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R&D goal seeking and risk taking in biotechnology R&D investments

RESEARCH ARTICLE

Desmond Ng[ⓘa]

[a]*Associate Professor, Dept. of Agricultural Economics, Texas A&M University, 600 John Kimbrough Blvd, TAMU 2124, College Station, TX 77843, USA*

Abstract

Rapid advances in biotechnology have made R&D (research & development) investments an important strategic goal. Yet, despite the increasing growth in R&D investments, an understanding of the decision-making processes surrounding the attainment of a firm's R&D goal remains underdeveloped. This study addresses this gap where a firm's R&D goal seeking process is offered. Specifically, unlike prior studies that focus on the firm's financial goals (i.e. return on assets (ROA)), this R&D goal seeking process draws on a concept of R&D performance aspiration deviations (PAD) where it introduces risk-taking behaviors that impact a firm's R&D investments. This study argues that a market's technological progress or market dynamism also influences this R&D goal seeking process. In using fixed effects (FE) linear regressions, hypotheses were developed to examine these arguments in the biotechnology industry.

Keywords: risk-taking, aspirations, R&D investments, innovation
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ⓘCorresponding author: dng@tamu.edu

1. Introduction

In the biotechnology industry, a firm's growth and success depend heavily on its commitment to research & development (R&D). This commitment has contributed to genomic advances ranging from improvements to the agronomic traits of the animal and seed sectors to the discovery of numerous drug therapies in the pharmaceutical industry (Eş *et al.*, 2019; Fulton and Giannakas, 2001; Wieczorek and Wright, 2012). For instance, genomic advances, such as C.R.I.S.P.R., have offered genetic editing tools that produce leaner pork and the treatment of various genetic disorders (i.e. sickle cell disease) (Brown, 2017; Eş *et al.*, 2019; Ng and James, 2018). R&D investments have been growing to capitalize on these and other related genomic advances. As a result, amongst the major / large cap U.S. biotechnology firms, R&D investments grew from $1.358 billion in 2019 to $1.512 billion in 2020 (BDO, 2021). With this growth in R&D investments, a firm's R&D goal is important to sustaining the firm's commitment to its R&D. This is because as the returns to a firm's R&D investments are often distant into the future and are risky (Lu and Fang, 2014), a firm's R&D goal involves taking on the risks in these commitments. Hence, a firm's R&D goal has become an important strategic priority because it not only influences a firm's commitment to take on the risks in its R&D investments, but such risk-taking impacts the firm's long-term ability to compete in the future (Pisano, 2015).

Behavioral research involving the behavioral theory of the firm has offered seminal insights to understanding such risk-taking behaviors (Cyert and March, 1963). This risk-taking has been explained by a goal seeking process where a goal reflects the firm's aspirations of realizing a future outcome. These aspirations are evaluated against the performance of a firm's current activities where deviations from the firm's aspirations or performance aspiration deviations (PAD) have been found to impact its risk-taking (Gavetti *et al.*, 2012; Greve and Gaba, 2020; Kotiloglu *et al.*, 2021). For instance, studies find declines in a firm's performance relative to its aspirations or *Below PAD* increase a firm's risk-taking to search for solutions that satisfy the firm's aspirations (Greve, 2003, 2007; Greve and Gaba, 2020; Lu and Fang, 2014). Such risk-taking behaviors not only impact the firm's ability to satisfy its goals, but they also offer a search that increases the firm's ability to adapt to changing markets (Gavetti *et al.*, 2012; Kotiloglu *et al.*, 2021). For instance, in Lu and Fangs' (2014) study of Taiwanese electronic firms, a firm's PAD influenced its risk taking in its R&D and that such risk-taking was central to assimilating the emerging technological opportunities of the market (see also Ben-Oz and Greve, 2012). Other R&D investment studies have reported similar findings (e.g. Bromiley and Harris, 2014; Greve, 2003, 2007).

Yet, despite the seminal contributions of behavioral research (Cyert and March, 1963), there remains a limited understanding of the firm's R&D goal seeking process. This is for two reasons. First, there is an implicit assumption that the firm's R&D goal seeking process is consistent with the satisfaction of the firm's financial goals. A firm's financial goals are often defined in terms of its short-term performance, such as its return on assets (ROA) (Ben-Oz and Greve, 2012; Gavetti *et al.*, 2012) where the financial goal seeking (i.e. PAD) process involves searching for solutions that satisfy this short-term performance goal. In contrast, since the returns to a firm's R&D are distant into the future, a firm's R&D goal emphasizes a long-term commitment to R&D investments that realize these future returns. Hence, unlike the short-term focus of a firm's financial goals, a firm's R&D goal seeking process involves a search that seeks to satisfy this long-term commitment. Behavioral studies argue that these temporal differences lead to conflicting search processes. These studies argue that because firms cannot fully anticipate the long-term consequences of their actions, firms favor a search that is biased towards solutions that offer immediate returns. This search involves solutions that build on the firm's existing competencies, such as the adoption of cost saving processes that improve a firm's scale efficiencies (Cohen, 2010; Levinthal and March, 1993; March, 1991). Yet, according to behavioral learning studies, this short-term focus leads to myopic behaviors that drive out a firm's ability to search for new firm-level competencies that increase its long-term value (Ahuja and Lambert, 2001; Cohen and Levinthal, 1990; Levinthal and March, 1993; March 1991, Nerkar and Roberts, 2004; Ng *et al.*, 2019; Rosenkopf and Nerkar, 2001). Hence, since a firm's search results from its risk-taking behaviors, the firm's financial goal seeking process introduces a search where short-term risk-taking behaviors are inconsistent with the achievement of its long-term R&D goals (see also Wibbens and Siggelkow, 2019). This is problematic because when

a firm's risk-taking behaviors are not closely matched with its goals, the firm cannot engage in a search that satisfies its goals (Gaba and Bhattacharya, 2012). Second, as the firm's risk-taking behaviors involve a search for external solutions, the technological conditions of the market should also influence the firm's R&D goal seeking process. These technological conditions have been described by a market dynamism. Market dynamism reflects the level of technological progress in society where studies find this dynamism impacts a firm's technical expertise (Requena *et al.*, in press; Revilla and Fernandez, 2013; Roberts, 2015). Yet, behavioral explanations have provided limited consideration of the impact of this market dynamism (Kotiloglu *et al.*, 2021) on the firm's R&D goal seeking process. This omission is problematic because this risk-taking can influence the firm's ability to adapt to dynamic or changing markets and thus offer an important source of competitive advantage. These shortcomings motivate the following research questions: how does a firm's R&D goal seeking process impact its risk-taking in its R&D and how does market dynamism impact the firm's risk taking in its R&D decision-making process?

To address these research questions, this study's objective is to theoretically and empirically examine the firm's R&D goal seeking process. This process is explained by a concept of R&D PAD where deviations between the firm's R&D expenditures and R&D aspirations have an asymmetric influence on the firm's risk taking. Market dynamism is also argued to influence this risk-taking process. Hypotheses were developed to examine these arguments in the biotechnology sector. Fixed effects (FE) linear regressions were used to examine these hypotheses. This study's FE findings provide support for these hypotheses. Three contributions are offered. First, as recent developments have called for a greater need to examine non-financial goal seeking processes (e.g. Greve and Gaba, 2020; Kotiloglu *et al.*, 2021; Martinez-Noya and Garcia-Canal, 2021; Tyler and Caner, 2016), this study's R&D goal seeking process explains those risk-taking behaviors that impact the satisfaction of a firm's R&D goals. Second, this study introduces a market dynamism to the firm's R&D goal seeking process where it appeals to the adaptive tenets of the behavioral view (Cyert and March, 1963). Third and subsequently, this market dynamism offers risk-taking behaviors that impact the firm's ability to adapt to the opportunities and threats of dynamic markets. This adaptation offers an important source of resiliency for biotechnology firms (Nauck *et al.*, 2021).

