

Balancing Exploratory and Exploitative Adaptation: Organizational and Environmental Dynamics

Juha Uotila

Balancing Exploratory and Exploitative Adaptation: Organizational and Environmental Dynamics

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Exploration and exploitation are considered the two key processes in organizational adaptation and strategic renewal, and balancing these two potentially conflicting forms of adaptive activity has been a central issue in the management literature. However, there is still considerable debate and lack of clarity regarding how exploration and exploitation should be balanced in organizations and how different contextual dynamics might influence the balance between the two processes. In this dissertation, I address this gap through four separate analyses, which are presented in the form of four independent essays.

In the first essay, I empirically examine the exploration–exploitation tradeoff using a panel sample of S&P 500 corporations for the years 1989–2004. I find that relative exploration displays an inverted U-shaped relationship with the financial performance of the organization and that this relationship is positively moderated by industry technological dynamism. In the second essay, I examine exploration and exploitation as two components of organizational adaptability using a formal simulation model and find that environmental complexity and turbulence impose increasing demands on both exploratory and exploitative adaptation. In the third essay, I use a similar simulation model to examine how exploration and exploitation can be balanced over time. I find that either turbulence or complexity may generate a punctuated equilibrium pattern, whereas ambidexterity is the preferred mode in stable and simple or highly complex and highly turbulent environments. Finally, in the fourth essay, I apply the organizational search framework to technological standard setting under network effects. By modeling organizations as boundedly rational actors conducting coevolutionary technological search, I find that while coordination can be used to exploit high-quality technological solutions by driving their acceptance as de facto standards, it must be balanced with sufficient diversity to allow for the exploration of potentially superior solutions.

This dissertation contributes to the organizational adaptation literature by empirically corroborating and theoretically extending key concepts in the literature on exploration and exploitation. I test and advance the exploration–exploitation theory by investigating the dynamics of the exploration–exploitation balance and the influence of contextual factors on this balance. I also contribute to the standard setting literature by showing that when search dynamics are taken into account, an appropriate balance between exploration and exploitation is necessary for optimal social efficiency in such an interorganizational context.

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Tekijä

Juha Uotila

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Organisaatio- ja toimintaympäristödynamiikat uuden luomisessa ja vanhan hyödyntämisessä

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Kokonaan uusien mahdollisuuksien etsiminen, luominen ja kehittäminen ja toisaalta olemassa olevien tilaisuuksien ja osaamisen jalostaminen ja hyödyntäminen ovat tärkeitä prosesseja organisaatioiden strategisessa sopeutumisessa. Näiden kahden joskus ristiriitaisen prosessin tasapainottelu organisaatioissa on yksi strategiatutkimuksen keskeisiä ongelmia. Tässä väitöskirjassa tarkastelen näiden prosessien välisen tasapainon etsimistä ja organisaatioiden ja toimintaympäristöjen dynamiikan vaikutusta tähän tasapainoon. Väitöskirja koostuu neljästä analyysistä, jotka on raportoitu neljänä erillisenä esseenä.

Ensimmäisessä esseessä tutkin S&P 500 -yrityksiä vuosina 1989–2004 ja havaitsen, että uusien mahdollisuuksien etsimisellä on käänteisen U:n muotoinen yhteys taloudelliseen suorituskyykyyn, ja että tasapainon etsiminen on tärkeämpää teknologisesti dynaamisilla toimialoilla. Toisessa esseessä tarkastelen simulaatiomallinnusta käyttäen uuden etsimistä ja olemassa olevan jalostamista kahtena sopeutumiskyvyn komponenttina. Simulaatiot osoittavat, että toimintaympäristön kompleksisuus ja muutosnopeus lisäävät vaatimuksia molemmantyyppisille sopeutumiskyvyille. Kolmannessa esseessä käytän samantyyppistä simulaatiomallia tutkiakseni, kuinka näiden kahden komponentin välinen tasapaino voidaan saavuttaa pitkällä aikavälillä. Havaitsen, että sekä toimintaympäristön kompleksisuus että muutosnopeus voivat saada aikaan uuden etsimisen ja olemassa olevan jalostamisen ajallisen eriyttämisen. Sen sijaan ympäristöissä, jotka ovat joko hyvin yksinkertaisia ja stabiileita tai hyvin kompleksisia ja nopeasti muuttuvia, molemmat komponentit ovat tyypillisesti jatkuvasti läsnä. Neljännessä esseessä sovellan etsivien organisaatioiden viitekehystä teknologisten standardien asettamisongelmaan. Organisaatioiden koevoluutiivisen etsinnän simulointi osoittaa, että vaikka organisaatioiden välinen koordinaatio auttaa olemassa olevien teknologiaratkaisujen hyödyntämisessä, koordinaation ja uusia ratkaisuja tuovan diversiteetin välisestä tasapainosta tulee huolehtia teknologisen lyhytnäköisyyden välttämiseksi.

Tämä väitöskirja edistää organisaatiomuutoskirjallisuutta sekä vahvistamalla empiirisesti että laajentamalla teoreettisesti nykytietämystä uuden etsimisen ja olemassa olevan hyödyntämisen välisistä yhteyksistä. Testaan ja edistän organisaatioteoriaa tutkimalla näiden prosessien välisen tasapainon dynamiikkaa ja sitä, miten kontekstitekijät vaikuttavat tähän tasapainoon. Edistän myös teknologiastandardeja koskevaa kirjallisuutta osoittamalla, että kun etsintädynamiikka otetaan huomioon, on myös tämänkaltaisissa organisaatioiden välisissä prosesseissa tärkeä löytää sopiva tasapaino uuden ja olemassa olevan välillä.

Avainsanat uuden etsiminen, olemassa olevan hyödyntäminen, sopeutumiskyky, tasapaino, toimintaympäristödynamiikka

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Espoo, June 2012

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LIST OF RESEARCH PAPERS

This dissertation consists of the present summary and the following four research papers:

- 1 Uotila, J., Maula, M., Keil, T. and Zahra, S. A. (2009), 'Exploration, exploitation, and financial performance: analysis of S&P 500 corporations,' *Strategic Management Journal*, 30, 221-231.
- 2 Uotila, J. (2012), 'Turbulence, complexity, and the exploration-exploitation balance,' 38 pages.
- 3 Uotila, J. (2012), 'Ambidexterity versus punctuated equilibrium: environmental determinants of the temporal dynamics of exploration and exploitation,' 40 pages.
- 4 Uotila, J., Keil, T. and Maula, M. (2012), 'Balancing coordination and diversity: technology development under network effects,' 49 pages.

Contributions of the author:

In paper 1, the author of this dissertation was responsible for collecting the textual data used for the content analysis and for conducting the statistical analyses. The development of hypotheses and the writing of the research report were a collective effort of the four authors. In papers 2 and 3, the author was solely responsible for designing, implementing, and reporting the research. In paper 4, the author of this dissertation was responsible for designing and implementing the simulation framework and for conducting the simulation analyses. The writing of the research report was a collective effort of the three authors.

CONTENTS

1. INTRODUCTION	1
1.1 OVERVIEW.....	1
1.2 THEORETICAL BACKGROUND.....	3
1.3 RESEARCH QUESTIONS.....	5
1.4 SCOPE AND DELIMITATIONS	7
2. DATA AND METHODS	11
2.1 QUANTITATIVE EMPIRICAL ANALYSIS	11
2.2 FORMAL SIMULATION MODELING.....	13
3. RESULTS AND CONTRIBUTIONS	16
3.1 ENVIRONMENTAL CONTEXT AND THE EXPLORATION–EXPLOITATION BALANCE .	16
3.2 BALANCING EXPLORATION AND EXPLOITATION OVER TIME	18
3.3 EXPLORATION AND EXPLOITATION IN COEVOLUTIONARY SEARCH PROCESSES ..	20
3.4 SYNTHESIS.....	22
4. DISCUSSION	25
4.1 IMPLICATIONS FOR THE EXPLORATION–EXPLOITATION LITERATURE	25
4.2 MANAGERIAL IMPLICATIONS.....	28
5. LIMITATIONS AND FUTURE RESEARCH	30
5.1 LIMITATIONS OF SCOPE.....	30
5.2 EVOCATIVE AND OPERATIONAL DEFINITIONS OF EXPLORATION AND EXPLOITATION	31
5.3 ORGANIZATIONAL ENVIRONMENTS AND ADAPTATION	33
6. CONCLUSION	35
REFERENCES.....	36
APPENDIXES	43

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1. INTRODUCTION

1.1 Overview

The strategic adaptation of organizations to changing business environments is one of the major themes in management research. In their adaptive efforts to keep pace with environmental demands, organizations must balance the need to explore new opportunities in order to increase the potential for future returns, and the need to exploit current knowledge and the organization's current position in order to maximize short-term gains (March, 1991). This tension between exploration and exploitation is a key issue in the organizational adaptation literature (Gupta, Smith, & Shalley, 2006; Lavie, Stettner, & Tushman, 2010). However, despite the centrality of the exploration–exploitation dichotomy in the organizational adaptation literature, how exploration and exploitation should be balanced in different contexts is still largely an unanswered question (Gupta et al., 2006; Lavie et al., 2010).

