers of control to manage the tension created through ambidextrous activities and different innovation modes. Bedford (2015) furthermore, showed the effect of controls on both an individual and combined manner. The Levers of control (LOC) present interactive, diagnostic, belief and boundary control as tools or instruments used by top management to not only guide organizational activity, but also provide management with the opportunity to steer innovative activities in the wanted direction. This was furthermore explained by O'reilly and Tushman (2013), who explained MCS as interdependent methods to both control and enable. Hence, their contrary roles where one takes from the resources of the other.

Diagnostic control systems are said to have a positive interaction with exploitative firms according to Bedford (2015). Diagnostic controls are controls which surface variations in terms of performance and implementation of intended strategy and aim to reduce or eliminate said variation. As such diagnostic controls are positively related and combined with exploitative modes and firms that focus on efficiency, performance enhancement and reducing slack to the minimum. Although according to Bedford (2015) diagnostic systems might surface unnecessary and unproductive arguments and discussions, such a thing should not happen in firms with proper implementation of communication and well-defined goals, for diagnostic systems should help achieve said goals in an efficient manner. When it comes to exploratory innovation firms, Bedford (2015) argued that although diagnostic control measures could reduce over innovation, the idea of slack and variation reduction is not well suited for firms which require walking off the beaten path to increase discovery. In addition, the reward system in diagnostic controls benefits efficiency which is not suited for exploratory work.

Interactive systems on the other hand walk hand in hand with exploratory firms. This according to Bedford (2015) is since in innovative firms, exploratory activities are undergone by lower and middle management. With that said intense communication and interaction of top management is required for the eventual understanding and allocation of resources in a proper manner.  Furthermore, interactive systems can also serve as a catalyst for debate, which in turn open the door and opportunity for discussion, argument, and eventually new ideas. This however is not the case when it comes to exploitative firms according to Bedford (2015), who argued that interactive control systems have added effect in the routine work of exploitation, where communication is more likely to be standardized and efficient to begin with.

It is in boundary control systems where one starts to see mutual and complementary effects of a control lever on multiple innovation modes. Boundaries have a positive effect for exploitative firms for it sets a threshold to eliminate over efficient activities or rather repeating the same process to no effect. According to Bedford (2015), boundary systems can also have a positive effect on exploration at least for the near future, and that is because boundary control helps management unlearn old values and purposes and learn new strategies. With that said boundaries limit experimentation in the long run and thus only has a positive effect on exploitative firms.

Belief control systems benefit exploratory firms the most according to Bedford (2015) in that the belief control systems focus exploratory efforts with the values, statement of purpose, and motivations which reduce over exploration. As well as motivate employees and innovators in a creative environment by aligning organizational purpose and values. Belief control systems also permit abandoning routines and exploring more when said strict routines sway away from the core values of the company. As such Bedford (2015) believed that variant activities and experimentation is central to an exploratory innovative company which is allowed and motivated by a strong belief system. With that said beliefs also influence exploitative firms as it eliminates disagreements regarding decision making and day to day work by presenting a general goal and guideline to follow. On the other hand, over emphasizing belief control systems can also have a negative effect on exploitation when it permits exploring off the known path. It also does not represent the best method of controlling behavior, unlike diagnostic systems for example.

It has been discussed in the literature review the importance of balancing both exploration and exploitation for the long-term survival and productivity for every company. Focusing one control lever to enhance one aspect is not sufficient for growth according to Bedford (2015) and thus a combination of control levers is required to observe and analyze if said control can be complementary to each other and implemented to enhance opposing strategies in the same company. Before moving on to control levers for ambidextrous companies it is worth noting that according to the research by Bedford (2015), companies can combine different complementary levers, which means levers that will amplify and enhance the effect of another lever to a single innovation mode. Such as diagnostic and boundary controls working in harmony in exploitative firms, for according to Bedford (2015) boundaries limit excess and unproductive efficiency which can be the result of diagnostic boundaries. Another example is the use of interactive systems in tandem with belief control systems. Belief systems here according to Bedford (2015) can act as a reference for debates and decisions which result from the communicative interactive control system. That said Bedford (2015) represents results in a different manner where control levers seem to be supplementary (adding value) rather than complementary for individual innovative modes. When it comes to ambidextrous firms a sequential use is unproductive and results in biases towards one strategy or another according to Bedford (2015) this was also supported by the previous literature (O'reilly and Tushman, 2013). Therefore, managers should embrace the contradictory element of different innovative modes and try to balance them using levers, where if a company seems to be pushed to a certain strategy the adverse effect of the other will pull it back again and thus creating balance. The most important combination according to Bedford (2015) for ambidexterity is interactive and boundary control. This combination will lead to a rise of opposing opinions and ideas, which in return will also lead to counterparties acknowledging the importance of pursuing the opposing strategies rather than picking one over the other. On the other hand, the results are contradictory to the literature review for boundary and belief control, thus showing no positive effect on performance for ambidextrous firms. With that said Bedford (2015) acknowledged the importance of belief control in ambidextrous firms as a tool to mitigate the effects that will rise when combining opposing control levers.

# 4. Empirical Materials

## 4.1 Case A

The company in case A is one of the biggest pharmaceutical companies in the world. According to the interviewee’s request, his name is to stay anonymous. The interviewee currently is a manager in the global medical affairs of the company and responsible for three early molecule pipelines of prescription drugs currently.

### 4.1.1 Views on Productivity

From the interviewee’s perspective, productivity in R&D was finding a novel target that is the suitable candidate which can go through all clinical processes with less failure. He also mentioned that what is of great importance in R&D productivity enhancement is to reduce the failure rate, especially in phase I and II.

The interviewee identified three challenges in the R&D in pharmaceutical companies. The first one is finding the right target to deliver research and invest. The interviewee added that countless diseases are identified nowadays but pharmaceutical companies as well as researchers may find it less challenging to develop treatment of those with high successful rates and safety levels. Also, companies should consider the payoff and cost. The second challenge he mentioned was the limited resources. Treatment and drug discoveries are long processes and consequently companies have two tough decisions to make: go or kill and the priority of those projects. The third challenge is to decide which candidate (more practical, medical product) has the highest success rate before moving further to the phase II trial since as mentioned by the interviewee, phase II consumes a huge amount of investment. This factor is challenging even with the assistance of artificial intelligence (AI) and machine learning because of the complexity in patients and symptoms.