2. Conceptual developments

2.1 Behavioral theory of the firm

Goal setting is a defining feature of management and forms the basis of a firm's strategic decision-making process (Cyert and March, 1963; Gavetti *et al.*, 2012; Ng, 2020; Shinkle, 2012). Such decision-making involves a goal-setting process where firm-managers seek solutions to satisfy their firm's aspirations or goals. A firm's aspirations reflect the firm's long-term goals or expectations in achieving a future outcome (Cyert and March, 1963). These aspirations provide an important reference point for evaluating a firm's current performance. Specifically, as a firm's goal-setting process is often defined in terms of its short term financial performance (ROA), the firm evaluates, for every period, its current performance (i.e. ROA_t) against aspirations involving a moving average of this past performance (i.e. ROA_{t-1}, ROA_{t-2}, ROA_{t-3}…) (Bromiley and Harris, 2014; Cyert and March, 1963; Gavetti *et al.*, 2012; Shinkle, 2012). Deviations between the firm's current performance and its aspirations or PAD have been widely associated with the firm's risk-taking behaviors (Bromiley and Harris, 2014; Cyert and March, 1963; Gavetti *et al.*, 2012; Shinkle, 2012). Studies find this risk-taking depends on whether the firm's current performance falls from below or above its aspirations (e.g. Gavetti *et al.*, 2012; Hoskisson *et al.*, 2017; Ref and Shapira, 2017). A firm's *Below PAD* and *Above PAD* are respectively defined by situations when the firm's current performance (i.e. ROA_t) falls from below (i.e. PAD<0) or from above (i.e. PAD>0) its aspirations (i.e. ROA_{t-1}, ROA_{t-2}, ROA_{t-3}...). Increases in the size of the deviations in the firm's *Below* and *Above PAD* have been found to impact a firm's risk taking on a variety of strategic outcomes, such as Mergers and Divestitures (Kuusela *et al.*, 2017), corporate venture capital (Gaba and Bhattacharya, 2012), alliance formation (Kavusan and Frankort, 2019; Martinez-Noya and Garcia-Canal, 2021; Tyler and Caner, 2016), product innovations (Greve, 2003, 2007) and R&D investments (Ben-Oz and Greve, 2012; Bromiley and Harris, 2014; Chen and Miller, 2007;

Greve, 2003, 2007; Lu and Fang, 2014; O'Brien and David, 2014; Xu *et al.*, 2019). For instance, in using the firm's ROA, the shipbuilding study of Greve (2003) found increases in the size of the deviations in the firm's *Below PAD*, increased the firm's risk-taking in its R&D to search for technological solutions outside of the shipbuilder's established manufacturing expertise. Furthermore, Greve (2003) found increases in the size of the deviations in the firm's *Above PAD* reduced this search and had no significant effect on the shipbuilding's R&D. Similar risk-taking behaviors have been reported in other R&D investment studies (Bromiley and Harris, 2014; Gaba and Bhattacharya, 2012; Lu and Fang, 2014)

While a firm's PAD – *Below PAD* and *Above PAD* – offer important insights to explaining a firm's risk taking in its R&D, a basic assumption underlying most behavioral models is that a firm's financial goals – rather than its R&D goals – govern the firm's risk-taking behaviors. This is because the attainment of a firm's financial goals (i.e. ROA) is not only an important strategic objective, but that the risk-taking behaviors used in satisfying a firm's financial goals are assumed to be similar to other goal seeking processes (i.e. R&D goals) (Greve and Gaba, 2020; Kotiloglu *et al.*, 2021). Yet, according to Cyert and March (1963), a firm's goal seeking process is driven by the interests of different constituent groups where studies find different goals can lead to different risk-taking behaviors (Gaba and Bhattacharya, 2012; Greve and Gaba, 2020; Kotiloglu *et al.*, 2021; Martinez-Noya and Garcia-Canal, 2021; Tyler and Caner, 2016). For instance, recent developments have argued and found that R&D scientists are motivated by the goals of their R&D unit and that these goals offer different risk-taking behaviors than the firm's financial goals (e.g. Gaba and Bhattacharya, 2012; Martinez-Noya and Garcia-Canal, 2021; Tyler and Caner, 2016). This is because unlike a firm's financial goals that involve taking risks to satisfy the firm's short-term performance (i.e. ROA) (Ben-Oz and Greve, 2012; Gavetti *et al.*, 2012; Pisano, 2015; Wibbens and Siggelkow, 2019), R&D goals involve taking long-term risks that advance its scientific knowledge (i.e. creation and discovery of new knowledge). Hence, while a financial based PAD (i.e. ROA) is commonly used in R&D investment studies (Greve and Gaba, 2020; Kotiloglu *et al.*, 2021), a financial based PAD can yield a goal seeking process in which short-run risk-taking activities conflict with the long-term development of a firm's R&D capability.

This conflict stems from long-standing arguments in behavioral learning research. According to this view, firms favor risk-taking activities that improve their existing capabilities over those that create new firm-level capabilities (Cohen, 2010; Levinthal and March, 1993; March, 1991). This is because efforts to improve the firm's existing capabilities, such as investments in their scale efficiencies, offer more immediate and certain returns. While efforts to create new capabilities, such as investing in a firm's basic research offer returns that are less certain and are often more distant into the future (Ahuja and Lambert, 2001; Cohen and Levinthal, 1990; Levinthal and March, 1993; March 1991, Nerkar and Roberts, 2004; Ng *et al.*, 2019; Rosenkopf and Nerkar, 2001). Hence, since a firm's financial goals (ROA) have a short-term focus, behavioral learning studies suggest a firm's financial goal seeking process favors risk-taking activities that improve the firm's existing capabilities. Yet, by satisfying this short-term financial goal, it drives out the firm's incentive to engage in risk-taking activities that create new firm-level capabilities. This reduces the firm's risk-taking in its R&D and thus reduces the firm's ability to satisfy its long-term R&D goals. This is consistent with Wibbens and Siggelkows (2019) empirical study who found efforts to maximize the firm's short term ROA performance was negatively related to its long-term valuation. This finding also follows other studies that argued and showed efforts to maximize a firm's short-term ROA can result in cost saving practices that undermine the firm's long-term ability to innovate (Ben-Oz and Greve, 2012; Nauck *et al.*, 2021; Pisano, 2015).

By focusing on the firm's short-term performance goals (ROA), Pisano (2015) argues that this focus can lead to an incoherent innovation strategy where a firm's business strategies / goals are not aligned with activities that develop a firm's innovation capabilities. For instance, Corning – a leading manufacturer of silicon components to the communications and life science sectors – made a long-term R&D commitment into the areas of glass and material sciences. Corning maintained this commitment, even when the telecommunication bust of the late 1990s destroyed their communication business (Pisano, 2015). This is because, while a reduction in R&D investments can mitigate such threats – and also increase the firm's ROA –, this reduction would undermine Corning's capacity to innovate in the communication sector. Yet, most behavioral studies

have focused on the firm's financial based PAD (i.e. ROA) to explaining such commitments to the firm's R&D where risk-taking is made with respect to satisfying the firm's short-term financial goals and not to its R&D goals. (Bromiley and Harris, 2014; Chen and Miller, 2007; Greve, 2003, 2007; Lu and Fang, 2014; O'Brien and David, 2014; Oz and Greve, 2012; Xu *et al.*, 2019). This type of decision-making can cause inconsistent goal seeking behaviors in which firms, such as Corning, would not be able to effectively learn from its PAD process and thus cannot engage in risk-taking activities that satisfy its R&D goal. This is consistent with Gaba and Bhattacharya (2012) who note:

> From a behavioral perspective, goals that are not closely matched to a given organizational activity may be ineffective because ill-defined problems will likely prevent the organization from initiating search... (p. 181)

2.2 R&D PAD

Since a firm's commitment to its R&D is an important goal or priority, a concept of R&D PAD is offered to explain the risk-taking behaviors that impact the attainment of a firm's R&D goal. This R&D goal is defined by a firm's commitment to investing in the firm's scientific discovery process (i.e. the creation and discovery of new knowledge) where their future returns are distant into the future and are highly risky (see also Lu and Fang, 2014). Hence, a firm's R&D goal seeking process involves a risk-taking where R&D investments are made with respect to developing a firm's long-term ability to innovate in the future. This R&D goal seeking process is explained by a firm's *R&D PAD*, where it is defined by differences between the firm's current R&D (i.e. $R\&D_t$) performance and its historic R&D aspirations / goals (i.e. $R\&D_{t-1,t-2,t-3,t-4}$). In particular, since a firm's aspirations are based on a moving average of its past performance (Cyert and March, 1963), a firm's R&D aspirations or historical R&D aspirations are defined by a moving average of the firm's past R&D performance (i.e. $R\&D_{t-1,t-2,t-3,t-4}$). A firm's *Below R&D PAD* and *Above R&D PAD* are subsequently defined by situations when the firm's current R&D performance (i.e. $R\&D_t$) respectively falls from below and from above its historical R&D aspirations (i.e. $R\&D_{t-1,t-2,t-3,t-4}$). Increases in the firm's *Below R&D PAD* and *Above R&D PAD* are defined by increases in the size of the deviations of these *R&D PAD* measures. As a large body of behavioral studies have related the size of these deviations to a firm's risk-taking behaviors (Bromiley and Harris, 2014; Gavetti *et al.*, 2012; Hoskisson *et al.*, 2017; Ref and Shapira, 2017; Shinkle, 2012), this study argues that increases in the firm's *Below R&D PAD* and *Above R&D PAD* impact a firm's risk-taking where this risk taking involves a search that influences the firm's R&D investments and thus commitments to satisfying its R&D goal.