One of the major conceptual and empirical gaps in the exploration–exploitation literature is the question of how environmental dynamics influence the balance of exploration and exploitation (Lavie et al., 2010). Although the literature suggests that the appropriate exploration–exploitation balance may depend on the environmental context (Lavie et al., 2010; Sidhu, Commandeur, & Volberda, 2007), a solid understanding of how different environmental contingencies influence exploration and exploitation is still lacking. In this dissertation, I address this gap by analyzing how the environmental context and different intra- and interorganizational dynamics affect exploration and exploitation and the balance between the two processes. I analyze a number of questions on the exploration–exploitation tradeoff in various contexts using both large-scale quantitative empirical research and formal simulation modeling, and I present the results of these analyses in the form of four separate essays.

In the first essay, reproduced in Appendix 1, I empirically test and find support for the existence of the exploration–exploitation tradeoff using a longitudinal sample of 279 S&P 500 corporations over the years 1989–2004. I further find that industry technological dynamism is a key determinant of the need to achieve an appropriate exploration–exploitation balance. In the second essay, presented in Appendix 2, I use a formal simulation study to examine how the characteristics of an organization’s task environment affect the relative balance between exploratory and exploitative adaptation. I find that environmental complexity and turbulence pose increasing challenges for both exploration and exploitation, and the consequent effects on the exploration–exploitation balance are nonlinear and partly inconsistent with the established literature. In the third essay, attached as Appendix 3, I analyze whether and in what contexts organizations should be expected to follow a punctuated equilibrium model of adaptation, in which long periods of exploitation are punctuated by brief periods of exploration, versus an ambidexterity model of adaptation, in which exploration and exploitation are pursued simultaneously. By simulating organizational adaptation processes in different task environments, I find that high levels of either turbulence or complexity bring about a punctuated equilibrium model of adaptation, whereas either low levels of both or high levels of both bring about ambidextrous adaptation modes. Finally, in the fourth essay, presented in Appendix 4, I examine a context in which organizations conducting adaptive search influence each other. Specifically, I simulate *de facto* technological standard setting as a process of coevolutionary technological search under interorganizational network effects. The exploration–exploitation balance is found to manifest itself in this context through the need to balance the countervailing forces of search diversity and the coordination of choices in the organizational population.

This dissertation contributes to the management literature by providing answers to several key questions in the literature on organizational search and adaptation and by raising new considerations in the exploration–exploitation balance. Essay 1 provides empirical corroboration of some of the previously untested key notions in the exploration–exploitation literature, and Essay 2 elaborates on the theory behind these notions, emphasizing the importance of both exploration and exploitation as key components of organizational adaptability in responding to potentially complex and turbulent environments. Essay 3 provides insight into the question of how exploration and exploitation can be balanced over time, and Essay 4 illuminates how interorganizational

interactions influence organizational search and adaptation processes and contributes to the literature on de facto standard setting by showing how the introduction of organizational search into the theorizing introduces an exploration–exploitation dilemma into technological standard setting processes, in the form of a need to balance diversity and coordination. Taken together, the four essays highlight the role of environmental factors in driving the need to explore, to exploit, and to balance the two processes.

This summary of the dissertation is structured as follows. In the remainder of this section, I provide the theoretical background for the dissertation, present the research questions that the four individual studies collectively aim to address, and determine the scope and delimitations of the research. In Section 2, I discuss the data and methods that I use to address the research questions. In Section 3, I present and synthesize the results and contributions of the studies, and in Section 4, I discuss the implications of the findings for theory and practice. In Section 5, I discuss the limitations of the dissertation and highlight some key issues for future research. Section 6 concludes.

1.2 Theoretical background

It is widely argued in the organizational adaptation literature that both exploration and exploitation are essential for the long-term performance of the organization (Benner & Tushman, 2002, 2003; Gupta et al., 2006; Levinthal & March, 1993; March, 1991; March, 2006; McGrath, 2001; Tushman & O'Reilly, 1996). Organizations must explore to find new opportunities, renew their knowledge bases, and prevent their existing competencies from becoming obsolete, and exploit the opportunities that they have found, building on and refining their current knowledge and capabilities. However, exploration and exploitation are also argued to pose conflicting organizational demands and to compete for scarce organizational resources (Gupta et al., 2006; Lavie et al., 2010; Levinthal & March, 1993; March, 1991; Raisch, Birkinshaw, Probst, & Tushman, 2009). The resulting tradeoff between exploration and exploitation on one hand, and on the other hand the necessity to engage in both, presents the organizational adaptation literature with one of its central dilemmas.

Despite the large amount of interest in the topic, the exploration–exploitation literature is still quite disjointed, and the empirical evidence and theoretical understanding of some of its central tenets are unclear or contested (Gupta et al., 2006; Lavie et al., 2010; Raisch & Birkinshaw,

2008). There is disagreement regarding the meaning and empirical factuality of the exploration–exploitation balance, as well as a lack of clarity on the contextual factors affecting the balance and the means to achieve that balance. Specifically, a major gap in the existing exploration–exploitation literature is in understanding the strategic role of balancing exploration and exploitation in different environmental contexts.

An organization’s environment could be expected to be a key factor in the exploration–exploitation balance, as an organization’s relationship to its environment is the fundamental issue of interest in the literature on organizational adaptation. Although it is possible to differentiate between external fit and internal fit in some contexts (Miller, 1992; Venkatraman & Camillus, 1984), and although organizations are not only influenced by, but can also influence their environment (Child, 1972; Pfeffer & Salancik, 1978), the central assumption in the organizational adaptation literature is that, ultimately, an organization’s “fitness” or performance is determined by how well aligned it is with the demands of its environment. Despite the centrality of the environment to organizational adaptation and, consequently, to the processes of exploration and exploitation, the existing literature has largely neglected the influence of environmental factors on the exploration–exploitation balance (Lavie et al., 2010).

Much of the existing exploration–exploitation literature is concerned with either intraorganizational factors, such as structures (Benner & Tushman, 2003; Fang, Lee, & Schilling, 2010; Rivkin & Siggelkow, 2003) and mindsets (Crossan, Lane, & White, 1999; Gibson & Birkinshaw, 2004), or interorganizational arrangements, such as alliances (Koza & Lewin, 1998; Lavie & Rosenkopf, 2006; Rothaermel & Deeds, 2004) and corporate venturing investments (Hill & Birkinshaw, 2008; Schildt, Maula, & Keil, 2005), that allow the organization to engage in exploration and exploitation. Whether and how much the organization actually needs to engage in these activities in different environmental contexts and how the environmental context influences the consequent tension between exploration and exploitation is relatively less well understood. In this dissertation, I address this gap by explicitly focusing on the organization–environment linkage and by examining environmental moderators to the exploration–exploitation balance as well as interorganizational interactions as they pertain to exploration and exploitation. In the four essays that comprise this dissertation, I tackle these issues through both empirical and theoretical examination of the

exploration–exploitation balance and the related environmental, organizational, and interorganizational dynamics.

1.3 Research questions

The focus of this dissertation is on examining the strategic role of the exploration–exploitation balance in different environmental contexts. Specifically, I investigate how environmental and organizational dynamics influence the tension between exploration and exploitation in organizational adaptation and the need to balance the two processes. This goal can be formulated as the following research question.

Research Question:

How do environmental dynamics influence the exploration–exploitation balance in organizational adaptation?

This overarching research question is examined from a number of different perspectives that all provide unique insight into answering the question. In the spirit of Poole and Van de Ven's (1989) discussion on addressing paradoxes in organization theory, I conduct the analysis of the tension between exploration and exploitation along three dimensions: 1) the contextual dimension, 2) the temporal dimension, and 3) the level-of-analysis dimension. Reflecting these three dimensions, the overarching research question is divided into three subquestions.

First, understanding the effect that the environmental context has on the exploration–exploitation balance is central to investigating the dynamics of balancing exploration and exploitation in different environments (Lavie et al., 2010; Raisch & Birkinshaw, 2008). The contextual dimension is also an important factor in the analyses along the other two dimensions, and it is therefore addressed first. The first subquestion is thus formulated as follows.

Subquestion 1:

How is the proper balance between exploration and exploitation influenced by the environmental context?

This question is empirically addressed in Essay 1 and theoretically examined in Essays 2 and 3. The aim of Essay 1 is to empirically validate the significance of balancing exploration and exploitation efforts at the

organization level and to examine how industry context affects this balance. Empirically addressing these questions requires the development of a novel approach to measuring firm-level exploration–exploitation balance. In Essay 2, I further examine the first subquestion using formal simulation modeling of organizational adaptation, focusing explicitly on whether and how exploratory and exploitative adaptation must be balanced in various simulated environments. In Essay 3, I use the simulation model to examine how exploration and exploitation processes unfold in organizations, gaining further insight into the first subquestion.