*“Identifying candidates is always challenging in this company, as well as in other companies”*, said by the interviewee in case A.

The interviewee regarded this company as ambidextrous. First, the company in case A was explorative in multiple ways: from one side, this company had large R&D groups aiming at identifying and developing novel ideas as well as concepts and from the other side, this company was also explorative in finding new partners. Secondly, this company implemented follow up projects to modify the formulation, to increase the stability and to reduce the side effects of current pipelines, which was also important in their business portfolio. The interviewee also added that there is no clear-cut of explorative or exploitative in the pure medical research field since in most of time those two aspects cannot be separated.

### 4.1.2 Views on Exploitation

As one of the leading pharmaceutical companies, case A had adopted exploitation strategies for decades, mainly for improving efficiency and reducing cycle time. The interview addressed their exploitation strategies as Toyota principle, which exactly shared the same spirit of lean principles. Among the Toyota principles, the continuous improvement model was the most-emphasized aspect. He added that rather than relying on huge and drastic change, his team preferred daily and slight perfection in different procedures since the latter consume less resources and require shorter waiting time and drastic change is also unrealistic for big pharma. The interviewee also stated that lean principles in this company were not copied from theory, rather they combined lean with corporate culture and derived different models as well as process among divisions and modify them on a regular basis to reduce waste and cycle time.

The interviewee believed the tradeoff between cost reduction (exploitation) and new thought generation was a problem that many pharmaceutical companies are facing. From his point of view, though cost saving was tempting because 80% of the investment did not result in the desired consequence, there should be a breakpoint of these two aspects.

*“In our company we believe that although cost reduction is something that can be seen in the short term, cutting too much on innovation is destroying our feature”*, said by the interviewee in case A.

Therefore, this company kept the necessary slack for innovative thoughts. However, waste, and low efficiency activities are also identified in the R & D process. The interviewee reflected that during the period of Covid-19:

*“a lot of things that can be done to achieve cost reduction, like the unnecessary meetings and travels.”*

Finally, he concluded that as a researcher, he believed pharmaceutical companies should invest to the largest extent in the R&D while as a manager, companies should find the balance level between those two aspects.

### 4.1.3 Views on Exploration

In the following section the interviewee shared viewpoints regarding open innovation. The company in case A was known for forming alliances and collaboration with other pharmaceutical companies as well as other institutions. The alliances were mainly driven by the desire to combine efforts, add capability and reduce risk as well as cost in investment. Many examples of open innovation were given and the newest one was the alliance with two small biotech companies during the Covid-19 pandemic period. Though detailed information was not provided because of this company’s confidentiality policy, the general pattern was that the small biotech companies provide specialists from different aspects, and the company A provided know-how, funds, platforms and facilitates the process of going through the three phases of clinical trials. Besides, the interviewee also added that open innovation was usually preferred when companies have multiple candidates but resources (including but not limited to money, time and equipment) are limited. By adopting open innovation this company can conduct all candidates simultaneously with well-selected partners.

“*By doing things like this''*, the interviewee complemented, “*we can conduct all the valuable research simultaneously without determining the priority”*

The interviewee also pointed out the benefit that came from the expanded business portfolio and diversification by utilizing open innovation.

As for the form of collaboration, the interviewee concluded three different forms of open innovation. The first and earliest kind of open innovation was with local governments and other not-for-profit organizations like the World Health Organization (WHO). The second was the collaborations with academia centers and universities. One example was the collaboration with the medical research centers in Cambridge, Massachusetts. The last kind of open innovation was with various pharmaceutical companies no matter the scale. What needs to be mentioned here is that this company utilizes both inbound and outbound open innovation and relies slightly more on inbound open innovation which means this company works more as an idea integrator.

The interviewee regarded open innovation helpful in two aspects of R&D. Firstly research in novel and front areas like genetics can benefit from open innovation since research required huge amounts of money and experts.

*“Sometimes though one pharma has good ideas or candidates, it still hesitates to conduct studies if they have to do it on their own because usually those breakthrough researches are risky.”*

Secondly and more practically, the interviewee believed open innovation can help with the development phase and particularly, open innovation was beneficial in population level. One recent example given by the interviewee was the degree of public acceptance of Covid-19 vaccinium. The interviewee argues that open innovation with authorities to encourage citizens to accept vaccine and and conduct follow-up research to increase the stability and reduce the side effect.

Apart from the potential risk of losing intellectual property (IP) control, the interviewee stated that other drawbacks of open innovation can be avoided, and the benefit of coloration outweigh its cost. The interviewee agreed that coloration with different organizations may be challenging but some techniques like lean and flow management can be utilized to reduce the negative influence. He emphasized that open innovation was a win-win strategy and never a zero-sum game.

### 4.1.4 Balance between Exploration and Exploitation

The interviewee held the belief that ideally companies should balance between explorative and exploitative activities in accordance with their own situations. He emphasized that this argument does not mean companies should have those two aspects fifty-fifty but rather arrange the proportion in line with their risk capacity, shareholders’ expectancy and business strategies.

*“After all, pharmaceutical companies are profit organizations and you cannot spend all your money as you wish.”* *“Maintain a balance that is suitable to you”*, said by the interviewee.

The interviewee also stated that relying solely on one side may limit the access to opportunities. What is more, the interviewee concluded that for big pharmaceutical companies, there is no clear boundary between explorative and exploitative companies and the difference mainly occurs in a division level. One division may lean more to exploration while another division conducts more exploitative activities. The interviewee also expresses his own preference:

*“Someone says that if your company is big enough with cash, you don’t need to have your own R&D team and what you need to do is to buy companies. I certainly dislike this kind of argument. If you do not have your own R&D team, you are always a follower.”*

Furthermore, the interviewee stated that maintaining a balance between exploration and exploitation was more challenging for small pharmaceutical companies because of the limited resources. To conclude, the interviewee claimed that it is beneficial to maintain a proper balance between those two activities after taking account their status, comparative advantage and firm size. Different companies have multiple choices and even shift between exploration and exploitation. The interviewee also concluded that is a general trend that small pharmaceutical companies may lean more to exploration while the giant firms are more conservative.