2.3 Below R&D PAD and risk-taking

To elaborate on these risk-taking behaviors, a firm's *Below R&D PAD* introduce a problemistic search that decreases a firm's R&D. Problemistic search involves a search for nearby solutions that solve a specific problem (Cyert and March, 1963; Kuusela *et al.*, 2017; Lu and Fang, 2014). According to Cyert and March (1963), increases in the firm's *Below PAD* increase a firm's risk taking in this problemistic search (see also Kuusela *et al.*, 2017; Lu and Fang, 2014). This is because the search for nearby solutions leverages a firm's existing experiences in solving the firm's problem task. In extending this argument, more recent hi-technology studies have argued that large declines in the firm's *Below PAD* increase a firm's risk taking where the firm engages in a problemistic search for non-local or distant solutions that fall outside of a firm's existing expertise (Greve and Gaba, 2020; Martinez-Noya and Garcia-Canal, 2021; Tyler and Caner, 2016). This is because when the firm experiences large declines in its *Below PAD*, the probability of finding a local or nearby solution that satisfies the firm's aspirations declines (Tyler and Caner, 2016). Hence, studies have argued and found that large declines in the firm's *Below PAD* increases a firm's problemistic search for non-local or distant solutions (Martinez-Noya and Garcia-Canal, 2021; Tyler and Caner, 2016). Yet, such findings are inconsistent with a large body of behavioral learning research. These studies argue and find that firms have a tendency to search for solutions that are in close proximity to their prior experiences (e.g. Cyert and March, 1963; Gavetti *et al.*, 2012; Levinthal and March, 1993; Ng *et al.*, 2019). This is supported

by various other learning studies where firms favor a search of closely related experiences, because there is a high cost in assimilating distant information sources (Cohen and Levinthal, 1990; Lane and Lubatkin, 1998; Laursen and Salter, 2006; Song *et al.*, 2018). These studies have also argued that distant search offers riskier solutions that are unrelated to the firm's problem task (see also Levinthal and March, 1993; Ng *et al.*, 2019; Song *et al.*, 2018). These considerations suggest that as the firm's *Below R&D PAD* increases, the firm reduces its problemistic search for distant information, because there are increasing costs and risks associated with this search. As a result, an increase in the firm's *Below R&D PAD* reduces a firm's risk-taking in its problemistic search of distant information and thus reduces a firm's R&D investments in discovering these distant solutions. For instance, when there are small declines in the firm's *Below R&D PAD* (i.e. declines in a firm's R&D expenditure at or near its historical R&D aspirations), a firm engages in a problemistic search for local experiences. This local solution leverages the firm's past R&D experiences in solving its problem task and thus a firm increases its R&D investments to discovering these local experiences. However, when a firm experiences large declines in its *Below R&D PAD* (i.e. declines in a firm's R&D expenditure well below its historical R&D aspirations), a firm's problemistic search for distant experiences becomes increasingly costly and risky to the firm's established R&D and thus a firm will not invest in its R&D to capitalize on this distant knowledge. Hence, unlike distant explanations (Greve and Gaba, 2020; Martinez-Noya and Garcia-Canal, 2021; Tyler and Caner, 2016), increases in the firm's *Below R&D PAD* reduce a firm's problemistic search for distant solutions to which reduce a firm's R&D in discovering these distant solutions.

Hypothesis 1: Increases in the firm's Below R&D PAD are negatively related to its R&D

In contrast, a firm's *Above R&D PAD* introduce a risk-taking where a firm's slack search increases its R&D investments. Unlike problemistic search, slack search involves an experimentation that does not solve a specific problem. But rather, slack search is associated with an experimentation that advances a firm's 'pure science' (Cyert and March, 1963). Namely, this slack search involves developing a firm's basic research where, through experimentation, the firm gains a fundamental understanding of the assumptions, concepts, and relationships of their scientific field. For instance, in the biotechnology industry, this slack search involves experimentations that draw on gene sequencing methods that identify and discover genes with harmful mutations. As this type of slack search requires a high degree of experimentation and risk taking, excess or slack resources are often required. Behavioral studies argue a firm's *Above PAD* offer the firm excess or slack resources to support the greater risk taking required by this slack search (Chen and Miller, 2007; Cyert and March, 1963; Greve, 2003, 2007; Greve and Gaba, 2020; Lu and Fang, 2014; Teirlinck, 2020). However, as slack is often defined in terms of a firm's excess financial resources (Chen and Miller, 2007; Greve, 2003, 2007; Greve and Gaba, 2020; Lu and Fang, 2014; Teirlinck, 2020), few have examined slack from the standpoint of a firm's excess R&D or R&D slack. In this study, R&D slack is defined by excess R&D resources / expertise that support a firm's slack search to advancing its basic or scientific knowledge. In particular, since advances in basic or fundamental science often involve high degrees of scientific risk, a firm's R&D slack increases a firm's risk taking in its slack search to tolerate such risks. Hence, as increases in the firm's *Above R&D PAD* increase the firm's risk taking in its slack search, this greater risk-taking increases the firm's tolerance to take on the risks in advancing its basic research. A consequence of this greater risk-taking is that it increases a firm's R&D investments to engage in experiments that not only tolerate the greater risks in advancing the firm's basic or pure science, but as a result of these investments increase the firm's ability to discover those experimental advances made by its slack search. Such risk-taking is consistent with capacity explanations of slack search, where excess or slack resources increase a firm's capacity' to tolerate losses in their experimentation efforts (Greve, 2003; Shinkle, 2012; Teirlinck, 2020).

Hypothesis 2: Increases in the firm's Above R&D PAD are positively related to its R&D

2.4 Market dynamism

While the firm's *Below* and *Above R&D PAD* offer risk-taking behaviors that impact a firm's R&D, market dynamism is also an important consideration. Market dynamism has been defined by 'the degree of uncertainty and turbulence in market and industry conditions, including the state of technology and overall economic performance...' (Thornhill, 2006, p. 690). In technology studies, high market dynamism is associated with industries that experience high rates of technological progress or technological change (Requena *et al.*, in press; Revilla and Fernandez, 2013; Roberts, 2015; Thornhill, 2006). For instance, such dynamism is reflected by the scientific advances in the biotechnology sector where recombinant DNA has displaced traditional methods of plant breeding and has revolutionized the production of vaccines (Eş *et al.*, 2019; Wieczorek and Wright, 2012). Such market dynamism renders a firm's existing technologies obsolete and creates incentives for firms to create new technologies (Requena *et al.*, in press; Revilla and Fernandez, 2013; Roberts, 2015). This suggests a firm's R&D is influenced by market dynamism, because the firm faces obsolescent pressures to invest in its R&D to create new areas of technical expertise. Furthermore, innovation studies find that a greater exposure to dynamic markets increases a firm's receptivity to emerging market developments (Requena *et al.*, in press; Revilla and Fernandez, 2013; Roberts, 2015). Market dynamism can increase a firm's R&D investments to capitalize on such developments (see also Revilla and Fernandez, 2013). This suggest that while a firm's R&D PAD – *Below* and *Above R&D PAD* – are important drivers of a firm's R&D, market dynamism also influences a firm's R&D investments because it offers a source of external technological knowledge that increases the firm's ability to adapt to external market developments (Revilla and Fernandez, 2013).

Hypothesis 3: Market dynamism has a positive influence on the firm's R&D

2.5 Market dynamism: moderating role

In examining the moderating influence of market dynamism, market dynamism has a positive moderating role on the firm's *Below R&D PAD*. As industries with greater market dynamism experience greater technological progress (Requena *et al.*, in press; Revilla and Fernandez, 2013; Roberts, 2015; Thornhill, 2006), such progress provides greater opportunities for search. With this market dynamism, increases in the firm's *Below R&D PAD* increase the firm's risk taking in its problemistic search. This is for two reasons. First, since a firm's R&D goal is ultimately motivated by a need to develop innovative products / services to the market (Pisano, 2015), increases in the firm's *Below R&D PAD* indicate that the firm cannot satisfy the innovation demands of a dynamic market (see also Gaba and Bhattacharya 2012; Ref and Shapira, 2017). To satisfy this demand, the firm engages in a problemistic search to discover the technological opportunities of market dynamism where this search would replenish the firm's R&D expertise (i.e. *Below R&D PAD*) (Gaba and Bhattacharya 2012; Ref and Shapira, 2017) to meet the innovative demands of dynamic markets. Second, while a firm's problemistic search is confined to a search for nearby or localized experiences, dynamic markets provide technological opportunities that support this localized search. This is because market dynamism involves multiple and often competing technologies (Roberts, 2015) where such variation in technologies increase the likelihood that a firm's problemistic search can reveal technologies that are near its R&D experiences. This problemistic search is consistent with absorptive capacity research (Cohen and Levinthal, 1990). Absorptive capacity (AC) refers to the idea that a firm assimilates external experiences that are closely related to its past experiences (Cohen and Levinthal, 1990). Various empirical studies have found that a firm's R&D expenditures are an important source of this AC where a firm's R&D investments increase its ability to assimilate external R&D that are closely related to its past R&D expertise (Ben-Oz and Shapira, 2012; Jo *et al.*, 2016; Lane and Lubatkin, 1998; Laursen and Salter, 2006; Ng and Sanchez-Aragon, 2022). Hence, since market dynamism offers technological opportunities that support a firm's local search, this dynamism increases a firm's risk taking to assimilate local experiences that are closely related to its past R&D expertise. This greater risk-taking is not only consistent with AC explanations, but such risk-taking offers a problemistic search that replenishes the firm's internal R&D expertise. As a result, market dynamism has a positive moderating influence on the firm's *Below R&D PAD* where the firm engages in a greater risk

taking in its problemistic search to not only assimilate external technological opportunities, but through this assimilation mitigate the obsolescent threats to its R&D.