A major unresolved question in the exploration–exploitation literature is the need to understand the dynamics of balancing exploration and exploitation over time (Gupta et al., 2006; Lavie et al., 2010; Raisch & Birkinshaw, 2008; Raisch et al., 2009). The second subquestion addresses this issue by extending the analysis of the exploration–exploitation balance along the temporal dimension. Two primary models of temporally balancing exploration and exploitation have been discussed in the literature: the punctuated equilibrium model, in which long periods of exploitative adaptation are punctuated by brief periods of exploratory adaptation (Gersick, 1991; Lant & Mezas, 1992; Miller & Friesen, 1980; Sabherwal, Hirschheim, & Goles, 2001; Tushman & O'Reilly, 1996; Tushman & Romanelli, 1985), and the ambidexterity model, in which both exploratory and exploitative adaptation are conducted continuously and simultaneously (Benner & Tushman, 2003; Cao, Gedajlovic, & Zhang, 2009; Gibson & Birkinshaw, 2004; He & Wong, 2004; Lubatkin, Simsek, Ling, & Veiga, 2006). However, the circumstances under which organizations should follow these models in their adaptation efforts are still unclear (Gupta et al., 2006). This is the focus of the second subquestion.

Subquestion 2:

How should exploration and exploitation be balanced over time?

The second subquestion is addressed in Essay 3. Specifically, it is argued that in determining the appropriate mode of balancing exploration and exploitation over time, the environmental context may be a significant influencing factor. Using formal simulation to model organizational adaptation, I look at how the processes of exploration and exploitation unfold over time in different environmental contexts.

After examining the exploration–exploitation balance at the organization level, in the third subquestion, I shift the analysis to a different

level and address the issue of how exploration and exploitation are balanced in an interorganizational context (Lavie et al., 2010). A key consideration in analyzing exploration and exploitation at this level of analysis is that an organization's adaptation environment consists partly of other organizations; therefore, the organization itself is part of the environments of these other organizations. Organizations are therefore not only influenced by their environment, but in their adaptive efforts, they may also influence the environment themselves (Child, 1972; Pfeffer & Salancik, 1978). How such coevolutionary interactions among organizations influence search and adaptation processes at the population level is the focus of the third subquestion.

Subquestion 3:

How do interactions among organizations influence exploration and exploitation at the population level?

To address the third subquestion, we examine the processes of de facto technological standard setting in Essay 4. Technological standard setting provides a context in which a number of organizations conduct independent adaptive search efforts while simultaneously being potentially influenced by the choices of other organizations. We examine the population-level exploration and exploitation processes in such a setting by simulating de facto standard setting as a process of coevolutionary technological search under network effects.

1.4 Scope and delimitations

Consistent with recent literature (Baum, Li, & Usher, 2000; Benner & Tushman, 2002, 2003; Gupta et al., 2006; He & Wong, 2004; Katila & Ahuja, 2002; Lavie et al., 2010; Wang & Li, 2008), I analyze the tension between exploration and exploitation in the context of organizational search. Although some scholars have conceptualized the exploration versus exploitation dilemma as a trade-off between search and implementation (e.g., Posen & Levinthal, 2011; Vermeulen & Barkema, 2001), in this dissertation I follow the suggestion of Gupta et al. (2006) and Lavie et al. (2010) and define both exploration and exploitation in the context of learning, innovation, and adaptation. Thus, processes of incremental adaptation that build on and refine the organization's existing knowledge and capabilities are considered exploitation, whereas processes of

experimental adaptation that aim for knowledge or changes that deviate significantly from the organization's current state are considered exploration. Therefore, in this dissertation, exploitation and exploration are used synonymously with local and distant search (Levinthal, 1997), respectively.

Although the results of this dissertation may be relevant to various types of organizations, my focus is on exploration and exploitation processes in large, established firms. The empirical part of the research is conducted on a sample of large corporations, and the theoretical models assume that the organizations have many interacting choice components in their organizational systems. The study is limited to established organizations because, first, a sufficient supply of public data on both exploratory and exploitative activities is available for such organizations to facilitate a large-scale empirical study and, second, the problem of balancing exploration and exploitation activities over the long term may be a more significant issue for large firms than for firms that are smaller and more focused in their activities (Gupta et al., 2006).

In the management literature, there are a variety of concepts that are conceptually somewhat similar to the exploration–exploitation tradeoff in organizational adaptation (Raisch & Birkinshaw, 2008). For example, the concept of double-loop versus single-loop learning in the learning literature (Argyris & Schön, 1978), the concept of radical versus incremental innovation in the technology development literature (Abernathy & Clark, 1985), and the concept of slack versus problemistic search (Cyert & March, 1963; Greve, 2007), all have parallels with the concept of exploration versus exploitation in organizational adaptation. Because the focus of this dissertation is on the processes of exploratory and exploitative adaptation as they occur in organizational systems, I will limit my treatment of the exploration–exploitation tradeoff to questions of organizational adaptation. I will therefore not elaborate on these related literatures except when they are relevant to the question of organizational adaptation in relation to its environment.

Organizational environments can vary along many dimensions, of which I focus on a few that previous literature suggests to be potentially important for the exploration–exploitation tradeoff. In the empirical section of this dissertation, presented in Appendix 1, I use the concept of industry technological dynamism, operationalized as industry R&D intensity (Audretsch & Feldman, 1996; Baysinger & Hoskisson, 1989; Ito & Pucik, 1993), to distinguish organizational environments based on the

demands that they impose on exploration and exploitation. Technological dynamism is relatively easy to operationalize and widely used in empirical research, and, furthermore, it can be expected to influence an organization's exploration and exploitation needs because technological change is a key driver in organizations' need to adapt (Sørensen & Stuart, 2000; Tushman & Anderson, 1986).

However, the concept of technological dynamism does not allow for a straightforward formalization in a simulation model. Consequently, in the theoretical elaboration of organization-level adaptation processes that is presented in Appendix 2 and Appendix 3, I operationalize environmental variation in terms of turbulence and complexity, two environmental characteristics that are not only widely used in the literature (Anderson & Tushman, 2001; Damanpour, 1996; Dess & Beard, 1984; Duncan, 1972) but that are formally tractable in that they can be relatively unambiguously incorporated into a simulation model of organizational adaptation (e.g., Siggelkow & Rivkin, 2005). Although some scholars use dynamism synonymously with turbulence and consider complexity a separate environmental construct (e.g., Dess & Beard, 1984; Duncan, 1972), environmental dynamism in the technological context can be considered to encompass not only turbulence but also complexity because technology-intensive industries not only change more quickly but are typically more complex than their technologically more stable counterparts (Fleming & Sorenson, 2001). Consequently, in this dissertation, I consider environmental turbulence and environmental complexity as two orthogonal components of environmental dynamism. Although the relationship between the three concepts is debatable, I use it here to integrate the analyses in this dissertation while being consistent with the terminology used by both the empirical ambidexterity literature and the formal organizational adaptation literature. The relationship between these environmental factors is further discussed in the limitations and future research section.

In the application of the exploration–exploitation framework to technological standard setting presented in Appendix 4, the environment is conceptualized as partly consisting of other organizations. Consequently, a further environmental factor in such a context is the intensity of the interorganizational interactions, and in addition to technological complexity (Fleming & Sorenson, 2001), I also examine the network effects (e.g., Katz & Shapiro, 1985) created by the choices of other organizations as

a further environmental characteristic that may influence exploration and exploitation processes.

Although all four essays in this dissertation are concerned with the general problem of balancing exploration and exploitation in different contexts, each essay addresses the question from a unique point of view. The focus of the first essay is on empirically corroborating the exploration–exploitation tradeoff at the organizational level and examining the environmental moderators of this balance, with a very general view on the exploration–exploitation balance in organizations. The second essay elaborates on this, taking a detailed theoretical look at exploratory and exploitative adaptation, on one hand, and environmental complexity and turbulence, on the other, and using simulation modeling to examine how these constructs interact and influence the exploration–exploitation balance. In the third essay, I take a process view of balancing exploration and exploitation and look at how the task environment influences the balancing of the two types of adaptation over time. Finally, in the fourth essay, I shift the analysis to the level of the organizational population and examine how interactions among searching organizations influence search and adaptation processes by simulating technological standard setting as a coevolutionary process of exploration and exploitation among a number of interacting organizations.

2. DATA AND METHODS

To address the research question, this dissertation combines large-scale quantitative empirical analysis, to test the existing exploration–exploitation theory, and formal simulation modeling, to extend the theory. The empirical section of the research is presented in Essay 1, and the theoretical elaborations are presented in Essays 2, 3, and 4.

2.1 Quantitative empirical analysis

The empirical analysis is conducted on a sample of 279 manufacturing firms. The sample includes all firms in the S&P 500 index in the year 1989 with SIC codes 2000–3999 and 7370–7379. These firms are analyzed over the years 1989–2004, yielding a panel data set of 2754 firm-year observations.