From a resources point of view, the interviewee admitted that exploration and exploitation to some extent share the same resources, i.e., human capital and investment and under certain situations they are exclusive to each other. However, the degree of mutual exclusion may vary from company to company and for big pharma, it is less challenging to cover both.

Lastly, the follow-up question regarding the complementary effect between exploration and exploitation were brought forward. The interviewee was positive towards the synergy effects. According to the interviewee’s feedback, on the one hand, the standardized process in exploitation can accelerate at least some parts of the exploration activities. On the other hand, the interviewee claimed that with the help of some exploitative techniques, firms can conduct innovative research with lower cost and fast speed. The interviewee also supplemented that from his point of view there is no clear boundary between exploration and exploitation and that researchers can accumulate experience from exploitation activities to avoid waste in R&D. One example was given is the adoption of artificial intelligence (AI) and Machine learning within this organization to facilitate decision making process, especially in the early stage. AI and Machine learning programs have their unique advantages in stimulating and modelling certain procedure in the R&D process. Finally, the interviewee added that personally, he stand firmly for the viewpoint that explorative and exploitative activities can be mutually benefit, but the contradictory effect is important when the resource is limited.

## 4.2 Case B

The interviewee in case B finished his PHD project in McGill university and postdoctoral at Harvard university. The interviewee worked at both Pfizer and Estella pharmaceuticals previously and is currently the vice president of discovery and chief science officer at case B. Case B is a small start-up in the pharmaceutical industry focusing on developing sophisticated packaging for agents to enable direct transfer to targets.

### 4.2.4 Views on Productivity

The interviewee argued that productivity in his point of view is the process that takes a concept or an idea and turns it into a feasible project and ultimately the output into the market. According to the interviewee, the factors that structured productivity was composed of the skillset of the employees, funds available, as well as the competitive landscape. He furthermore added that the higher ups in pharmaceuticals usually focus on the most processes and design which result in candidate molecules, or the leads that will more likely result in a successful drug. Everything else in terms of discovery was not looked upon as part of productivity. He did acknowledge the importance of innovation and discovery and as the necessary inputs for the process which ultimately turned said inputs into outputs. He furthermore added that cycle times are not important in the very early stages of R&D which is his role in the company.

 In terms of how to increase productivity in R&D, the interviewee emphasized that this company was a small start-up which is financially constrained and did not have the funding nor the sources of investments the bigger pharmaceuticals had. Therefore, the company did not indulge in the same exploratory work nor the same risk taking a company like case A can take. Instead, this company focused on more selective validated ideas or the ideas that will more likely generate the best lead.

In terms of the main challenges in R&D or interviewee stated that the main challenge is to reach a successful result. Reaching a successful result required one to be flexible and to constantly reprioritize goals depending on results and the environment.

### 4.2.2 Views on Exploitation

The interviewee argued that as a start-up focused on the early stages of R&D the company has not and was not thinking of applying performance enhancing strategies for, they were focusing more into lead discovery at this point and finding the most validated molecules. With that said he did acknowledge the effect and importance of exploitation such as lean principles especially in bigger companies that can afford both time and resources into making the R&D process more efficient.

The interviewee voiced his concern and agrees that pursuing cost and time saving will interfere with exploratory work. One cannot aim to decrease cost while also look to increase innovation, for exploratory work required both funding and experimentation which ultimately results in variation and slack. He moreover recalled his time with Estella which he mentioned focus mainly on well-known disease areas and optimize and enhance drugs for said areas. He mentioned that the working structure was leaning more towards exploitation where constant updates and results are required and passed through multiple layers of approval until they reach the CSO (Chief science Officer) they focus on creating value through areas that are well known in the company.

### 4.2.3 Views on Exploration

As a start-up the company has received funding from small investors but was now looking to make partnerships with big pharmaceutical companies. The interviewee argued that open innovation was important for exploration works, especially in the secretive bigger pharmaceutical companies. Small biotech companies cannot afford being secretive in their innovative ideas for they required external ties to both survive and evolve. He also mentioned that Harvard has started implementing an open science program with pharmaceuticals in orphaning new targets. This program aimed to find small and new molecules between different Pharmaceutical partners.

Being a small start-up focused on the discovery of new ideas and molecules, company B was exploratory in nature. The biology the company was pursuing was exploratory since the platform the company was using was not well validated and was new in the industry. With that said he added that the company tried to take less risk in drug discovery and development and as such only go after well validated and optimized leads, and in that sense, they were exploitative, trying to cut losses and increasing success rates by pursuing selected leads.

*“We are more exploratory in our work”*, said by the interviewee.

The interviewee moreover argued that open innovation was more prevalent in the earlier stages of R&D, or the part that was more geared towards academia and publication. With that said he states that open innovation was more beneficial in the later stages in development, though collaboration and open science was not implemented often in the lead optimization stage and was more secretive.

In terms of pros and cons the interviewee stated that conducting exploration via open innovation helped one leverage expertise and know-how from other companies, but the cons are that it might compromise the capability of being the first in line or the only company pursuing an impactful and profitable drug.

### 4.2.4 Balance between Exploration and Exploitation

The interviewee mentioned that he has worked all his life in the early stages and exploratory phases of R&D and leans more towards exploratory work. With that said he acknowledged the importance of being ambidextrous and implementing a hybrid system. He argued that most companies should try to balance between exploitation and open innovation, but such work requires a company big enough to be agile in implementing and balancing both systems and structures. An example of this was the high risk taking of Pfizer and the biotech’s collaboration in the discovery of certain vaccine. It was not a really validated platform, but the company took a high risk that paid off well for them. Pfizer had the capability to be efficient and agile in making this discovery process viable. He furthermore argued the importance of these bigger companies engaging in exploratory work and championing an idea for this motivates other companies around it to be more explorative.

The interviewee also argued that exploration and exploitation do not have to be adversely related but complementary to each other. An example of this is the checkpoint inhibitor phase in molecules in cancer targeting drugs. There was little interest in pursuing these targets and most work was done exploratory in academia, but as targets became more validated throughout time labs started pursuing these targets and practical work is now being done in that area.

However, the interviewee also added that one cannot exaggerate the synergies. Though standardization indeed helped in bringing ideas into the market by making it more efficient and viable, every drug discovery program is unique and requires its own structure. One example that was given to back this point of view was that in one program the biology might be easy to develop and pursue but finding the molecule to synthesize and having the right properties to go into development turned out to be the tough issue. The opposite might also be true.