Hypothesis 4: Market dynamism positively moderates the relationship between the firm's Below R&D PAD and its R&D

In contrast, market dynamism has a negative moderating influence on the firm's *Above R&D PAD*. This negative moderating role involves reducing the firm's risk taking in its slack search. Namely, unlike the firm's *Below R&D PAD*, firms with an *Above R&D PAD* signal that the firm is successful in meeting the innovation demands of dynamic markets. As a result, firms with *Above R&D PAD* face fewer obsolescence pressures and therefore do not need to discover the technological opportunities of dynamic markets (see also Ref and Shapira, 2017). This suggests that increases in the firm's *Above R&D PAD* will reduce a firm's risk-taking in its slack search to discovering these technological opportunities (see also Gaba and Bhattacharya, 2012; Ref and Shapira, 2017). Furthermore, market dynamism reduces a firm's risk taking in its slack search, because this greater risk taking would commit a firm's R&D slack to the uncertainty of dynamic markets. This follows resource dependence theory explanations that argue firms seek to buffer their core technical expertise from external market changes, because these external changes undermine the firm's ability to leverage its core competencies (Hillman *et al.*, 2009; Pfeffer and Salancik, 1978). These considerations suggest that with dynamic markets, increases in the firm's *Above R&D PAD* will reduce the firm's risk taking in its slack search to discovering the technological opportunities of dynamic markets and thus reduces a firm's R&D investments in discovering these opportunities. This is consistent with studies (Gaba and Bhattacharya, 2012; Lu and Fang, 2014; Ref and Shapira, 2017) that argue successful innovative firms develop strong feelings of self-efficacy or confidence that reject alternative technologies not found within its internal R&D (see also Teirlinck, 2020). As a result, these considerations suggest market dynamism negatively moderates a firm's *Above R&D PAD* where this market dynamism reduces a firm's risk taking in its R&D.

Hypothesis 5: Market dynamism negatively moderates the relationship between the firm's Above R&D PAD and its R&D

To summarize this study's hypotheses, increases in the firm's *Below* (Hypothesis 1) and *Above* (Hypothesis 2) *R&D PAD* have an asymmetric influence on the firm's risk taking in its R&D and that such risk taking is directly (Hypothesis 3) and indirectly (Hypotheses 4-5) influenced by market dynamism. As various theories have been offered to explain a firm's risk-taking, it is important to highlight how this study's hypotheses differ from these existing explanations. Specifically, prospect theory (PT) has had a prominent influence (Kahneman and Tversky, 1979) on behavioral economics and management research. According to PT explanations, an individual's risk-taking is dependent on their perceptions of gains and losses. When individuals suffer great losses, indviduals engage in a greater risk-taking to recover these losses. In contrast, when individuals experience large gains, they become more risk-averse because individuals seek to avoid the losses to their gains (see also Hoskisson *et al.*, 2017). Yet, the focus of PT explanations is on the size of these losses and gains, rather than the reference points used in determining these losses and gains. Various behavioral researchers have thus called for a greater need to examine a firm's reference points from the standpoint of their different goals (Hoskisson *et al.*, 2017). This study's hypotheses were developed in response to such calls. By examining a firm's R&D goal, as a reference point, this study argues that unlike PT explanations, increases in the distance in the firm's *Below R&D PAD* favor risk averse rather than risk-taking behaviors (i.e. Hypothesis 1). This risk-aversion occurs because in situations of loss (i.e. *Below R&D PAD*), a firm favors investments that offer immediate and certain returns and thus will reduce their investments in R&D. Furthermore, unlike PT, increases in the distance of a firm's *Above R&D PAD* (i.e. gains) favor a greater risk taking (i.e. Hypothesis 2). This occurs because a firm's excess R&D or slack resources support a firm's slack search to engage in a greater risk taking in its R&D. Hence, a firm's R&D goal offers a reference point where it introduces risk-taking behaviors not considered by PT explanations. Furthermore, while market dynamism has been identified as an important consideration to behavioral explanations (Hoskisson *et al.*, 2017), few studies – including PT explanations – have examined its role on the firm's R&D goal-setting

process (see review Barberis, 2013). This dynamism is argued to have a positive influence on a firm's R&D, because it offers external technological opportunities not found within a firm's internal R&D (Hypothesis 3). Furthermore, in situations when the firm experiences a *Below R&D PAD*, dynamism offers opportunities to assimilate technologies that are consistent with the firm's established expertise and thus has a positive moderating role in the firm's R&D (Hypothesis 4). In contrast, when a firm experiences an *Above R&D PAD*, market dynamism has a negative moderating role because the firm has excess R&D resources (i.e. R&D slack) where it does not require an external search to complement this internal expertise (Hypothesis 5).

3. Methodology

3.1 Data and sample

This study's hypotheses were empirically examined in a panel of U.S. biotechnology firms. The BioScan database was used to identify this study's sample and has been used in a variety of biotechnology studies (e.g. Grigoriou and Rothaermel, 2017; Ng *et al.*, 2019; Ng and Sanchez-Aragon, 2022). This Bioscan sample was used to collect the biotechnology firm's financial and patent data. This data was sourced from the Mergent and U.S.P.T.O (United States Patent and Trade Office) databases. This resulted in a panel of 405 firms covering a 26-year sampling period, from 1987 to 2013. Within this sample, a total of 3368 observations were used in this study's empirical examinations where the average number of yearly observations for each firm was 8.3 years.

3.2 Dependent variable

R&D investments have been used in several behavioral studies (Ben-Oz and Greve, 2012; Bromiley and Harris, 2014; Chen and Miller, 2007; Gaba and Bhattacharya, 2012; Greve, 2003, 2007; Lu and Fang, 2014; O'Brien and David, 2014; Xu *et al.*, 2019) to measure a firm's efforts in building its long-term innovation capabilities (Xu *et al.*, 2019). Studies have used a firm's R&D intensity (i.e. ratio of firm's R&D expenditures / sales), because it accounts for scale effects (e.g. Chen and Miller, 2007; Greve, 2003; Xu *et al.*, 2019). Yet, Bromiley and Harris (2014) and Lu and Fang (2014) have argued that a firm's sales are influenced by external market conditions (i.e. business cycles) and are subject to accounting manipulations. To avoid these distortionary influences, Bromiley and Harris (2014) and Lu and Fang (2014) have chosen the firm's R&D investments instead of the firm's R&D intensity measure. In following these studies, a biotechnology firm's R&D investments are measured by its R&D expenditures, *R&D Exp*, and are measured in the sampling period *t.*

3.3 Measures: independent variables

*R&D IPAD***.** As various behavioral studies have used a firm's PAD to measure its risk-taking behaviors (Bromiley and Harris, 2014; Greve, 2003, 2007; Gavetti *et al.*, 2012; Hoskisson *et al.*, 2017; Ref and Shapira, 2017), this study subscribes to this behavioral view. In particular, the firm's risk-taking is measured by the *R&D PAD* variable. The *R&D PAD* variable follows Bromiley and Harris (2014) methodological approach and is shown in equation 1 (see also Greve, 2003, 2007; Martinez-Noya and Garcia-Canal, 2021; Tyler and Caner, 2016). Equation 1 consists of the difference between the firm's current R&D performance, $R\&D_t$, and its R&D historical aspirations ($HA_{t\text{-}1\ldots t\text{-}3}$). The firm's current R&D performance is measured by its R&D expenditures, $R\&D_t$, in period *t*. The firm's $R\&D\ HA_{t\text{-}1\ldots t\text{-}3}$ are measured by a weighted average of a firm's R&D past performance in period *t-1*, $R\&D_{t\text{-}1}$, and a moving average of its R&D performance, $R\&D\ MA_{t\text{-}2..t\text{-}3}$, in the previous 2 years (i.e. *t-2, t-3*). A common convention used in behavioral research is to estimate the alpha, α, value by identifying a value that maximizes the model's fitness (e.g. Bromiley and Harris, 2014; Greve, 2003, 2007; Gaba and Bhattacharya, 2012). An alpha value of 0.6 was determined. An assumption underlying this specification was that managers place a greater weight on their firm's previous period's performance, $R\&D_{t\text{-}1}$, over the moving average of its past performance, $R\&D\ MA_{t\text{-}2..t\text{-}3}$. This specification is consistent with Bromiley and Harris (2014) who argue that managers assign greater weight to aspirations that are based on the firm's recent past performance.

$$R\&D\ PAD = R\&D_t - \text{R\&D HA}_{t\text{-}1,\ t\text{-}2,\ t\text{-}3} \quad (1)$$

$$\text{where } R\&D\ HA_{t\text{-}1,\ t\text{-}2,\ t\text{-}3} = [\alpha \cdot R\&D_{t\text{-}1} + (1\text{-}\ \alpha) \cdot R\&D\ MA_{t=t\text{-}2,\ t\text{-}3}]$$

■ *Below R&D PAD / Above R&D PAD*

In drawing on the *R&D PAD* variable, a functional form involving a spline specification was used to create the *Below R&D PAD / Above R&D PAD* variables (Chen and Miller, 2007; Greve, 2003, 2007; Gaba and Bhattacharya, 2012; Martinez-Noya and Garcia-Canal, 2021; Tyler and Caner, 2016). A spline specification allows researchers to examine the *Below* and *Above PAD* variables as separate effects and is commonly used in behavioral research (e.g. Bromiley and Harris, 2014; Greve, 2003, 2007; Martinez-Noya and Garcia-Canal, 2021; Tyler and Caner, 2016). To implement this spline specification, the *Below R&D PAD* variable was created by setting its value to the difference between the firm's R&D and its R&D HA, when the *R&D PAD* variable is less than 0. When the *R&D PAD* variable is greater than 0, the *Below R&D PAD* variable is set to 0. Similarly, the *Above R&D PAD* variable is set to the difference between firm's R&D and its R&D HA, when the firm's *R&D PAD* variable is greater than 0 and is set to 0 otherwise.