The goal of the empirical study is to test the key notion in the literature that there is a tradeoff between exploration and exploitation and that the two must be properly balanced for optimal performance (Benner & Tushman, 2002, 2003; Ghemawat & Ricart i Costa, 1993; Gupta et al., 2006; March, 1991; McGrath, 2001). Further, the study examines how such a balance depends on environmental conditions. Specifically, it is hypothesized that sufficient exploration is more important in technologically dynamic industries because of the abundance of technological opportunities (Baysinger & Hoskisson, 1989; Zahra, 1996) and the increased risk of technological obsolescence (Sørensen & Stuart, 2000). For these purposes, data are required on the firm’s exploration versus exploitation strategies; financial performance, operationalized as Tobin’s Q (Bebchuk & Cohen, 2005; Brown & Caylor, 2006; Gompers, Ishii, & Metrick, 2003; Kaplan & Zingales, 1997); and industry technological dynamism, operationalized as industry R&D intensity (Audretsch & Feldman, 1996; Baysinger & Hoskisson, 1989; Ito & Pucik, 1993). As control

variables, we use the firm's size in number of employees, R&D intensity, and a dummy variable denoting missing values for firm-level R&D data.

The financial and R&D data are collected from the *Compustat* database. However, there is no established, generally accepted measurement for the firms' adaptation strategy in terms of the exploration–exploitation balance. Existing operationalizations of exploration and exploitation are typically limited to a specific context (e.g., Bierly & Chakrabarti, 1996; Katila & Ahuja, 2002; Rosenkopf & Nerkar, 2001). We therefore set out to develop a novel empirical approach that can be used to directly measure the exploration–exploitation balance at the organization level over a number of years and in a variety of contexts by using automated content analysis of published news documents.

For the automated content analysis, news articles and newswires describing each of the firms in the sample are collected from the Factiva database Reuters News archive. All news documents with the name of a sample company in the headline are collected for 1989–2004, yielding a total of 258,513 news documents and 428 megabytes of textual data. For each company-year, a measure of relative exploration orientation is generated by a computer program that analyzes the news documents and calculates the relative exploration orientation variable as the number of exploration words divided by the sum of exploration and exploitation words.

The word lists for identifying exploration and exploitation activities are taken from March's (1991: 71) definitions of exploration as “search, variability, risk taking, experimentation, play, flexibility, discovery, innovation” and exploitation as “refinement, choice, production, efficiency, selection, implementation, execution.” These word lists are validated with a separate sample of 14 companies and a total of 328 business news documents by comparing, for each company, the relative exploration orientation measure obtained by the automated procedure with an exploration–exploitation measure obtained by a manual classification of the news documents. The manual classification procedure is based on the subjective judgment of two trained human coders, similar to the procedure used by Volberda, van den Bosch, Flier, & Gedajlovic (2001). Comparing the automated and manual exploration–exploitation measures yields a correlation of 0.52 ($p = 0.06$) between the two operationalizations. Based on a key-word-in-context analysis (Krippendorff, 1980: 122), the word list used to measure the exploration–exploitation balance is further refined to

exclude a number of common irrelevant word occurrences, such as “Internet Explorer.”

In this longitudinal setting with variables that are highly persistent over time, classical regression methods such as ordinary least squares (OLS) or generalized least squares (GLS) are found to be inappropriate because the assumption of the independence of the residuals is violated due to temporal autocorrelation. To test the hypotheses, a System GMM estimator (Arellano & Bover, 1995; Blundell & Bond, 1998) is employed. A System GMM estimator can be used to alleviate the problems stemming from autocorrelation, and it allows endogeneity and unobserved heterogeneity to be controlled for in the panel data set.

2.2 Formal simulation modeling

In Essays 2, 3, and 4, I use formal simulation modeling to elaborate on the existing exploration–exploitation theory by formalizing some of the key assumptions of the theory and by looking at their implications under various conditions. In all of the simulation studies, I use an application of the NK landscapes framework (Kauffman, 1993; Levinthal, 1997), a model of complex adaptive systems that is widely used in organization studies (e.g., Gavetti & Levinthal, 2000; Knudsen & Levinthal, 2007; Levinthal & Posen, 2007; Rivkin, 2000; Rivkin & Siggelkow, 2003; Siggelkow & Levinthal, 2003; Siggelkow & Rivkin, 2005). The NK framework has proven useful in studying organizational adaptation because the characteristics of the NK model facilitate modeling boundedly rational search behavior and the distinction between exploitative, local search and exploratory, distant search.

In the NK framework, the organization is modeled as an N -dimensional vector of binary decision elements. For example, “01001” for $N = 5$ refers to an organization that has made the choice of “0” on the first, third, and fourth decision elements, and the choice of “1” on the second and fifth decision elements. The performance or fitness of each decision element is determined not only by the organization’s choice on the element itself but also by its choice on K other, interacting decision elements. The performance of a decision element is drawn from the uniform distribution $U[0, 1]$ for each combination of binary choices of the decision element itself and its K interconnecting elements. The performance of the entire organization is the average of the performances of the N individual decision elements that comprise the organization. Thus, this framework creates an

adaptation landscape with 2^N unique landscape positions (i.e., vectors of decision elements) that the organization can assume.

As noted above, the parameter K controls the density of interdependencies in the decision landscape. With a high K , this approach generates a rugged decision landscape in which there are several local peaks. Local peaks are landscape positions in which the organization cannot improve its performance by changing any single decision element, but that may not be globally optimal choice configurations. In contrast, when $K = 0$, all decision elements are independent and there is only one peak, at which each decision element is set at its optimal value.

Organizations adapt in this decision landscape by seeking for choice configurations that improve their present fitness. This often occurs through hill-climbing local search, which is a form of incremental, exploitative adaptation (Levinthal, 1997). In local search, the organization experiments by changing one decision element from 0 to 1 or vice versa and adopting the new position in the decision landscape if it offers improved fitness. In a stable landscape, local search eventually leads the organization to a local peak.

Escaping the local peak in search of better fitness requires distant search and long-jump adaptation, i.e., a radical, exploratory transformation of the entire organizational system (Levinthal, 1997). This need for distant search is exemplified in Figure 1. Figure 1 depicts a rugged landscape with $N = 3$ choice dimensions. Each vertex represents a position in the landscape, with the first number denoting the vector of choice elements and the second number denoting the overall fitness of the landscape position. As shown in Figure 1, an organization located at the local peak in landscape position “100” has no potential to improve its fitness by changing any of the three elements, as a change in any single element would lower its performance. There is a higher fitness peak at landscape position “001,” but this is attainable from the local peak at position “100” only by changing both elements 1 and 3 simultaneously. Thus, an organization located at position “100” would only be able to improve its fitness through an exploration of distant positions in the landscape, not through local, exploitative search.

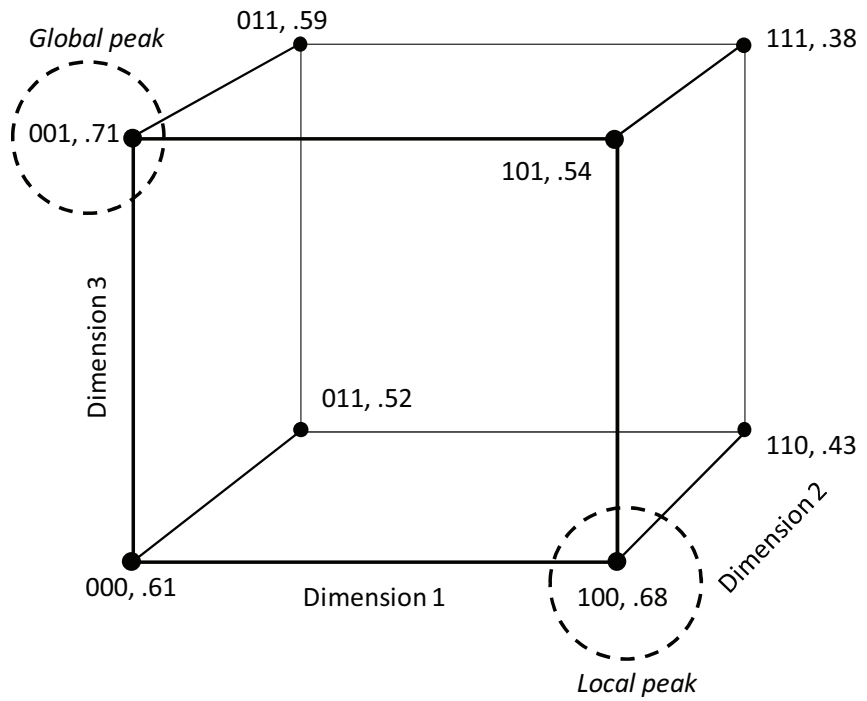


Figure 1. Local and global peaks in an NK landscape

This tension between the short-term efficiency of local optimization through exploitative search, on one hand, and the potential need to find distant but uncertain landscape positions through exploratory search, on the other, makes the NK framework an ideal model for investigating the exploration–exploitation balance. By changing the level of complexity, K (i.e., the number of interactions between choice elements), and the level of turbulence (i.e., the rate of change of the performance potential of landscape positions), the NK framework can be used to examine exploration and exploitation processes in a variety of environmental contexts. The NK model can be used to simulate organizational adaptation and to examine how the organization’s search strategy or other factors influence different aspects of the adaptive process. One can look at, for example, the average performance of the organization over time, as in Essay 2; how the adaptation process unfolds over time, as in Essay 3; or the solution found at the end of the search process, as in Essay 4.