## 4.3 Case C

The interviewee in case C was one of the major scientists in company C. His responsibility includes leading a team that was responsible for characterization of antibodies for cancer, testing drugs’ efficacy and functionality on cells. The interviewee also was responsible for determining which program should move forward to the next stage of clinical development.

### 4.3.1 Views on Productivity

The interviewee defined R&D productivity as being able to offer treatments and solutions in clinics that can provide significant improvement over current ones, with fast speed, high quality and low cost:

*“Science is complex, and productivity has different meanings in different factors. For my division, productivity means that we are able to offer something in the clinic that provides significant improvement and is as cheap and fast as possible”,* said by the interviewee.

The interviewee argued that the most important way to increase R&D productivity was to increase collaboration. As mentioned by the interviewee, company in case C had small transactional groups that integrate ideas generated within and outside the organization. One of the key points was to make sure transactional groups and labs can coordinate well with each other. For example, the interviewee mentioned that in his team experts came from different basic aspects of the clinic to deal with different symptoms in patients.  Integrating information and designing the group structure to facilitate communication is vital from his point of view.

*“Our approach is, really, to increase collaboration”.* Said by the interviewee.

From the interviewee’s perspective, though his group leaned more to exploration, Company C was an ambidextrous company with follow-up programs regarding the current products as well as programs that are aimed at coming up with new drugs.

*“From an organizational level, we have a hybrid model that emphasizes both” “We don’t have a clear-cut division that focuses only on one of those two aspects, it is the degree that makes the difference among divisions.”.* Said by the interviewee.

Three main challenges in the R&D process in Company C were given by the interviewee. The first and most important one was that, as mentioned above, the complexity of cancer requires experts from different fields and coordination was the critical problem. The second one was the complexity to come up with a treatment that can cover a large section of the patient population with the significant improvement over the current one. In other words, introducing products that perfectly outperform the current blockbuster was a long journey. The third challenge was to learn as much as possible about the disease in each field. As mentioned by the interviewee, the progress of cancer treatment in any field may stimulate solutions elsewhere, so first-line researchers have to keep in sync with the academic and clinical research.

### 4.3.2 Views on Exploitation

In the company of case C, some exploitative strategies were taken to increase the efficiency and to reduce cycle time. Though there were no documents stating clearly about exploitation strategy such as lean principles in this case, some of the measures shared the same spirit. One of the measures regarding the management structure was to keep the work and transactional group small thus responding and moving swiftly to change. From an operational level, this company required that for each step within a program, a strict deadline and timetable should be set together with the breakdown of the goal. Case C also had a go-or-kill decision model which was modified based on modified stage gate model to accelerate the decision-making process.

In the interviewee’s group, some rules were also set to reduce cycle time and most of them, stated by the interviewee, borrowed ideas from lean principles. Firstly, the group made each step identifiable as much as possible because:

“*Different steps in drug discovery have various features and each step requires certain procedures and resources.*” Said by the interviewee.

Secondly, members were asked to identify prerequisites of each step at the start point in step. These rules resemble Kanban rules adopted by Toyota. As argued by the interviewee, by adopting those two rules the group can cut down the waiting and cycle time and eliminate the activities that consume resources but did not create medical value.

“*We reduced our average cycle time from 40 days to 21days*.” Said by the interviewee.

### 4.3.3 Views on Exploration

According to the interviewee, open innovation was the main source of new ideas in exploration in this company. Basically, there were two types of open innovation in this institution: inner and outside open innovation. The interviewee concluded that inner open innovation referred to the multi divisional joint R&D that a transactional group (like his team) integrated ideas and experts from various aspects while outside open innovation focused on the collaboration with other companies, universities and research lab.

*“I would say open innovation is our main idea, we collaborate with experts with specific experience on certain field, with big and small pharma, that is the essential part of how this company functions.”* Said by the interviewee. Said by the interviewee.

The interviewee deemed open innovation as an accelerator that can facilitate the innovative part of discovery. He added that the R&D activities in company C can be divided into two categories:

*“It can refer to develop something that completely new or make something that has been already discovered work better” and the former one is more innovative while the later was more about improvement and perfection. From his perspective, open innovation can “give access that other may do not have.”* Said by the interviewee.

Consequently, the probability of breakthrough would be increased. The interviewee also added that though less obvious, open innovation also helped the second form of R&D activities since it provided a platform to absorb experience of implementation and transformation from other divisions and organizations.

Though the interviewee mentioned that open innovation has many advantages, he also admitted open innovation still has some dark sides. One tough issue is selecting the collaboration counterparts.

“*choosing the right partner who shares the approach, objects and experience with us*” could be the most challenging task his team faced when implementing the open innovation. “*After all, collaboration is money and time consuming, wrong partner may destroy the whole process.*”

He also mentioned that some procedures in the very beginning of open innovation were set to make good selection in his team.

### 4.3.4 Balance between Exploration and Exploitation

The next follow-up question we brought in the semi-structured interview was about the balance between exploration and exploitation. The interviewee firstly talked about the slight difference between the theories and practice of exploitation. As mentioned above, the second kind of R&D (improvement and perfection of current products) may also fall in the scope of exploration activities.

“*Typically, we use follow-up projects to increase the effects of our current treatments.*” Said by the interviewee.

Then the interviewee said that the balance should depend on the risk appetite of the firm, the current risk level as well as the resource the firm possess. The interviewee also concluded that the company in this case focused on both by dividing the organization into different divisions that emphasis on one of these two aspect and his group is more explorative by adopting open innovation (the interviewee sometimes used collaboration and joint R&D to replace open innovation during the interview) to both generate new ideas and share risks. We also brought a sub-question about the common practices of the balance between exploration and exploitation. The interviewee responded that the risky part of R&D (exploration) sometimes were outsourced to SMEs by big pharma and big pharma focused on the less risky activities (exploitative).

In the last question the interview expressed his positive attitudes towards the complementary effect between the exploration and exploitation. According to the interviewee, there were mainly two reasons. First, techniques in exploitation activities can benefit exploration by standardizing processes. The interviewee admitted that innovative activities require slack but there are still room for time and cost-saving strategies such as lean. One example in case C was that some procedures in R&D and open innovation, i.e., partner scrutiny and information gathering, were standardized to reduce waiting time. Secondly, the breakthrough in explorative activities provided opportunities to implement exploitative activities since groups and organizations should conduct follow-up projects to create value on current products.