■ *Market dynamism*

While there are various measures of market dynamism, market dynamism has been defined by the industry's technological progress and has been measured by the aggregate R&D investments in an industry (Fourné *et al.*, 2019; Jo *et al.*, 2016; Thornhill, 2006). This characterization of market dynamism is particularly appropriate for the biotechnology industry, because investments in basic research, such as genome sequencing, CRISPR and other biotechnological advances, have played a pivotal role in shaping the technological as well as commercial opportunities in this sector. These and other technological advances offer an important source of market dynamism that can impact a firm's R&D process. This is because as innovations are often built on the technological achievement of others, various absorptive capacity studies have found that a firm's investment in R&D increases its ability to assimilate and integrate external R&D experiences (e.g. Ben-Oz and Shapira, 2012; Cohen, 2010; Cohen and Levinthal, 1990; Lane and Lubatkin, 1998; Laursen and Salter, 2006; Ng and Sanchez-Aragon, 2022). Hence, market dynamism not only captures the technological progress of the biotechnology industry, but that such technological progress offers a set of external R&D experiences that can be assimilated into the firm's R&D goal process[1]. Thus, in drawing on this characterization of market dynamism, the market dynamism, *Dyn*, variable is measured by aggregating the R&D expenditures of the sampled firms where larger values indicate greater technological progress (Thornhill, 2006). To capture its moderating influences, the product or interaction of this market dynamism, *Dyn*, variable with the firm's *Below and Above R&D PAD* variables were created.

■ *Control measures*

A firm's net income, *NI*, was included because Schumpeterian explanations argue that a firm's profits offer a source of capital to the firm's R&D investments (Cohen, 2010; Lu and Fang, 2014). A firm's revenue, *Rev*, was included to account for size effects. Furthermore, a firm's patents, *Patents*, involving the firm's number of patent applications were included because patent applications require an understanding of the field's prior technological art (Ng *et al.*, 2019) and thus can influence the development of its R&D. Moreover, a firm's specialization or depth of expertise, *Depth*, can impact a firm's R&D (Greve, 2003). This depth, *Depth*, variable is measured by the ratio of a firm's self-citations to all citations in the firm's patent portfolio. In addition, investments in a firm's R&D depend on the firm's ability to appropriate the returns from such investments (Cohen, 2010; Cohen and Levinthal, 1990; Revilla and Fernandez, 2013). In that, since the

[1] While patents can be used to measure the technological progress of a market, such a measure of market dynamism exhibits patent protections that do not permit the examination of a firm's assimilation of external R&D experiences and thus would not be suitable to examining this study's moderating effects.

returns from a firm's R&D investment are distant into the future, a firm's appropriability is used to measure its ability to capturing these future returns. Two measures of appropriability were used. A firm's market share, *MS*, accounts for market power influences (Cohen, 2010) and is measured by the ratio of the firm's sales to the aggregates sales of the sampled firms (Ng and Sanchez-Aragon, 2022). An industry's intellectual property right (IPR) regime, *IPR_Regime,* was included to reflect the degree to which IPR are enforced in the industry (Cohen, 2010; Cohen and Levinthal, 1990; Revilla and Fernandez, 2013). *IPR_Regime* variable was measured by aggregating the patent claims made by the sampled firms (Ng *et al.*, 2019). Table 1 offers a brief description of this study's variables and their impacts on the firm's R&D.

3.4 Data analysis and econometric approach

To take advantage of this study's panel structure, a fixed effects (FE) linear regression was used. A FE linear estimation is appropriate because it controls for different rates of R&D spending across firms, while controlling for firm-specific influences in R&D spending. With this FE linear specification, all explanatory variables – including the *Below* and *Above R&D IPAD* variables – were lagged by one period. This lag structure is commonly used by studies of this kind and avoids problems of simultaneous bias (i.e. reverse causality)

Table 1. Description and impact of variables.

Variable name	Description	Relationship to R&D	Expected impact on R&D
NI	Firm's net income	Schumpeterian innovation hypothesis	+
Rev	Firm's revenue	Scale economies	+
Patents	No. of patent applications	Knowledge of prior aet	+
Depth	Ratio of a firm's self citations to its total citations	Specialized expertise	+
MS	Market share	Market power	–
IPR_Regime	Intellectual property (IP) right regime	Enforcement of IP claims	+
Below R&D PAD	$R\&D_t$ – R&D $HA_{t-1, t-2, t-3}$ where $R\&D_t$ – R&D $HA_{t-1, t-2, t-3} < 0$	Risker aversion	–
Above R&D PAD	$R\&D_t$ – R&D $HA_{t-1, t-2, t-3}$ where $R\&D_t$ – R&D $HA_{t-1, t-2, t-3} > 0$	Risk taking	+
Dyn	Market dynamism: aggregation of R&D expenditures in sample	Direct and moderating influence	+ and varies by risk preference
ΔROA_{t+1}	Annual rates of change in the firm's ROA at time t+1. (1 period forward lag)	Controls for variability of return (i.e. ROA) to R&D investments based on a 1 period forward lag	–
ΔROA_t	Annual rates of change in the firm's ROA at time t	Controls for variability of return (i.e. ROA) to R&D investments based on period t	–
ΔNI_{t+1}	Annual rates of change in the firm's net income at time t+1. (1 period forward lag)	Controls for variability of return (i.e. NI) to R&D investments based on a 1 period forward lag	–
ΔNI_t	Annual rates of change in the firm's net income at time t	Controls for variability of return (i.e. NI) to R&D investments based on period t	–
Below ROA PAD	ROA_t – ROA $HA_{t-1, t-2, t-3}$ where ROA_t – ROA $HA_{t-1, t-2, t-3} < 0$	Risk aversion	–
Above ROA PAD	ROA_t – ROA $HA_{t-1, t-2, t-3}$ where ROA_t – ROA $HA_{t-1, t-2, t-3} > 0$	Risk taking	+

(Bromiley and Harris, 2014; Greve, 2003, 2007; Kuusela *et al.*, 2017; Martinez-Noya and Garcia-Canal, 2021; O'Brien and David, 2016; Tyler and Caner, 2016). In addition, biases arising from outlier observations can be an issue. A 1% winsorizing was applied to all the data where extreme values are replaced for less extreme values (e.g. Bromiley and Harris, 2014; Kuusela *et al.*, 2017; O'Brien and David, 2014). Lastly, and consistent with prior studies, all variables were constructed on the basis of their nominal as opposed to real values (see also Bromiley and Harris, 2014; Martinez-Noya and Garcia-Canal, 2021; O'Brien and David, 2014; Tyler and Canner, 2016). This is because the majority of the sample period falls during the periods between the mid-1990s to mid-2000s where the rate of inflation was relatively low ranging from 2.8 to 3.3%. Furthermore, as this study's main variables of interest *Below* and *Above R&D IPAD* – and their interactions with Market Dynamism – are based on performance differences, an adjustment for interest rates was not necessary to examine their hypothesized effects.

4. Results

The descriptive statistics and correlations are shown in Supplementary Table S1. Table S1 shows that the revenue and market share variables exhibit high correlations. A variance inflation factor (VIF) test for these variables shows respective values of 4.55 and 2.46 and the overall VIF score was 2.18. These values fall well below the recommended value of 10 and thus multi-collinearity does not appear to be a significant issue. Table 2 reports the FE linear estimations.

In explaining this study's controls, the *NI* variable was negative and significant in all models. This finding does not support Schumpeterian explanations (Cohen, 2010). The *Rev* variable was positive and significant in all models. R&D is thereby subject to size effects. The *Patent* variable was positive and significant in all models and is consistent with this study's explanations. The market share, *MS*, variable was negative and significant in all models. This finding is consistent with market power explanations (Cohen, 2010). The *IPR_Regime* variable was positive and significant in all models and is consistent with innovation studies (Cohen, 2010). Last, the *Depth* variable was not significant in any model and thus a firm's specialization of expertise does not influence the development of the firm's R&D (Greve, 2003).