3. RESULTS AND CONTRIBUTIONS

3.1 Environmental context and the exploration–exploitation balance

The first subquestion regarding the influence of the environmental context on the proper balance between exploration and exploitation is addressed empirically in Essay 1. The empirical study, presented in Appendix 1, sets out to test the existence of an exploration–exploitation tradeoff at the organization level and the consequent need to balance exploration and exploitation for optimum performance (Benner & Tushman, 2002, 2003; Ghemawat & Ricart i Costa, 1993; Gupta et al., 2006; March, 1991), as well as to examine the environmental factors affecting this balance, specifically, the role of industry technological dynamism (Audretsch & Feldman, 1996; Baysinger & Hoskisson, 1989; Ito & Pucik, 1993; Zahra, 1996).

The empirical analysis in Essay 1 supports the hypothesis that the relative exploration versus exploitation orientation at the firm level exhibits an inverted U-shaped relationship to the firm's financial performance. This finding suggests that firms typically need to engage in both exploration and exploitation and that concentrating excessively on either exploration or exploitation has an adverse effect on performance. Thus, the empirical findings support the importance of balancing the two types of adaptation. Furthermore, the majority of firms are found to underinvest in exploration, with approximately 80 percent of companies having relative exploration below the optimum value, providing support for the notion that in large firms, exploitation tends to drive out exploration (Benner & Tushman, 2002, 2003; Lewin, Long, & Carroll, 1999).

However, the inverted U-shaped relationship is moderated by industry technological dynamism in such a way that the relationship is significantly more pronounced in technologically highly dynamic industries. In contrast, in industries with low technological dynamism, the balance between exploration and exploitation at the firm level has little

influence on firm performance. The empirical analysis thus suggests that environmental dynamism is a key determinant of the need to balance exploration and exploitation.

The findings of the formal exploration–exploitation simulations in Essays 2 and 3, presented in Appendixes 2 and 3, respectively, are consistent with these empirical findings. First, in the simulations presented in Essay 2, the relative amount of exploratory versus exploitative adaptation generally exhibits an inverted U-shaped relationship to the long-term fitness of the organization, and the examination of the exploration and exploitation processes in Essay 3 also suggests that successful firms typically need to engage in both types of adaptation. Second, however, the simulations also suggest that the need for exploratory and exploitative adaptation is brought about by the turbulence and complexity of the task environment; in sufficiently stable and simple environments, the problem of balancing exploration and exploitation may even disappear.

The relationship between environmental factors and the optimal exploration–exploitation balance is investigated in more detail in Essay 2. Although the simulations show a general inverted U-shaped relationship between relative exploratory versus exploitative adaptation and the long-term performance of the organization, the position of the optimal relative share of exploration versus exploitation on the inverted U curve is found to significantly depend on the turbulence and complexity of the task environment. The results of the simulations regarding the optimal exploration–exploitation balance in different task environments diverge from the existing research, suggesting that turbulence and complexity increase the importance of both exploratory and exploitative adaptation in nonlinear and interdependent ways.

The first-order effect of turbulence on the optimal relative share of exploration versus exploitation is found to be generally U-shaped, with exploitative adaptation being relatively more important than exploratory adaptation at moderate degrees of turbulence, thus somewhat contradicting the existing literature that generally argues for a positive turbulence–exploration relationship (Fang et al., 2010; Lavie et al., 2010; March, 1991; Sidhu, Volberda, & Commandeur, 2004). The first-order effect of complexity on the optimal share of exploration is found to be generally positive, consistent with the established literature (Levinthal, 1997; Rivkin & Siggelkow, 2007). However, the interaction between turbulence and complexity has a negative effect on the optimal share of exploration by

increasing the importance of exploitative adaptation more than it increases the need for exploratory adaptation.

Taken together, both the empirical and theoretical results of this dissertation suggest that there is typically a need to balance exploration and exploitation. However, the results further suggest that this need is due to the dynamism of the organization's adaptation environment; in stable and simple environments, the significance of the exploration–exploitation balance may be low or even nonexistent. This result suggests that there may be boundary conditions to the applicability of the exploration–exploitation theory.

These results contribute to the organizational adaptation literature both by providing a robust empirical test of the general significance of the exploration–exploitation balance using a large-scale longitudinal panel data set and sophisticated statistical estimation methods and by providing a theoretical corroboration of the general need for an exploration–exploitation balance using a widely accepted simulation model of organizational adaptation. Thus, the results provide support for one of the key concepts in the organizational adaptation literature: the need to balance exploration and exploitation in organizational adaptation. Further, the results also contribute to the understanding of environmental contingencies in the exploration–exploitation tradeoff by showing that the dynamic adaptive pressures provided by a changing and complex environment are a major contributing factor to this need to balance exploration and exploitation. The study also provides an explicit theoretical investigation of the relative merits of exploratory and exploitative adaptation in response to environmental turbulence and complexity and shows that, contrary to established wisdom, increasing exploration at the expense of exploitation may not always be the optimal response to increased turbulence or complexity. The results thus highlight both exploration and exploitation as essential components of organizational adaptability. The empirical study on the exploration–exploitation balance further provides a methodological contribution by illustrating the feasibility of automated content analysis as a method of measuring organizational constructs that are otherwise difficult to quantify, such as exploration and exploitation.

3.2 Balancing exploration and exploitation over time

The second subquestion on how exploration and exploitation should be balanced over time is addressed in the third study, included as Appendix

3. I investigate this question with a specific focus on whether and in what contexts organizations follow the pattern predicted by the punctuated equilibrium model, in which long periods of exploitative adaptation are interspersed with short bursts of exploratory adaptation (Gersick, 1991; Lant & Mezias, 1992; Miller & Friesen, 1980; Sabherwal et al., 2001; Tushman & O'Reilly, 1996; Tushman & Romanelli, 1985), versus the ambidexterity model, in which both exploration and exploitation are conducted continuously and simultaneously (Benner & Tushman, 2003; Cao et al., 2009; Gibson & Birkinshaw, 2004; He & Wong, 2004; Lubatkin et al., 2006). I use a similar simulation model as that used in Essay 2, in this case analyzing how environmental turbulence and complexity affect the temporal patterns of exploration and exploitation.

The results suggest that there are two distinct factors that may bring about the punctuated equilibrium pattern: the need to occasionally use exploratory adaptation to keep pace with rapidly accumulating environmental demands brought about by high levels of turbulence and the need to periodically escape suboptimal local peaks created by structural constraints due to environmental complexity. When the environment is simple and stable enough, the long-term adaptation pattern of successful organizations represents a stable form of ambidexterity in which incremental improvements accumulate to produce radical change when necessary, and when the combined influence of turbulence and complexity is high enough, organizations need a dynamic form of ambidexterity in which exploration and exploitation efforts are constantly intertwined. These results are summarized in Figure 2 (Appendix 3, page 40).

		Turbulence	
		Low	High
Complexity	Low	<p>Stable Ambidexterity</p> <p>Organizations are able to keep pace with the environment through continuous incremental adaptation. Large-scale transformation occurs as a slow accumulation of incremental adaptive steps over time.</p>	<p>Catch-Up Punctuated Equilibrium</p> <p>The rate of environmental change is too fast for incremental adaptation alone to be sufficient in the long term. Occasional radical transformation is needed to catch up with rapidly accumulating environmental demands.</p>
	High	<p>Structural Punctuated Equilibrium</p> <p>Organizations get stuck on locally optimal choice configurations due to task interdependencies. Occasional radical transformation is needed to escape these local peaks when the accumulation of environmental change makes these peaks suboptimal.</p>	<p>Dynamic Ambidexterity</p> <p>Interdependencies limit the potential for incremental adaptation, and local peaks are quickly destroyed by environmental turbulence. Organizations constantly engage in both incremental and radical changes in search for temporary local peaks.</p>

Figure 2. Balancing exploration and exploitation in different task environments.

These results contribute to the organizational adaptation literature by providing insight into the question of whether organizations evolve according to the punctuated equilibrium or the ambidexterity model (Gupta et al., 2006) and by showing that the answer can depend on the characteristics of the task environment. The results can be helpful in illuminating the boundary conditions of the punctuated equilibrium and the ambidexterity models of balancing exploration and exploitation and, consequently, in resolving conflicting empirical findings on the long-term adaptive patterns of successful organizations (e.g., Brown & Eisenhardt, 1997; Romanelli & Tushman, 1994; Wischnevsky & Damanpour, 2005).