## 4.4 Case D

The interviewee in case D worked at a diagnostic lab in the hospital for the university of Montreal. He previously worked for the research center for the hospital. The interviewee’s division specialized in genetic disorders.

### 4.4.1 Views on Productivity

Productivity in R&D in the interviewee’s opinion is the ability to make a concept or an idea to reach the audience or the market in a successful manner. He added that productivity was also based on the equipment and facilities available to the researchers, as well as the expertise and skill set of the scientists and researchers themselves.

In terms of the challenges of R&D, the interviewee emphasized issues with funding especially for small R&D companies and university owned laboratories. With that said he added that his division and the university try to form multiple alliances and partnership with larger pharmaceuticals and biotech companies. Moreover, he added that another challenge is innovation and finding novel leads and molecules not found before.

### 4.4.1 Views on Exploitation

The lab in this case applied exploitative performance enhancing strategies such as increasing the turnover time and trying to find reasons of delay in different processes and minimizing said delays. Furthermore, the interviewee added that the diagnostics lab was also implementing automation to speed up processes. With that said the interviewee believed that university R&D, especially the ones which included professors and students, did not focus solely on lean principles and performance enhancement but rather on the generation of ideas and publication. That was to say, the interviewee believed though strategies to speed up the process exist, his division paid more attention to exploration. The interviewee also stated that larger pharmaceutical and biotech companies were implementing and focusing more on performance enhancement and lean principles.

The interviewee voiced his concern on the issue of pushing time and cost saving methods.  He said that If one pushes efficiency to the extreme blindly it will interfere with R&D negatively. He also said that it was important to give up properly. For a lot of companies fail to kill a project, trying to speed a process which leaded to a failed result is useless. Therefore, companies must have systems and strict goals in check which triggers a go or kill phase.

### 4.4.2 Views on Exploration

The interviewee mentioned that his division indulged in many collaborations, such as government institutions, for example, Geno Canada and Quebec, as well as external ties with many biotech and pharmaceutical companies to boost exploration. The diagnostics division had also lately collaborated with a big genomics company which supplies them with reagents for free, which helps in both cutting costs and creating clinical samples for genomic sequencing. Interestingly, the interviewee furthermore added that the type of collaboration used most by his division is inbound rather than outbound to leverage bigger company’s expertise, which is contrary to our first though that a university lab can be an idea provider.

In terms of pros the interviewee believed that open science in exploration was the future in R&D laboratories. Montreal university had an open science program which put findings available to the public before publication. He believed that this was a great initiative for it will help the science move faster and get more intelligent people on board and interested in finding solutions to diseases and disorders. It would also help smaller organizations leverage expertise from bigger companies. In terms of cons, according to the interviewee, a plethora of collaborations and partnerships can ultimately be difficult to manage which leaded to organizations having to shut down labs and end ties abruptly. Therefore, one should know “the sweet spot” in terms of collaborations and the organization’s ability to control and manage them.

“*The pros of collaborations though outweigh the cons*.” Said by the interviewee.

### 4.4.4 Balance between Exploration and Exploitation

From a pure research perspective, the interviewee believed that his division is more explorative in nature, for if a project was too mainstream it might not get funding. From a diagnostics perspective it was more exploitative in nature since one must build on projects more complete and then transfer it into translation.

The interviewee believed that it is more important to innovate and publicize on the given research question. This can be explained by the fact that university owned labs are more interested in publication and the research side of R&D. He furthermore added that a fifty-fifty balance between exploration and exploitation cannot happen in his perspective and one side would always dominate the other. The interviewee argued that bigger companies can be agile enough and have enough resources and a financial cushion to experiment on this balance. Furthermore, the interviewee said though a true balance cannot be achieved, he believed that exploitation and exploration can be complementary instead of adversely related to each other. One example was given to support the above opinion: when his lab was trying to add more collaboration and innovation, they implemented more automation to help the new ideas generated from the external ties to move along the process more efficiently.

The results of each interview are concluded briefly in appendix 2.

# 5 Discussion

## 5.1 Summary and comparison of empirical findings

The interviewees in our case studies gave different definitions of productivity in their respective department. Although none gave the same definition as Paul et al., (2010), who defined productivity in R&D as work in progress, success rate, value, cost, and cycle time but gave similar enough answers to show that most of the organizations involved in our case studies strive for ambidexterity. For big pharmaceutical companies like A and C, the productivity emphasized on both the quality of innovation and the speed to market, as well as the reduced cost. Although the definition of productivity given by the interviewees was related to increased efficiency and thus exploitation, interviewee in case C mentioned that his group believed that to increase productivity they should increase collaboration and open innovation, which was explorative. This showed that the interviewee did not necessarily separate exploitation from exploration and believe that collaboration could increase speed, quality and decrease cost.  An interesting point was that both cases A and C identified the important role that cost plays in the definition of productivity while case B did not share this point of view. As for their approaches to increasing productivity, they were quite similar. Big organizations like the companies in case A, C and the institution in case D emphasized the coordination of divisions and outside knowledge while case B did not share this viewpoint. Possible answer was that the big organizations work with both inbound and outbound innovation and one of their roles is idea integrators while small organizations like the one in case B are more like idea providers. When asked about the different challenges in R&D one answer was common among all cases, it was finding proper funding and maintaining cost. This was more prevalent with the last case being a university owned laboratory, mainly funded by the government and multiple collaborations, as well as case B being a small start-up. In terms of the identity of the firms both organizations in case B and the case D mentioned that they considered their departments exploratory rather than exploitative, while organizations with large scale (case A and case C) considered themselves ambidextrous in nature. All our interviewees agreed that size played a important role in terms of strategy implementation.