In examining Hypotheses 1 & 2, models 2-6 (full model) show that the *Below* and *Above R&D PAD* variables were significant and were respectively negative and positive. Hypotheses 1 and 2 cannot be rejected. These findings indicate that increases in the *Below R&D PAD* variable (models 2, 3, 4, and 6) reduces a firm's investments in R&D, while increases in the *Above R&D PAD* variable (models 2, 3, 5, and 6) increases these investments. This pattern of risk-taking offers an alternative to existing behavioral findings. For instance, in using a firm's product innovation counts, Tyler and Caners' (2016) biotechnology study found large declines in the firm's *Below PAD* increased the firm's problemistic search for distant information. This distant search increased the firm's ability to form a greater diversity of R&D partnerships. Martinez-Noya and Garcia-Canal (2021) used a firm's patent counts and found similar risk-taking behaviors with a firm's alliances. Yet, when examining a firm's *Below R&D PAD* variable, models 2, 3, 4 and 6 show that increases in the *Below R&D PAD* variable has a declining influence on the firm's R&D investments. This finding suggests that increases in the firm's *Below R&D PAD* does not lead to a problemistic search for distant information. Regarding the *Above R&D PAD* variable, behavioral studies find increases in the firm's *Above PAD* can lead to competency trap behaviors that reduce a firm's risk taking (Gaba and Bhattacharya, 2012; Gavetti *et al.*, 2012; Greve, 2003; Greve and Gaba, 2020; Kotiloglu *et al.*, 2021; Teirlinck, 2020). Models 2, 3, 5, and 6 do not support this competency trap explanation. These models instead show that increases in a firm's *Above R&D PAD* support greater risk taking in its R&D investments.

To examine the influence of market dynamism, *Dyn*, models 3-6 show a consistently significant and positive influence on the firm's R&D. Hypothesis 3 cannot be rejected. To examine its interactions with the *R&D PAD* variables, model 4 shows that the *Below R&D PAD* * *Dyn* interaction variable was positive and significant. A similar positive finding was also observed in the full model 6. Regarding the interactions with the *Above R&D PAD* variable, models 5 and 6 show the *Above R&D PAD*Dyn* interaction variable

Table 2. Fixed effect linear regression (R&D Exp).[1,2]

Variables	1	2	3	4	5	6
NI	-0.025**	-0.022**	-0.022**	-0.024**	-0.021**	-0.021**
	(1.9^{e}-03)	(1.8e-03)	(1.8e-03)	(1.9e-03)	(1.8e-03)	(1.8e-03)
Rev	1.7e-03**	1.5e-03**	1.4e-03**	1.6e-03**	1.4e-03**	1.4e-03**
	(1.2e-04)	(1.1e-04)	(1.1e-04)	(1.2e-04)	(1.1e-04)	(1.1e-04)
Patent	1.6e+06**	1.3e+06**	1.3e+06**	1.6e+06**	1.3e+06**	1.3e+06**
	(1.2e+05)	(1.1e+05)	(1.1e+05)	(1.2e+05)	(1.1e+05)	(1.1e+05)
MS	-9.6e+08**	-8.0e+08**	-7.8e+08**	-9.2e+08**	-7.9e+08**	-7.8e+08**
	(9.0e+07)	(8.7e+07)	(8.7e+07)	(9.0e+07)	(8.7e+07)	(8.7e+07)
IPR_Regime	438**	237**	145*	260**	163**	142*
	(41.3)	(42.1)	(56.5)	(58.2)	(56.3)	(56.4)
Depth	-1.1e+07	-1.9e+07	-1.7e+07	-5.7e+06	-1.1e+07	-1.5e+07
	(1.5e+07)	(1.4e+07)	(1.4e+07)	(1.5e+07)	(1.4e+07)	(1.4e+07)
Below R&D PAD		-6.88**	-6.36**	-23.9**		-25.3**
		(1.57)	(1.58)	(8.27)		(7.94)
Above R&D PAD		3.02**	2.96**		4.37**	4.47**
		(0.186)	(0.187)		(0.61)	(0.609)
Dyn			7.0e-05*	1.4e-04**	1.0e-04**	9.5e-05**
			(2.8e-05)	(3.0e-05)	(2.9e-05)	(2.9e-05)
*Dyn*Below R&D PAD*				1.3e-10**		9.9e-11*
				(4.2e-11)		(4.0e-11)
*Dyn*Above R&D PAD*					-8.9e-12**	-8.3e-12**
					(3.1e-12)	(3.1e-12)
Constant	-1.0e+07*	-9.9e+04	-9.0e+04	-1.1e+07*	-3.6e+06	-3.0e+06
	(4.8e+06)	(4.6e+06)	(4.6e+06)	(4.8e+06)	(4.7e+06)	(4.7e+06)
Observations	3,368	3,368	3,368	3,368	3,368	3,368
R-squared	0.213	0.278	0.279	0.221	0.277	0.283
AIC	131,947.74	131,662.34	131,657.46	131,917.57	131,664.72	131,642.86
BIC	131,990.59	131,717.44	131,718.68	131,972.67	131,719.82	131,704.08

[1] Standard errors between parentheses.

[2] Significance: * $P<0.05$; ** $P<0.01$.

was negative and significant. To further examine these interactions, the marginal effects and confidence intervals of the *Below R&D PAD* (Figure 1) and *Above R&D PAD* (Figure 2) variables were plotted against increases in the Market Dynamism, *Dyn*, variable. Figure 1 shows that the marginal effects of the *Below R&D PAD* variable increased with increases in the values of the Market Dynamism, *Dyn*, variable. In contrast, Figure 2 shows that the marginal effects of the *Above R&D PAD* variable decreased with increases in the values of the Market Dynamism, *Dyn*, variable. The predicted marginal effects in Figure 1 and 2 were also significant at $P<0.01$. Hence, in addition to the interaction estimates in models 4-6, Figure 1 and 2 show that the interactions between the Market Dynamism, *Dyn*, and the *Below R&D PAD* and *Above R&D PAD* variables were respectively positive and negative. Hypotheses 4 and 5 cannot be rejected.

This study's Market Dynamism, *Dyn*, findings show that market dynamism not only impacts a firm's R&D investments, but that this Market dynamism, *Dyn*, also moderates a firm's risk-taking in such investments. In particular, studies find that market dynamism has a positive influence on the firm's innovative activities (Requena *et al.*, in press; Revilla and Fernandez, 2013; Roberts, 2015; Thornhill, 2006). Hypothesis 3 builds on this argument where market dynamism, *Dyn*, has a positive influence on the firm's R&D, because it increases the firm's ability to develop innovation assets to compete in dynamic markets. With respect to this study's moderating findings, few studies have examined the moderating role of market dynamism on the

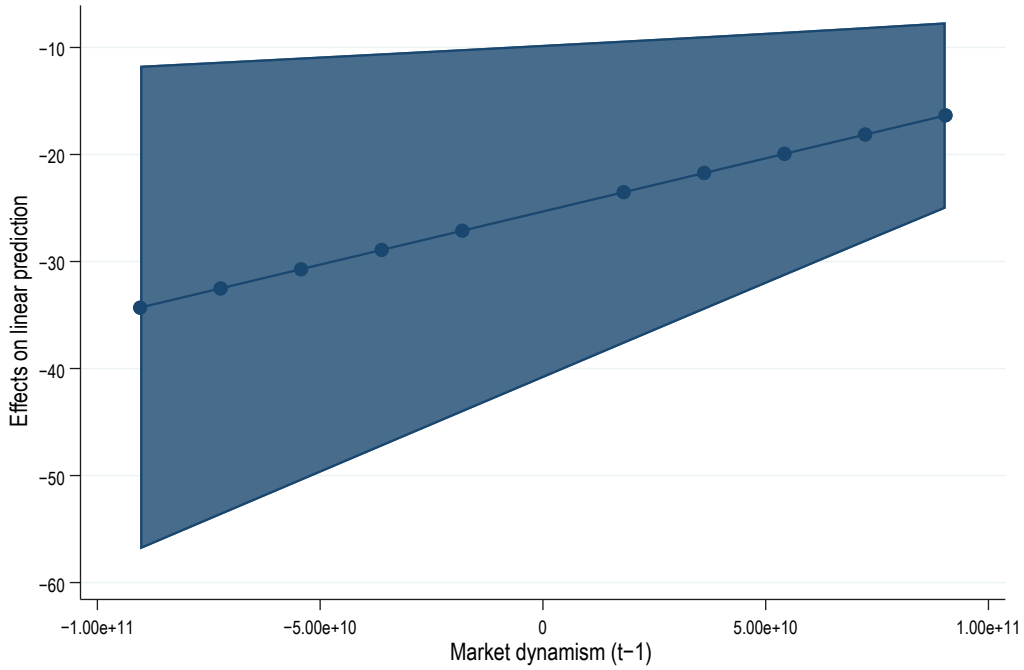

Figure 1. Average marginal effects of below R&D PAD (t-1) with 95% CIs.