3.3 Exploration and exploitation in coevolutionary search processes

The third subquestion is concerned with how interactions among organizations influence the exploration–exploitation dynamics at the level of the organizational population. This issue is examined in the context of technological standard setting. The fourth essay, presented in Appendix 4, uses the NK simulation framework to analyze the coevolutionary technological search of a population of interacting technology supplier organizations striving to establish a de facto technological standard. We argue that, in such a setting, the organizations frequently influence each other's technological choices at the technology development stage (e.g.,

Arthur, 1989; Christ & Slowak, 2009; Cusumano, Mylonadis, & Rosenbloom, 1992; Wade, 1995). We examine the influence of such network effects between suppliers as well as the influence of the complexity of the technology landscape (Fleming & Sorenson, 2001) on the socially optimal organization of technological search in terms of the quality of the technological solution established as the de facto standard.

We find that network effects make the coordination of choices through search concentration more advantageous because coordination allows for exploiting the best solutions that have been found and avoiding lock-in to an inferior solution. In contrast, technological complexity is found to increase the importance of diversity and, consequently, the distribution of search to avoid technological myopia and allow for the exploration of new, potentially superior solutions. When both network effects and complexity are present, these two considerations provide a need to balance the countervailing forces of coordination and diversity. Thus, in environments characterized by both network effects and technological complexity, we find an inverted U-shaped relationship between the concentration of technological search and the quality of technological solutions found by the search process.

Our findings suggest that in de facto standard setting processes, organizations conducting technological search in a complex technological landscape while being influenced by network effects are faced with a population-level tradeoff between exploiting high-quality solutions through search coordination and exploring potentially better solutions through search diversity. Faced with network effects, organizations can facilitate more efficient exploitation at the micro level by coordinating their search activities, whereas exploration occurs at the macro level when diversity among the organizations facilitates the exploration of new technological solutions.

We further find that organizations that are highly influential in terms of the network effects they provide for the technological standard candidate that they support may have nonlinear effects on the social efficiency of the population-level search process. Although such leader organizations improve the coordination of choices in the search for high-quality solutions under network effects, they may also have the countervailing effect of accelerating the process of lock-in to a potentially inferior solution due to their high level of influence on network effects. Furthermore, the effect of accelerating lock-in begins when the leader is only moderately more influential than other organizations, whereas

sufficient coordination to escape such an emerging lock-in requires the leader's relative influence to be much greater. This suggests a U-shaped relationship between the leader's relative influence and the social efficiency of the population-level search process.

These results contribute to the exploration–exploitation literature by showing that the exploration–exploitation tradeoff can be relevant not only at the level of a single organization but also at the level of the organizational population. Furthermore, by bringing the framework of boundedly rational organizational search into the analysis of de facto standard setting, a domain that is traditionally examined through rational economic analysis, this analysis contributes to the network effects and de facto standard setting literature (e.g., Farrell & Saloner, 1985, 1986, 1988; Funk & Methe, 2001; Hossain & Morgan, 2009; Lee & Mendelson, 2007; Ratchford et al., 2009; Tellis, Yin, & Niraj, 2009). The results show that suboptimal lock-in may occur even when no observable superior technologies are present and highlight the need to balance the benefits of coordination (Farrell & Saloner, 1988; Katz & Shapiro, 1994) with the benefits of search diversity and the risk that coordination may accelerate, rather than control, the lock-in process.

3.4 Synthesis

The results of the analyses related to the three subquestions all contribute to answering the overarching research question: “How do environmental dynamics influence the exploration–exploitation balance in organizational adaptation?” Environmental dynamics not only influence the exploration–exploitation balance, but they are fundamental in creating the tension between exploration and exploitation in the first place.

Taken together, the results of this dissertation highlight the role of environmental contingencies as the drivers of the need to exploit, to explore, and to balance the two processes. Some contextual factors, such as network effects, primarily impose pressure for more efficient exploitation, whereas other factors, such as environmental complexity, primarily increase the need for more wide-ranging exploration. Some factors, such as environmental turbulence, influence both the need to exploit and the need to explore, although potentially nonlinearly and at different rates.

This centrality of environmental factors in driving the need to explore and exploit suggests that, while common, the tension between exploration and exploitation is not ubiquitous. Specifically, the results of

this dissertation suggest that the exploration–exploitation tension arises when the environment imposes sufficiently high pressures for both exploration and exploitation. When either or both of these pressures are missing, the tension disappears. This can be seen in the empirical finding in Essay 1 that relative exploration orientation has little influence on financial performance when industry technological dynamism is low; in the finding in Essay 3 that in stable and simple industries, balancing exploration and exploitation should not pose particular problems for organizations; and in the finding in Essay 4 that under weak network effects and low technological complexity, any type of search process tends to lead to the optimal solution. Further, the results of Essays 2 and 4 suggest that when the environmental pressures for either exploration or exploitation dominate, the optimal adaptive strategy may be a purely exploratory or a purely exploitative one, and in such cases, balancing the two is unnecessary.

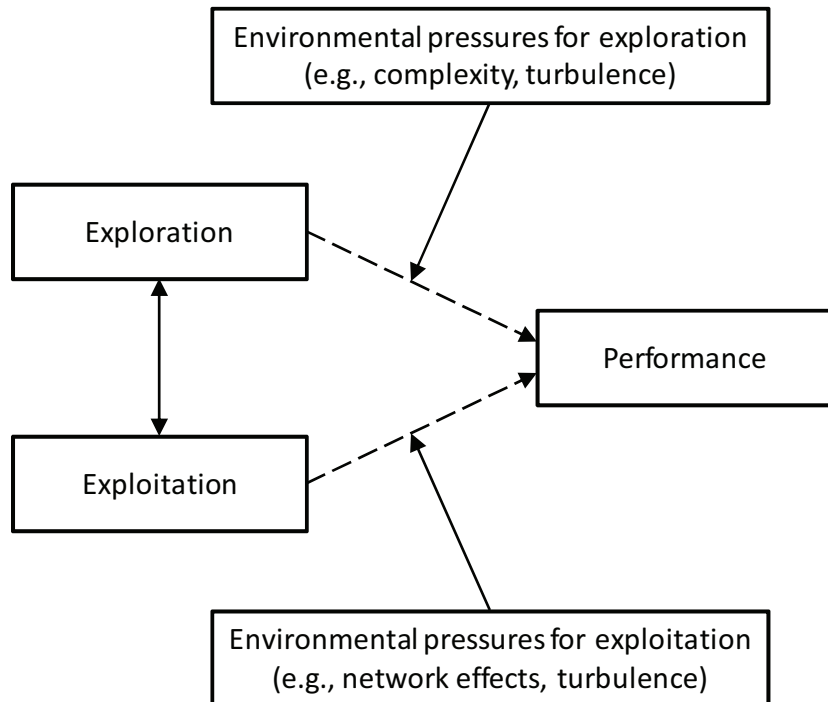


Figure 3. Tension between exploration and exploitation.

The results of this dissertation can be synthesized into a general model of the emergence of the tension between exploration and exploitation, as depicted in Figure 3. A few details of the model are worth

highlighting. First, as Figure 3 suggests, the direct first-order effects of exploration and exploitation on the organization's performance are insignificant; only in the presence of relevant environmental pressures does either type of adaptive activity become necessary. Second, some environmental factors may increase the pressures for both exploration and exploitation, and the influence of some factors may be nonlinear or contingent on other factors. For example, the results of Essay 2 suggest that low levels of turbulence mainly increase the pressures for exploitation, whereas high levels of turbulence also increase the pressures for exploration, and further, the influence of turbulence on exploitation pressures is positively moderated by environmental complexity. Third, the model emphasizes that environmental contingencies do not directly influence the exploration–exploitation balance; rather, different contextual factors may have a different influence on the need for exploration, the need for exploitation, or both, and the consequent effect of such factors on the exploration–exploitation balance emerges as the aggregation of the effects on the two adaptation types. Fourth, the model suggests that the tension between exploration and exploitation that occurs because these two forms of adaptation compete for scarce organizational resources only becomes a significant factor in determining organizational performance when both exploration and exploitation are required (i.e., when the environment poses pressures for both exploration and exploitation). Only in such environmental contexts does the tension between exploration and exploitation arise.

4. DISCUSSION

4.1 Implications for the exploration–exploitation literature

The four essays presented in this dissertation illuminate how the need to balance exploration and exploitation is manifested in a variety of organizational and environmental contexts. The three studies reported in Essays 1, 2, and 4 examine the performance implications of exploration and exploitation processes and produce consistent findings: in a variety of contexts, there seems to be an inverted U-shaped relationship between relative exploration versus exploitation and the long-term performance of organizations or organizational populations, providing support for the widely argued notion that the two types of adaptive processes must be balanced for optimum performance (Gupta et al., 2006; Lavie et al., 2010; March, 1991). Furthermore, the general organizational level of the empirical analysis presented in Essay 1, the fact that the NK model used in Essays 2 and 3 can be considered a general model of complex adaptive systems, and the consistent findings at the level of the organizational population presented in Essay 4 all support the view that the need to balance exploration and exploitation is a phenomenon that can be relevant in the change processes of a wide variety of organizational systems.