None of the interviewees mentioned the implementation of lean principles in their exploitative activities and none of them were familiar with this term except for the company A which referred to it as Toyota Methods. However, after being explained by the interviewer, they all agreed that their organization adopted performance enhancement that shares the spirit of lean, except company in case B, which itself was already leaner and paid much attention to new idea generation. In terms of performance enhancement, case D stated that smaller companies and university Labs did not focus solely on efficiency but implemented automation to reduce delays in the diagnostic lab and speed up different processes to a certain extent. Case B also supported this argument and stated that case B had not and were not thinking of applying efficiency strategies for they are focusing on the early stages of R&D. Instead, the company’s idea in case B was to counter this lack of performance enhancement by narrowing down the exploratory domains into more well-known and validated areas. In that sense they reduced risk and did not have to spend on wild exploratory research while also maintaining a certain success rate. Interestingly case C was the one company that have implemented performance enhancing strategies resembling Lean principles, to the largest extent, aimed at reducing cycle times. All interviewees regardless of scale agreed that pushing exploitation can affect exploration to a certain extent which is in line with the previous research. Specifically, the interviewee from case B mentioned that while he was working in one of the biggest companies, they focused so much on exploitation that it interfered with their drug discovery process and hindered it. Also, it is interesting to compare the ideas of a leader in a small start-up with that of one of the big pharmaceutical companies like the companies in case A and C. The interviewee in case A agreed with the unique importance of creativity and acknowledged the value of cost cutting in the short term, though emphasizing too much on those activities can have a negative long-term effect.  One can see here that the different sizes and culture of the companies influenced the attitudes towards exploration and exploitation. The smaller companies focused on exploration because they focused on the earlier stages of R&D and cannot afford the money or time to invest in performance enhancement. It also seemed that they cater more for exploratory work. Bigger companies though implement performance enhancement strategies more often and focused on trying to balance exploration and exploitation. With that said we did not have any company which explicitly stated that they focus on exploitation.

It was accepted by the interviewees that open innovation was an important source of new ideas for pharmaceutical companies. Remarkably, large companies like the ones in case A and C had built various kinds of alliances with both big and small and medium sized enterprises (SMEs). However, Case B did not have relation with big pharma but instead received funds from small investors.  What need to be mentioned is that large companies also had relationships with academia and other non-profit organizations. Relatively big organizations (case A, C and the research lab) all implement open innovation. As for the pros and cons of open innovation, though different opinions were given. the four interviewees still share similarities, mainly regarding the benefit of open innovation. First, interviewees in four different organizations all agreed that open innovation can accelerate the R & D process by leveraging outside resources, i.e., expertise, knowhow and capital. However, divarication regarding the question of which part of R&D can open innovation can help the most was observed. The manager in for-profit organization (case A, B and C) all agreed that open innovation is most helpful in the early stage of research since the earlier stages demand investment and collaboration of experts. Thirdly and interestingly, the interviewee from the company in case C also stated the learning effect achieved from open innovation while other interviewee did not share this perspective. Interviewees had different opinions towards the negative side of open innovation. Interviewee from companies in case C and case D believed that selecting the proper collaboration partners is time consuming and is also the biggest challenge in open innovation while interviewee from case A argued that selecting good partner is challenging at the beginning of implementation of open innovation but with the accumulate of experience this issue is less problematic. what the interviewee of case A believed to be questionable is losing intellectual property (IP) control. Particularly, interviewee from case B mentioned that the most serious of open innovation is that companies may lose the opportunity to achieve market exclusivity and the benefits of being first mover.

Attitudes toward the balance between exploration and exploitation showed a high degree of similarity in this multiple case study. All the interviewees (Case A, B, C and D) believed that companies should aim for ambidexterity, and that balancing exploration and exploitation was the best strategy to increase productivity. However, they also all believed that larger companies with ample resources are the only ones that can manage said balance. That is why the relatively smaller companies such as case B and D focus more on exploration. Another issue that also was came up with was risk taking. Bigger companies (in this case, case A and C) had a bigger risk appetite and thus can invest and delve more into novel drugs and discovery.  According to Haustein et al. (2014) direct control systems such as result and action control have a positive effect on external contingencies, such as excessive risk taking in R&D and can reduce uncertainty. However Instead of researching themselves and to reduce risk big Pharma were delegating R&D to smaller pharmaceutical and biotech companies. The problem here was that smaller companies did not have the same risk appetite and resources available to bigger companies. Therefore, smaller companies were instead targeting more validated areas such as the company in case B. Although one can be exploratory in a well validated area as also argued by the interviewee from case B. Drug discovery had a very high failure rate as discussed in the literature review and this can explain why the interviewee from the biggest company believes that success rate is the biggest factor in productivity. For when the success rate is low this is causing large companies to delegate R&D to companies with relatively lesser capabilities, who in turn are tackling areas with higher success rate. Hence the interviewee from the large company argued that big pharma must retain their own R&D program for it is important to be a leader and not a follower. This argument was also given by interviewee from case B, who argues that it is critical for bigger companies to champion new discoveries in novel areas, which will motivate smaller biotech and pharmaceuticals to then explore within that area even more. Although the interviewees believed that exploration and exploitation share and consume the same resources, they shared agreement that exploration and exploitation can be complimentary instead of adversely related to each other. Interviewee from the university lab argued that even though his lab pursues open science (open innovation), they were implementing automation to get the new ideas from concept to output. The interviewee from the biggest company was the most supportive of the complimentary and hybrid effect of exploration and exploitation. He argued that his company adopts artificial intelligent and machine learning programs that can stimulate and model certain processes in R&D. Another important aspect in the balance and especially lean principles was the different view regarding standardization. The interviewee from case C explained how standardizing certain activities speeded up the R&D process such as standardizing information gathering. He furthermore added that open innovation and discovery requires follow up which opens the opportunity for exploitative activities.