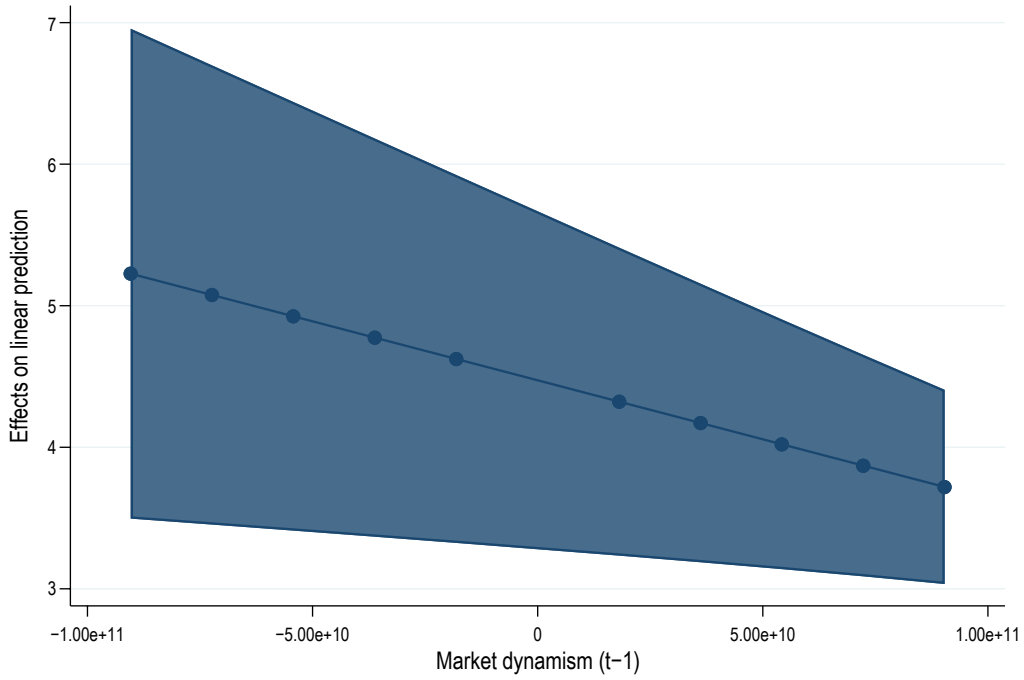

Figure 2. Average marginal effects of above R&D PAD with 95% CIs.

firm's risk-taking behaviors (Kotiloglu *et al.*, 2021). For instance, Roberts *et al.* (2015) argued and found that market dynamism moderated the relationship between the firm's connectedness with its external market environment and its R&D. However, they did not examine the firm's PAD decision process. Furthermore, while behavioral studies have identified environmental conditions (i.e. legal institutional and competition) that moderate a firm's PAD process (Xu *et al.*, 2019), the moderating role of market dynamism on the

firm's PAD has not been examined. This study's moderating findings advance both market dynamism and behavioral research where hypotheses 4 and 5 show that market dynamism, *Dyn*, moderates a firm's risk-taking in its R&D.

While the prior findings provide support for this study's hypotheses, concerns can be raised that these findings did not directly account for the risks surrounding the firm's R&D investments. Specifically, while the appropriability measures – *MS* and *IPR_Regime* – control for the firm's ability to capture the future returns from its R&D investments, they do not control for the variability of returns generated by these investments. Since R&D investments impact a firm's returns (see also Hoskisson *et al.*, 2017), this variability is measured by the annual rates of change in the firm's ROA, ΔROA, and net income, ΔNI. In computing their annual rates, behavioral studies find that because managers cannot fully anticipate the long-term consequences of their actions, managerial assessments of their investment decisions are often based on a short-term time horizon (see also Bromiley and Harris 2014; Tyler and Canner, 2016). To capture this short-term time horizon, these annual rates were computed for the period *t* in which R&D expenditures were made – ΔROA_t and ΔNI_t – as well as a 1-year forward lag of these annual rates, ΔROA_{t+1} and ΔNI_{t+1}. Additional forward lags – up to 5 periods – were also included. They, however had no appreciable impact on this study's main findings and thus were not included. In Table 3, models 1-3 show that the 1 period forward lag estimates of the ΔROA_{t+1} and ΔNI_{t+1} variables were not significant. The current period estimate for the ΔROA_t variable was also not significant, while the current period estimate for the ΔNI_t variable was negative and significant. The estimates on the *Below R&D PAD* (models 1 & 2), and *Above R&D PAD* (models 1 & 3) variables are consistent with the findings in Table 2. With respect to Hypothesis 3, the estimate on the market dynamism variable, *Dyn*, was not significant (models 1-3). When examining its moderating influence, the *Below R&D PAD*Dyn* interaction variable in model 2 was positive and significant (Hypothesis 4). In model 3, the estimate on the *Above R&D PAD*Dyn* interaction variable was not significant (Hypothesis 5). Hence, when controlling for the variability of returns in the firm's R&D investments, hypotheses 1, 2 and 4 was robust to this specification, but not for hypotheses 3 and 5. Furthermore, since different goals (i.e. financial vs R&D goals) can lead to different risk-taking behaviors, models 1-3 were re-estimated in models 4-6 with a firm's financial goals involving its ROA (e.g. Greve, 2003, 2007). The *ROA PAD* variables involving a firm's *Below_ROA_PAD* and *Above_ROA_PAD* were created using the methodology outlined earlier. Their interactions with the market dynamism, *Dyn*, variable were also included in models 4-6. In these models, the *Below_ROA_PAD* and *Above_ROA_PAD* variables and their interactions with market dynamism, *Dyn*, were not significant. The market dynamism variable, *Dyn*, was significant, but negative (models 4 and 6). Hence, when using a firm's *ROA_PAD*, Hypotheses 1-5 were not supported. These findings indicate a firm's financial goal-setting process does not impact its R&D investments. According to Tyler and Canner (2016), a firm's investments in R&D activities (i.e. patents) not only develop the firm's long term-competitive advantage in innovation, but that such investments form the basis of a firm's financial goals. The lack of significant findings in models 6-9 are consistent with this view.

5. Discussion

As firms face multiple goals, this study examined the risk-taking behaviors surrounding a firm's R&D. In the context of the firm's R&D decision-making, this study's findings broaden behavioral explanations of risk-taking. Most notably, PT explanations have played a prominent role in behavioral research (Gavetti *et al.*, 2012; Greve and Gaba, 2020; Kotiloglu *et al.*, 2021). Studies have argued and/or found that firms are risk taking in loses (i.e. *Below R&D PAD*) and are risk averse in gains (i.e. *Above R&D PAD*) (e.g. Gaba and Bhattacharya, 2012; Greve, 2003). The findings from hypotheses 1 and 2 offer an alternative explanation where increases in the firm's *Below R&D PAD* reduces rather than increases a firm's R&D investments and increases in the firm's *Above R&D PAD* increases rather than reduces a firm's R&D. Hence, as there remains considerable debate surrounding PT explanations in organizational research (Greve and Gaba, 2020; Hoskisson *et al.*, 2017; Kotiloglu *et al.*, 2021), this study's arguments and findings suggest that PT explanations may not be universally applicable to all types of goal seeking behaviors. Thus, this study offers

Table 3. Ex-post analysis fixed effect linear regressions (R&D Exp).[1]

Variables	1	2	3	4	5	6
NI	-3.3e-03	-3.8e-03	-3.7e-03	-3.7e-03	-3.8e-03	-3.7e-03
	(2.4e-03)	(2.5e-03)	(2.4e-03)	(2.5e-03)	(2.5e-03)	(2.5e-03)
Rev	1.5e-03**	1.8e-03**	1.5e-03**	1.8e-03**	1.8e-03**	1.8e-03**
	(2.3e-04)	(2.4e-04)	(2.3e-04)	(2.4e-04)	(2.4e-04)	(2.4e-04)
Patent	7.9e+05**	1.0e+06**	7.9e+05**	1.0e+06**	1.0e+06**	1.0e+06**
	(1.3e+05)	(1.4e+05)	(1.3e+05)	(1.4e+05)	(1.4e+05)	(1.4e+05)
MS	6.7e+08**	6.4e+08**	6.7e+08**	6.4e+08**	6.5e+08**	6.4e+08**
	(2.2e+08)	(2.3e+08)	(2.2e+08)	(2.3e+08)	(2.3e+08)	(2.3e+08)
IPR_Regime	148*	352**	221**	363**	357**	364**
	(68.3)	(68.5)	(67)	(68)	(67.8)	(68)
Depth	3.1e+05	9.6e+06	4.8e+06	9.6e+06	1.0e+07	9.5e+06
	(1.6e+07)	(1.7e+07)	(1.6e+07)	(1.7e+07)	(1.7e+07)	(1.7e+07)
Below R&D PAD	-7.52**	-11.9+				
	(1.71)	(6.92)				
Above R&D PAD	2.26**		1.91**			
	(0.195)		(0.54)			
Dyn	-5.9e-05	-5.4e-05	-6.1e-05	-7.3e-05+	-6.7e-05	-7.6e-05+
	(4.1e-05)	(4.4e-05)	(4.5e-05)	(4.3e-05)	(4.5e-05)	(4.6e-05)
ΔROA_t	6.8e+04	5.8e+04	5.6e+04	5.7e+04	5.9e+04	6.0e+04
	(1.1e+05)	(1.1e+05)	(1.1e+05)	(1.1e+05)	(1.1e+05)	(1.1e+05)
ΔNI_t	-19.5**	-20.5**	-19.7**	-20.7**	-20.7**	-20.9**
	(6.1)	(6.34)	(6.14)	(6.36)	(6.37)	(6.36)
ΔROA_{t+1}	4.6e+04	3.4e+04	3.4e+04	3.4e+04	3.5e+04	3.6e+04
	(1.1e+05)	(1.1e+05)	(1.1e+05)	(1.1e+05)	(1.1e+05)	(1.1e+05)
ΔNI_{t+1}	-30.9	-51.9	-49.9	-41.2	-45.4	-48.9
	(177)	(185)	(178)	(185)	(185)	(185)
*Dyn*Below R&D PAD*		6.2e-11+				
		(3.5e-11)				
*Dyn*Above R&D PAD*			1.2e-13			
			(2.8e-12)			
Below ROA PAD				6.9e+04	-1.2e+05	
				(1.3e+05)	(3.6e+05)	
Above ROA PAD				-1.4e+05		-1.5e+05
				(1.4e+05)		(3.6e+05)
*Dyn*Below ROA PAD*					6.8e-07	
					(1.9e-06)	
*Dyn*Above ROA PAD*						2.4e-07
						(2.0e-06)
Constant	2.8e+07**	1.3e+07*	2.5e+07**	1.7e+07*	1.5e+07*	1.6e+07*
	(6.2e+06)	(6.5e+06)	(6.6e+06)	(6.5e+06)	(6.8e+06)	(6.8e+06)
Observations	1,938	1,938	1,938	1,938	1,938	1,938
R-squared	0.201	0.136	0.192	0.135	0.135	0.135
AIC	74,757.58	74,907.12	74,778.81	74,911.67	74,912.78	74,911.97
BIC	74,835.55	74,979.53	74,851.21	74,989.65	74,990.75	74,989.94