However, in addition to highlighting the general importance of the exploration–exploitation balance, the results of this dissertation also emphasize that this balance can be highly context-specific. Despite the general importance of the exploration–exploitation tradeoff, the findings of the essays are consistent in that, in all four studies, environmental factors are found to have a significant influence on the optimal exploration–exploitation balance or, in some cases, even the very existence of such a balance in the first place. Further, the results suggest that in some extreme conditions, or at particular times, it may be optimal to focus only on exploration or only on exploitation instead of attempting to balance the two. Although it is not optimal to concentrate solely on exploration or solely

on exploitation in most environmental contexts, the precise balance between the two heavily depends on contextual factors.

The results of this dissertation thus show that the adaptive demands presented by the environment play a key role in determining whether and how exploration and exploitation must be balanced in the organization's adaptation strategy. Whereas in most empirical contexts, environmental pressures for exploration and exploitation are sufficiently high such that the two must be balanced for optimal performance – as suggested by the empirical finding in Essay 1 of a significant curvilinear effect when industry technological dynamism is set at its average value – the results of this dissertation highlight that in the theoretical examination of the performance effects of exploration and exploitation, these two modes of adaptation should not be analyzed independently of the environmental context.

Specifically, the results of this dissertation, as highlighted in Figure 3, suggest that in the absence of environmental pressures to adapt, exploratory and exploitative adaptation do not have a direct effect on organizational performance. Rather, their impact on performance is contingent on the adaptive pressures imposed by the environment. Specifically, dynamic environmental factors such as turbulence and complexity may decrease organizational performance by throwing the organization off its alignment with environmental demands or by making it more difficult to achieve the optimal alignment. Organizations must undertake exploratory and exploitative adaptive actions to counteract such environmental dynamics and regain or improve their alignment with the demands of the environment. Thus, rather than environmental factors moderating the performance impact of exploration and exploitation, an alternative perspective could be that of various dynamic environmental factors having negative performance effects that are moderated (i.e., attenuated) by exploratory and exploitative adaptation. Such a perspective, in which the environmental demands are given analytical primacy, might prove useful for a better theoretical understanding of organizational adaptation.

As a further implication to the exploration–exploitation literature, the studies in this dissertation highlight that both exploratory adaptation and exploitative adaptation are vital in responding to environmental turbulence and complexity. Although previous literature has widely argued for the importance of exploration in coping with dynamic environments (e.g., Benner & Tushman, 2003; Levinthal & March, 1993; Siggelkow &

Levinthal, 2003), the results of Essays 1 and 2 suggest that exploitative adaptation may also play a vital role in such highly demanding environmental contexts. It is notable that in the regression analysis in Essay 1 (Appendix 1, page 226), the interaction between technological dynamism and the squared exploration term is negative and significant. This result suggests that when a firm engages in excessive exploration at the expense of exploitation, the decline in performance is steeper in technologically dynamic industries than in stable industries, providing empirical support for the theoretical simulation result in Essay 2 that turbulence and complexity increase the importance of both exploratory adaptation and exploitative adaptation. Although the majority of the firms studied in Essay 1 engaged in relatively too much exploitation at the expense of exploration, there were also a significant number of firms that may have neglected exploitative adaptation in their effort to stay exploratory in a highly dynamic environment. Taken together, the results of this dissertation suggest that the roles of both exploratory and exploitative adaptation must be taken into account when examining organizational adaptation to highly dynamic environments. Even when the exploration–exploitation balance is operationalized as a single-dimensional continuum (Gupta et al., 2006; Lavie et al., 2010), a theoretical understanding of the influence of contextual factors on this balance requires an examination of the influence of such factors on both types of adaptation.

In addition to these theoretical implications, this dissertation also provides a methodological contribution to the study of exploration and exploitation. The automated content analysis method of measuring exploration and exploitation that is used in Essay 1 provides a novel approach to operationalizing these two concepts. An approach that allows for measuring exploration and exploitation in a wide variety of contexts, for a large number of organizations, and over extended periods of time can be a useful tool in facilitating the large-scale empirical examination of the exploration–exploitation balance. This dissertation also demonstrates the usefulness of formal simulation in the study of exploration and exploitation processes, as well as the benefits of combining large-scale empirical research with formal theoretical examination to gain a deeper understanding of the dynamics of exploration and exploitation.

4.2 Managerial implications

The results of this dissertation suggest that managers must be keenly aware of the adaptive demands posed by the organization's environment when devising adaptation strategies. Environments that are more complex and turbulent generally require more attention to balancing exploration and exploitation. Further, organizations tend to undervalue exploration, suggesting that in highly dynamic environments, ensuring a sufficient amount of exploratory activity is a key adaptive challenge.

However, the results also suggest that a purely exploratory focus is not sufficient for optimally adapting to changing and complex environments. In addition to ensuring sufficient exploratory activity, the second component of organizational ambidexterity – exploitative adaptation – must also be given increased attention in increasingly dynamic environments. In addition to finding new opportunities through exploration, organizations in such environments must also pay attention to the ability to rapidly and efficiently exploit such opportunities.

The understanding that the exploration–exploitation tension arises from different contextual factors that impose pressure on both exploration and exploitation, as well as the knowledge that such a factor may impose pressure on the two types of adaptation to different degrees, may be useful in identifying and tackling specific adaptive challenges that the organization faces. For example, in the case of de facto standard setting, network effects are found to be a contextual factor that may impede the exploitation of the best of the known technologies by potentially forcing lock-in to an inferior technology. Under network effects, an organization can facilitate the adoption of the best available alternative as the technological standard through the exploitative action of coordinating its choice with other organizations. However, in emerging technological fields, technological complexity is another contextual factor that has a different effect: it necessitates exploration by making the optimal technological solution more difficult to find. Thus, as seen in Essay 4, in environments characterized by both of these contextual factors, balancing between the exploration and exploitation pressures imposed by technological complexity and network effects becomes essential.

A similar logic could be applied in other managerial contexts. An analysis of the pressures for exploration and exploitation imposed by a variety of contextual factors can be used to determine whether the key adaptive challenge that the organization faces is an exploratory challenge or

an exploitative challenge, or whether the challenge lies in balancing the two types of adaptation. Being mindful of the contextual factors can also be helpful in identifying specific exploratory or exploitative actions that the organization can use, such as coordination in tackling the exploitative challenges posed by network effects in the standard setting context.

5. LIMITATIONS AND FUTURE RESEARCH

5.1 Limitations of scope

My focus in analyzing the balance between exploration and exploitation has been on the general-level analysis of organizational adaptation in various environments, and consequently, I have ignored many other factors that may be important for the exploration–exploitation balance. For example, when examining the influence of environmental pressures on exploration and exploitation in organizations, I have ignored the influence of potential differences between organizations in the internal factors influencing their exploration and exploitation efforts. Organizations may differ, for example, in the amount of resources that they have available for exploration, exploitation, or both (e.g., Voss, Sirdeshmukh, & Voss, 2008); in how their organization structure supports exploration and exploitation attempts (e.g., Fang et al., 2010); and in their expertise in conducting different types of adaptive activities (e.g., Cohen & Levinthal, 1990). Thus, for example, the degree of exploration pressures imposed by environmental complexity may partly depend on factors internal to the organization, and the consequent effect on the exploration–exploitation tension may be different for different types of organizations. Such interactions between environmental and organization-level factors provide an interesting avenue for future research.

When analyzing exploration and exploitation across different levels of analysis, I have only considered the interplay between the micro level of individual organizations and the macro level of the organizational population. Going into an even more micro level and looking into how the actions of the variety of individuals, groups, or departments inside the organization collectively influence exploration and exploitation processes at the organization level is an issue that is given little attention in this dissertation. Further, I only study interorganizational interactions in the context of standard setting, thus omitting other types of interorganizational

interactions, such as strategic alliances (Koza & Lewin, 1998; Lavie & Rosenkopf, 2006; Rothaermel & Deeds, 2004), that may influence exploration and exploitation processes. The interplay between different intra- and interorganizational processes that facilitate exploration and exploitation warrants further research attention.

Because of the general nature of both the empirical and theoretical analysis presented in this dissertation, there are notable limitations on the applicability of these results to the management of exploration and exploitation in organizational adaptation. For one, the firm-level exploration–exploitation measure based on word counts of news documents that is used in the empirical analysis does not provide a concrete reference as to what, specifically, organizations should do to increase their exploratory or exploitative focus. In addition, the theoretical analysis uses a general model of local versus distant search, but how these different search processes correspond to different adaptive activities in organizations is given little attention. The results of this dissertation are thus on a highly abstract level, and interpreting them in a specific organizational context requires significant attention to the substantive details of the context.