## 5.2 Comparison to Previous Research

Similarities between the interviewees' answers and the literature review are noticeable. For starters, the two bigger companies in our interviews both defined productivity in an explorative and exploitative manner. This goes hand in hand with both Haustein et al. (2014) and O'reilly and Tushman (2013) who emphasized that ambidexterity was better suited and implemented by bigger companies with resources available to implement two structures and balance between them. Interestingly, although case C defined productivity in an exploitative manner, the way of increasing said productivity in the interviewees point of view is increasing collaboration. This showed that the division of case C leans to the contextual definition of ambidexterity as per O'reilly and Tushman (2013) where exploration and exploitation were considered outcomes of each other and not necessarily two pure structures balanced by management and employees alike. This was also the case with case B. Cost only played a big role in the bigger companies while it is not of upmost concern for case B. This goes hand in hand with Haustein et al. (2014) who furthermore argued that direct and more exploitative MCS such as action and result control are not suitable and produce adverse results in smaller innovative firms. Cost and budget can become a hinderance for explorative firms and serve as a threshold for exploration. When it comes to challenges in R&D the company in case A had the most similarities with the previous research. The interviewee in case A mentioned three challenges which go hand in hand with Rafols et al., (2014) which were resources or cost, high failure rates and finding novel targets. None of the interviewees mentioned cycle time as an important challenge in productivity. This was contradictory to researchers and the literature review which mention cycle time as the most important factor in productivity and has the most effect when decreased. Johnstone et al., (2011) argued for example that cycle time was the most important factor in productivity. Interestingly, case A went hand in hand with the study of Reinertsen and Shaeffer (2005) who mentioned that failure rates were the most critical element in terms of R&D productivity. All the interviewees argued that bigger companies can afford implementing performance enhancement strategies and balancing between exploration and exploitation while smaller companies must indulge in exploration or they will shut down, which is like the argument of both Haustein et al. (2014) and O'reilly and Tushman, (2013). The company in case C implemented lean and observed changes in the closest manner to Reinertsen and Shaeffer (2005), where implementing Lean reduced cycle time from 8 to 2 weeks. With that said the company in case A implemented lean in the past in their day-to-day activities but witnessed no changes to success rate. This is contrary to the research by Reinertsen and Schaefer (2005) which argued that the application of manufacturing principles such as lean can have an impact on success rates. The company in case A and D emphasized the role that open innovation played in the later development stage. Secondly, they all agreed that open innovation can achieve risk sharing and cost reduction, which is confirmed by Barnes et al. (2009) and Vanhaverbeke & Cloodt (2006). But this argument was contradicted by Munos (2010), who argued that existence coloration among pharmaceutical companies indeed makes R&D more innovative but drives down efficiency.

All the interviewees agreed that a company must become ambidextrous if it is to survive and thrive in the future, which is in accordance with Haustein et al. (2014) and O'reilly and Tushman, (2013). A company must exploit to compete in the current market, and also explore in order to change and meet demands in the future. When it comes to the balance between exploration and exploitation, the company in case A argued that companies do not always try to balance exploration and exploitation within the same process or division, where one decision could focus on either. The company in case D gave an example of this where the interviewee explained that the research department in the Montreal University Lab was purely explorative, while the diagnostics division is exploitative. This is interesting for this is the only example of simultaneous ambidexterity as argued by O'reilly and Tushman (2013) where separate divisions in the same company follow purely explorative and exploitative structures, connected by company values and the goal. Moreover, this came from a small public funded organization rather than a big firm such as company A and C. With that said he believed that it was more important to be explorative in a university laboratory. On the other hand, this is contrary to the research by Getz & Kaitin (2015) and by Owens (2007) who argued that this silo structure was problematic for productivity and the implementation of lean can help in creating a singular structure and mindset.

The interviewee in case C argued that open innovation promotes exploitation due the necessity of following up after external ties and deals. This was supported by O'reilly and Tushman (2013) who argued that like lean principles, open innovation and external ties was an ambidextrous structure in the contextual ambidexterity context. That was because external ties helped companies focus on efficiency on one end and employ exploitative strategies to get the new idea into the market faster. On the other hand, the interviewee from case B argued that specific processes in drug discovery such as lead discovery cannot be standardized for every molecule and process was unique and said strategy can be detrimental. This goes hand in hand with Johnstone et al., (2011) who argued that although standardization can be harmful for exploration, said standardization must be flexible and adaptable to both the company and the process. This is furthermore supported and argued by Haustein et al. (2014) who said that innovative companies should not apply MCS that were standardized or implemented by non-innovative or differentiation companies. Innovative companies on the other hand should adopt and customize MCS according to their activities. highly innovative companies will have an adverse reaction with both result and action control to the innovation capabilities, but positive effect to external contingencies such as uncertainty.

## 5.3 Management Control Systems in Case Organizations

Using levers of control to enhance the mode of innovation which according to Bedford (2015) is exploration and exploitation is an important aspect for the management control literature. Most importantly though is that the LOC framework could represent a way for companies to properly balance the tensions between exploitative and explorative activities, and not allowing the overall strategy of the firm to be pulled or pushed into one direction, thus not creating negative and unproductive consequences, hence ultimately leading to ambidexterity. The interviewees in our cases did not use the specific terms of the levers such as belief or boundary controls but have implemented activities and processes like said controls to lead the company in a certain direction. For instance, the company in case B which was more focused on exploratory work and pursued no exploitative procedures, as well as the university laboratory use both internal and external ties extensively. This is a form of an interactive control system. Bedford (2015) argued that increased communication leaded to the development of good ideas through sharing different opinions and the rise of discussion. This was furthermore the purpose of open innovation which required slack, differentiation and experimentation to develop a new idea, which is in this case a new drug discovery. With that said belief control systems as per Bedford (2015) had not been mentioned by either case B or D. This could be due to the nature of the narrow focus of case B, which was a start-up with a known goal and heading. Furthermore, the university Lab focused more on student collaborations and publication.

The interviewees from case B and the laboratory (case D) both agreed that a bigger firm with ample resources can employ exploitative measures which act as a pulling system for the tensions created by exploration. An example of this is case C. The interviewee from case C mentioned that his company tried to employ exploration and exploitation in tandem. An example of how case C balanced the tensions that result from open innovation was by the strict follow up system they employ on collaborations and ideas on a regular basis. In this example external ties generate ideas as an interactive control system and follow ups and check-ups are employed as diagnostic control systems. Bedford (2015) argued that diagnostic control systems were controls which surface variations in terms of performance and implementation of intended strategy and aim to reduce or eliminate said variation. Most importantly though diagnostic controls weave out arguments and discussions that are not productive. Therefore, case C combined interactive and diagnostic control systems to generate the right ideas, which were the best fit for the companies’ goals. It was also worth noting that both case A and C employed lean systems in one way, or another as discussed earlier. Lean according to O'reilly and Tushman (2013) did not necessarily only represent exploitative procedures. Lean did standardize procedures and eliminate waste, but it also promoted job changing and required decentralization and communication amongst every member in the company for it to be most effective. In that sense lean acted as a diagnostic system as it increases efficiency and focuses on reducing cycle time for drug discovery and development but also acted as an interactive control system for it promoted communication which makes the exploitative part possible. A clearer example of this was the way that the company in case A implemented lean. This company had implemented lean in its day-to-day operations and culture, hence being more contextual rather than a supplementary aspect. In that sense exploratory activities in R&D will be backed up by efficiency and performance enhancement principles at the very least. Furthermore, the only company which mentioned belief control systems as an aspect in daily routines is company A. Values, motivation, and goals are a fit for ambidextrous organizations as argued by Bedford (2015), since it both promotes exploration but focuses it as well when said exploratory activities get off the track.