[1] Standard errors between parentheses.

[2] Significance: + $P<0.1$; * $P<0.05$; ** $P<0.01$.

a potentially important boundary condition for PT research where gains and losses need to be examined from the standpoint of a firm's goals.

While this study's findings differ from PT, it nevertheless offers a pattern of risk-taking that is more in line with Staw *et al.* (1981) threat rigidity hypothesis and the capacity explanations of slack search (Xu *et al.*, 2019). The threat rigidity hypothesis (Kim and Rhee, 2016; Staw *et al.*, 1981) argue that situations of crisis restrict a firm's field of attention. This restricted attention reduces the firm's ability to search and thus reduces a firm's ability to change in situations of crisis. Studies have found empirical support for the threat rigidity explanation of Staw *et al.* (1981), where increases in the firm's *Below PAD* reduces a firm's risk-taking (Kim and Rhee, 2016). This study's *Below R&D PAD* finding builds on this threat rigidity explanation. This study argues that crisis situations (i.e. large declines in the firm's *Below R&D PAD*) restrict the firm's field of attention, because the firm's problemistic search limits a firm's search to local solutions. This suggests that threat rigidity explanations should take into greater account this problemistic search. Furthermore, this study's *Above R&D PAD* findings appeal to the capacity explanations of slack search (Xu *et al.*, 2019). Slack research studies have argued and shown that increases in the firm's *Above PAD* increases a firm's capacity to innovate because a firm's slack search increases its ability to experiment with new solutions (Teirlinck 2020). Yet, because a firm's slack is commonly defined by its excess financial resources (e.g. Tierlinck, 2020), agency theory explanations argue that these slack resources can advance a firm-manager's self-interest and thus may not advance a firm's goals. By drawing on the firm's R&D goal seeking process, this study argues that increases in the firm's *Above R&D PAD* yields an R&D slack that is less vulnerable to the discretionary influences described by agency theory. This is because a firm's R&D slack exhibits a form of fixed capital or absorbed slack (Greve, 2003; Tierlinck, 2020) that cannot be readily redeployed. Hence, a firm's *Above R&D PAD* offers fewer agency problems in developing a firm's capacity to innovate. The broader implication of this study's R&D goal seeking process is that it introduces risk-taking behaviors that can impact the development of a firm's absorptive capacity (AC). In particular, as a firm's AC is focused on the assimilation of external experiences, few efforts have examined the role of a firm's decision-making in the development of this AC (Ben-Oz and Greve, 2012). Since a firm's AC is strongly related to its R&D (Cohen and Levinthal, 1990; Song *et al.*, 2018), this study's R&D goal seeking process introduces risk-taking behaviors that can shape the development of a firm's AC. Such risk taking is an important advance to AC research because AC does not offer a decision-making process to explain its development (see exception Ben-Oz and Greve, 2012).

In addition, while behavioral research has offered important contributions to a firm's decision-making process, this study's market dynamism findings offer additional insights to this decision-making process. Specifically, this study introduces a market dynamism that explains a firm's adaptation to changing markets. This study shows that market dynamism positively moderates the firm's *Below R&D PAD* where the opportunities of dynamic markets increase a firm's risk taking. Such risk-taking offers an adaptation that enables the firm to assimilate emerging technological opportunities. This study also shows that market dynamism has a negative moderating influence on the firm's *Above R&D PAD* where the firm engages in risk averse behaviors that insulate the firm from the changing conditions of the market. Such risk averse behaviors are important to sustaining a firm's commitment to its R&D competencies to which mitigate the firm from searching technologies not directly related to its advancement. These risk-taking behaviors not only explain a firm's adaptation, but it also offer an important source of resilience to dynamic markets. According to Nauck *et al.* (2021), the changing market conditions of 21st century markets (i.e. covid, supply chain disruptions, climate change, cyber breaches, geo-political risks) require that firms develop a resilience. This resilience involves developing a firm's ability to adapt to these market level changes, while at the same time, maintain the firm's commitment to its core business competencies. This study argues that as market dynamism moderates a firm's risk-taking, this moderating effect offers the firm the flexibility to assimilate (i.e. Hypothesis 4) opportunities in changing markets, while also develop the firm's commitment to its R&D core (i.e. Hypothesis 5). This study's moderating findings offer an important source of resiliency.

With respect to implications for management, this study's concept of *R&D PAD* offers two insights into the leadership of biotechnology firms. First, although a biotechnology firm's financial goals are an important strategic objective, leaders who fail to consider their firm's R&D goals can undermine their firm's long-term performance. Hence, leaders should avoid a myopic focus on short-term quarterly earnings (i.e. ROA, EPS) because such a focus can ignore the R&D goals that make such earnings possible (Pisano, 2015; Tyler and Canner, 2016; Wibbens and Siggelkow, 2019). Second, while crisis situations can often motivate leaders to act, large declines in a firm's *Below R&D PAD* favor a greater prudence to such actions. Such prudent or risk averse behaviors are important to the biotechnology industry because leaders may feel pressured by their board members to explore projects / investments that do not directly leverage their firm's R&D competence. In contrast, when a firm's experience increases in their *Above R&D PAD*, these non-crisis situations can offer opportunities to develop new firm-level capabilities.

6. Limitations and future research

As the concept of aspirations has played a vital role to a firm's risk-taking, this study's concept of *R&D PAD* is based on a firm's historic R&D aspirations. As a result, this study does not account for alternative specifications, such as social aspirations, weighted aspirations and switching aspirations (Bromiley and Harris, 2014). Behavioral researchers have argued these aspirations reflect different reference points and can have different impacts on the firm's risk-taking (Bromiley and Harris, 2014). Future research is called to examine these alternative specifications. Furthermore, a biotechnology firm's R&D goals were identified as an important strategic goal because they impact the growth and survival of biotechnology firms. However, R&D goals are less important to other firms, such as food manufacturing firms. These firms are more likely to prioritize goals that emphasize their scale efficiencies and capacity utilization and tend to operate in stable or non-dynamic markets (Requena *et al.*, in press). As a result, this study's *R&D PAD* and market dynamism arguments are not applicable to these firms. Future research is called to examine the risk-taking behaviors surrounding the goals and market dynamism of the food manufacturing industry. In addition, this study examines risk-taking behaviors at the group level and thus does not account for individual level influences. Individual level risk-taking introduces biases in judgements of risk and thus the resolution of such biases is important to a firm's goal seeking process. Future research is called for to examine such individual biases in the goal seeking process (see also Ng, 2020). Lastly, when interpreting this study's findings, the causal and moderating influences of the *Below and Above R&D PAD* and *Market Dynamism* variables should be viewed as being tentative. The use of alternative estimation techniques and specifications is needed to further examine the robustness of this study's findings.

7. Conclusions

As R&D investments are vital to the long-term performance of biotechnology firms, a R&D goal seeking model was developed to explain the risk-taking behaviors that impact a biotechnology firm's investments in R&D. A central argument of this study is that a firm's *Below* and *Above R&D PAD* influence a firm's risk-taking in its R&D and that market dynamism plays an important role in this decision-making process. This study's FE Panel estimations support this central argument.

Supplementary material

Supplementary material can be found online at https://doi.org/10.22434/IFAMR2022.0081

Table S1. Descriptive statistics and correlations.

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