In addition to the overall results discussed in Sections 3 and 4, the research reported in the four essays subtly presents some general issues related to exploration and exploitation in different environments. Due to limitations of space and scope, these issues are either omitted or only briefly touched upon in the individual essays, and they will be discussed more in depth in the next two subsections. Specifically, I will problematize two issues that I have largely taken as unproblematic in the individual essays, thus revealing some further limitations of the present research and suggesting paths for future research on organizational adaptation. In Section 5.2, I take a critical look at the definitions of the concepts of exploration and exploitation, and in Section 5.3, I examine the potential conceptualizations of an organization's environment in terms of its dynamic properties and the related implications to organizational adaptation.

5.2 Evocative and operational definitions of exploration and exploitation

When examining the operational definitions of exploration and exploitation used in the four essays of this dissertation, as well as the variety of operational definitions used in the existing exploration–

exploitation literature (e.g., Fang et al., 2010; Gupta et al., 2006; Lavie et al., 2010; Posen & Levinthal, 2011; Raisch & Birkinshaw, 2008; Rivkin & Siggelkow, 2007; Siggelkow & Rivkin, 2006), it can be seen that these concepts have been defined in various ways. Furthermore, all of the various definitions may not be mutually consistent, and what can be said for the exploration–exploitation tradeoff when operationalized in one way may not hold for the exploration–exploitation tradeoff in a different context with a different operational definition (Lavie et al., 2010). For example, both “search” and “change” have been used to define exploration (March, 1991), yet the exploitative concepts of “local search,” “incremental change,” and “refinement” are clearly embodied in these concepts. Similarly, “flexibility” is generally associated with exploration (Adler, Goldoftas, & Levine, 1999; Lavie et al., 2010), but as shown in Essay 2, has a distinct exploitative component. The boundary between exploration and exploitation thus seems blurred.

Furthermore, a look at different conceptualizations in the literature reveals a related but distinct issue with the definitions of exploration and exploitation. Namely, there is significant internal variation between concepts that can be considered clear exploration or clear exploitation. For example, many studies of organizational search and adaptation consider “search,” “adaptation,” and “change” to be a singular concept (e.g., Levinthal, 1997). However, can “distant search” be considered the same as “radical change,” even when both are considered exploratory adaptation? Obviously, finding distant alternatives is conceptually quite different from actually implementing those alternatives. Similarly, do the exploitative words “refinement,” “implementation,” and “selection” (March, 1991) really denote the same concept? Are they even conceptually related?

Much of the exploration–exploitation literature builds on the evocative definitions of the two concepts by March (1991). Although these definitions are, at the general organizational level, directly operationalized in Essay 1, they are not readily operationalizable in most substantive contexts. Consequently, scholars have found a variety of ways to operationalize a number of different constructs that have been labeled “exploration” and “exploitation,” linking them to March’s evocative definition. However, as the discussion above suggests, these constructs may be largely unrelated, and linking them to the concepts of exploration and exploitation may bring more confusion than coherence to the literature. Although the definitions of exploration and exploitation have been problematized in the extant literature (Gupta et al., 2006; Lavie et al.,

2010), the unity of the concepts is typically taken for granted. Perhaps integrating the exploration–exploitation literature could be facilitated by disaggregating the concepts of exploration and exploitation into more readily operationalizable components and by relegating “exploration” and “exploitation” as evocative notions that describe this variety of operational concepts that exhibit some type of a tradeoff between “old” and “new.”

5.3 Organizational environments and adaptation

As the results of this dissertation suggest, the organization’s environment can be a key factor in affecting its adaptation strategy. Specifically, when environmental dynamism, turbulence, and complexity increase, finding the proper balance between exploration and exploitation becomes increasingly important. But what do the concepts of environmental dynamism, turbulence, and complexity really mean?

First, what is the difference between environmental dynamism and environmental turbulence? In the first essay, in which I conducted an empirical examination of the exploration–exploitation balance, the technological dynamism of the environment was operationalized using the R&D intensity of the industry. Similar to the majority of the literature, I did not problematize the concept of environmental dynamism but rather used an established definition. However, it is notable that although some scholars use the words “dynamism” and “turbulence” interchangeably (e.g., Dess & Beard, 1984; Li & Simerly, 1998), “dynamism” seems a much more appropriate word to use here, with its connotations of not only change and uncertainty but also a certain degree of direction and intent that describes the organization’s need to be proactive. In other words, the term “technological dynamism” refers not only to the rate of technological change but also to the availability of technological opportunities (Baysinger & Hoskisson, 1989; Zahra, 1996). Further, as noted in Section 1.4, the concept of technological dynamism carries with it not only the notion of turbulence, but also the notion of some degree of technological complexity (Fleming & Sorenson, 2001). In contrast, “turbulence” seems the appropriate word to use in the simulation studies in Essays 2 and 3 because its meaning is largely limited to the connotations of change and uncertainty – precisely what is being formally modeled.

The notions of direction and intent associated with the concept of dynamism bring about a second issue related to environmental dynamism that is frequently neglected in the literature: dynamism always has a

context. Many studies on organizational adaptation simply use the concept of “environmental dynamism” to denote the rate of dynamic change, without an explicit theoretical consideration of what is changing, how it changes, and how the change affects the organization in terms of adaptive pressures. As an example of the significance of the context of environmental change, industries that score high on the technological dynamism index used in Essay 1 can be very different from those industries that score high on Dess and Beard’s (1984) demand-based dynamism. Demand-based dynamism is frequently high in cyclical industries that may not be technologically particularly dynamic – an issue noted in passing by Bourgeois and Eisenhardt (1988: 816) in their discussion of high-velocity industries. Thus, in different environmental dimensions, the type of change can be qualitatively different and pose different adaptive demands for the organization. For example, a sudden increase or decrease in the level of market demand may be expected to be only temporary in some industries, and the demand environment may later revert to its previous state. However, the same cannot be said of the technological environment: a black-and-white television will never be state-of-the-art again, and the wheel will never be uninvented. Does market dynamism therefore provide the organization with adaptive challenges that are similar to the challenges provided by technological dynamism? This context-specificity of environmental dynamism illuminates a key limitation of the context-free examination of turbulence and complexity in Essays 2 and 3, and it is an issue that must be given a more explicit consideration in future research on organizational adaptation.

A further consideration that is particularly relevant to the discussion in Essay 4 is that a major component of organizational environments consists of other organizations. Although the analysis in Essay 4 was conducted from the point of view of the organizational population, the finding that interacting organizations can generate nonlinear feedback loops that influence the adaptive activity of the organizations can also have significant strategic implications for individual organizations. In such coevolutionary adaptive processes, organizations must take into account the implications of their actions on the adaptive responses of other organizations and how these responses may change their environment. Although this notion of reciprocal influences between organizations has a long history in the management literature (e.g., Pfeffer & Salancik, 1978), the theoretical implications of such influences on coevolutionary organizational adaptation warrant further research attention.

6. CONCLUSION

In this dissertation, I have shown that while the exploration–exploitation tradeoff is a significant consideration in organizational adaptation, it is also highly context-specific. The nature as well as the very existence of the exploration–exploitation balance is dependent on a variety of contextual factors, such as environmental turbulence and complexity, technological dynamism, and interactions between organizations. Further, I have shown that both exploration and exploitation may be vital in adapting to increasingly dynamic environments.

This dissertation contributes to the organizational adaptation literature both by empirically testing the significance of the exploration–exploitation tradeoff and the moderating effect of technological dynamism on that tradeoff and by theoretically elaborating on the organizational, interorganizational, and environmental dynamics related to the exploration–exploitation framework using formal simulation modeling to analyze organizational adaptation processes. In using complexity theoretical frameworks to examine questions of organizational adaptation in larger environmental contexts, this dissertation builds on and informs the neo-Carnegie perspective of organizational scholarship (Gavetti, Levinthal, & Ocasio, 2007). By examining the complex interdependencies between exploration and exploitation processes in the adaptation dynamics of organizations and industries, this dissertation advances the theory of exploration and exploitation and, on a more general level, an organic perspective on strategy (Farjoun, 2002).

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APPENDIXES

APPENDIX 1

Uotila, J., Maula, M., Keil, T. and Zahra, S. A. (2009), 'Exploration, exploitation, and financial performance: analysis of S&P 500 corporations,' *Strategic Management Journal*, 30, 221-231.

APPENDIX 2

Uotila, J. (2012), 'Turbulence, complexity, and the exploration–exploitation balance,' 38 pages.

APPENDIX 3

Uotila, J. (2012), 'Ambidexterity versus punctuated equilibrium: environmental determinants of the temporal dynamics of exploration and exploitation,' 40 pages.

APPENDIX 4

Uotila, J., Keil, T. and Maula, M. (2012), 'Balancing coordination and diversity: technology development under network effects,' 49 pages.



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