Interestingly although two of the interviewees considered themselves ambidextrous, all the interviewees tend to lean more towards exploration. Although all interviewees acknowledge that ambidexterity is crucial for the future it does not seem that they believe in a 50-50 balance. This countered the argument by Bedford (2015) who warned against tensions being biased or swaying to one end. The interviewee from the university lab even argues that a 50-50 balance is not possible, and the nature of pharmaceutical companies is R&D, which is in turn exploratory. This raised the question, such as if it is possible at all to pursue a perfect 50-50 balance or will tensions created by multiple strategies ultimately sway more in one direction. It is also worth noting that all interviewees work in R&D and as such due their education and background could prefer a certain strategy even in the bigger companies. Another possibility is that even if a division considers its work ambidextrous and sways to exploration, another division in the company could sway more towards exploitation thus creating a balance. This is argued by case D where the interviewee argues that although the R&D division is exploratory, the diagnostics division is more exploitative in their work.

## 5.4 Practical Implications

Considering all theories and empirical materials, we believed the practical implication of this research was that an adverse relationship between exploration and exploitation did not always have to be the case. Bigger Companies according to the interviewees implemented exploitation and exploitation simultaneously and work towards employing both strategies in a complementary manner by balancing the tensions generated by each strategy. Furthermore, although smaller companies did not employ said hybrid strategy, they also believed that it was the way to thrive in the future.

## 5.5 Limitations and Further Research Suggestions

Admittedly, this research inevitably exposed to some limitations. First, though selected carefully, one interviewee for one organization may be problematic if the interviewee did not see the whole picture of R&D. Secondly, four organizations as interviewees may be less convincing when compared with some of the previous research with more interviewees.

Further studies could incorporate more interviewees in each case and incorporate more entities that are involved in different stage, i.e., the launching stage of R&D, to have a boarder picture. Furthermore, as mentioned in the interview, exploration and exploitation sometimes share the same resources and the resources conflict have not been well settled. Further studies may combine LOC and other management and control theories to find solutions.

# 6. Conclusion

To summarize, by using multiple case studies and incorporating organizations with different characteristics, this paper firstly investigated how pharmaceutical organizations define and increase productivity in the R & D process. We find that though the definition of productivity may vary across organizations, basically identifying a novel idea (target) and commercializing the idea with high speed and low cost are two important aspects that were identified by all interviewees. Secondly, this paper investigated how exploration and exploitation activities were implemented in the R&D process in the four organizations. An interesting phenomenon was that though all interviewees acknowledged the importance of both two kinds of R&D activities, only organizations with large scale can be more ambidextrous. Besides, we also focus on more specific R&D management techniques to investigate how those two kinds of activities were implemented. For exploitative activities we investigate the lean principle for its well-known and fund that except for one start-up company which focuses on coming up with new solutions all other organizations adopted modified lean principle as performance enhancement method. For explorative activities, all organizations in this multiple case study adopted open innovation to accelerate the process of R&D. Thirdly, we investigate the attitudes towards the balance between exploration and exploitation. All interviewees shared the viewpoint that though consuming the same resources, exploration and exploitation activities are mutually reinforcing and some examples of the synergies were presented in the discussion. Lastly, we combine the empirical results with LOC and other theories in management control and reckon that exploitation and exploration should not be necessarily exclusive but have synergies and the possibility to achieve the synergies exist if managers utilize different levers of control properly.

To our knowledge, case studies that combine the productivity in R&D and tradeoff between exploration and exploitation in the pharmaceutical industry are not sufficient and there is also no such research that combines LOC, MSC with pharmaceutical R&D. We believe this paper can contribute to previous research by considering organizations characteristics (the difference between large and small organizations as well as the difference between profit and non-profit organization), applying management and control theories, giving detailed description and analysis of the managers’ opinion towards productivity, open innovation and towards lean method.

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# Appendix 1: Interview Design

**Introduction**

Introduce ourselves: name, school, supervisor, the confidentiality of the interview, the use scope of the data and result.

Information of the interviewees: position & work experience, responsibility

**Questions**

Open questions to warm up：

1. How would you define productivity in R&D?
2. What is your company doing to increase productivity in R&D?
3. What are the main challenges in the R&D process in your company? and what is the company doing to tackle these challenges?
4. Would you consider your division explorative or exploitative?

**Exploitation Strategies**

1. Has your company applied any performance enhancing strategies to your R&D process such as decreasing cost, cycle times or increasing success rates?
2. How has your company applied these strategies?
3. Has your company applied any lean principles in research and development before?  If not, do you think there is a benefit in doing so?
4. To what extent do you think one can push cost and time saving methods without sacrificing innovation in research and development?
5. Have you ever thought of applying lean to reduce the cycle time in drug discovery (iterative process)? Why and Why not?

**Exploration Strategies**

1. Have your company applied Open innovation/External ties?
2. The history of open innovation in your division: when did your division start making external ties? What kind of open innovation does your company currently use most, the inbound or outbound?
3. What are the main external ties that your company relies on?
4. Why does your company implement open innovation?
5. Which part of research and development do you think open innovation/external ties can affect the most?
6. What are the pros and cons of open innovation and external ties, from your point of view?

**The balance and tradeoff**

1. Do you think pharmaceutical companies should focus more on exploration and the generation of new ideas? Or rather focus on making the process of drug discovery and development more efficient?
2. Do you think companies can balance between exploration and exploitation, and do you think one can balance between lean principles and open innovation in that sense?
3. In what ways do you think exploitation and exploration share the same resources?
4. Do you think it is possible for exploration and exploitation to be complementary instead of adversely related to each other?

# Appendix 2: Summary of Empirical Material

