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TABLE OF CONTENTS

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ORGANIZATION THEORY AND THE CHANGING NATURE OF SCIENCE

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Abstract: Dramatic changes in the practice of scientific research over the past half century, including trends towards working in teams and on large projects, as well as geographically distributed and interdisciplinary collaboration, have created opportunities and challenges for scientists. Some of the newer ways of doing science create opportunities and challenges for organization theory. We describe how applying organization theory to science can enhance our knowledge of research organizations and raise questions for theories of coordination, social identity, the knowledge-based view of the firm, social networks, organizational learning, and absorptive capacity. We argue that an organizational perspective on science is critical to understanding the sources of technological innovation, making national policy on R&D investment, and designing successful 21st-century research organizations.

Keywords: Organization theory, social studies of science, interdisciplinary collaboration, distributed work, research policy

Since 1901, Nobel Prize committees have honored eminent individuals for their scientific achievements. Stars will always be important in science, but by current trends, few will succeed singlehandedly. In the last few decades, science increasingly has become an effort performed by organizations. Evidence of this change can be seen in the growing number of co-authored scientific papers (Wuchty, Jones, & Uzzi, 2007) and papers published by large groups (Newman, 2001). Growing co-authorship reflects not merely a change in norms regarding collaboration and credit, but that teams now conduct most research. Science teams and projects within universities are the most prevalent form of research, but they also exist in large numbers in other organizations, including industrial laboratories, nonprofit research institutes, scientific alliances, online consortia, and government agencies such as NASA and NIH. A growing number of projects are large and geographically distributed, involving scientists nationally or globally. The NIH Clinical and Translational Science Consortium, the DARPA Grand Challenge, and the NSF Network for Earthquake Engineering Simulation (NEES) exemplify large, distributed team-based research organizations. In 2014, the U.S. spent more than $3 billion to help maintain the International Space Station, which not only supports astronomy and physics but also the biological sciences (e.g., researchers found that salmonella bacteria become more virulent in space). The size and complexity of research teams, and the increasing policy, social, and economic importance of science-based innovation, led us to consider how organization theory might be applied and developed in the burgeoning domain of science.

Many innovative businesses (Genzyme, Google, Novartis, Red Hat, and Twitter, to name a few) began with advances in science and technological innovation. Growth in the GNP and our standard of living depend on research, whether this be research into rice crops, computer logic, or the causes of chronic disease. New methods in research are making possible an understanding of the human and world condition that was once inconceivable. Yet comparatively few faculty members with expertise in the fields of organizational behavior, strategic management, economics, psychology, sociology, or communications

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study the scientific research process and its organizational context as a wellspring of our economic, health, and social systems. Is it a problem of representation? Do organizational scholars assume that computer scientists are chiefly techies sitting in front of a computer, or that biologists are individual bench scientists working with microarrays in the lab? If so, the field of organization theory is missing an important opportunity to understand what is really going on – the large increases in collaborative work, new organizational structures, virtual communities, and innovative approaches such as crowdsourcing (Wood et al., 2011) are changing the nature of teamwork and creating new types of alliances and partnerships among researchers. We argue that researchers should embrace science as an appropriate domain for applying and examining organization theory.

In putting together an agenda for applying organization theory to science, we address how the changing nature of science intersects with a variety of organizational theories. An organizational approach to understanding science has some overlap with an organizational approach to understanding law, medicine, or business, but there are significant differences in how science is organized. The overarching goal of discovery in science differs from that of law (justice), medicine (healing people), or business (making money). The underlying mechanisms that support scientific work also differ. In science, the dominant funding model is the grant or research contract. Publicly funded and not-for-profit institutions, and managers within companies, decide which projects to support, and distribute money to research organizations. In law, medicine, and business, funding arises from an exchange with customers for a product or service. This is not to say that science lacks business goals. On the contrary, historians of science have long noted the potential of user-inspired basic research – for example, "Pasteur's Quadrant" in which Louis Pasteur discovered through basic research, among many other things, a method that can be used for causing milk not to spoil, now referred to as pasteurization (Stokes, 1997). The commercialization of science, and in particular the blurred intersection between public and private science (Colyvas & Powell, 2006), has received increased attention in the organizational literature (Feldman et al., 2002; Gittleman, 2007). However, other important and emerging topics related to the organization of science have been neglected such as how scientists collaborate with one another, how virtual scientific projects are organized, and how interdisciplinary learning occurs within and across research institutions.

In 1966, Donald Pelz and Frank Andrews published an influential book titled *Scientists in Organizations: Productive Climates for Research and Development*. They argued that the outcomes of research were determined, in part, by the working environment of the laboratories in which scientists worked. They developed the concept of "productive climate," referring to a stimulating rather than inhibiting local environment for scientific progress, and showed how it impacted the productivity of university researchers. Pelz and Andrews (1966) studied research collaborations within single laboratories and institutions, where researchers knew one another personally. It is not clear how productive climates would operate when researchers collaborate across institutional boundaries with colleagues they might not have met face-to-face. Theories of the knowledge-based view, coordination, and social networks suggest that research managers and collaborators will experience greater coordination costs in collaborations with others in different locations and will have difficultly integrating the knowledge and expertise needed to be effective (Boh et al., 2007; Cummings & Kiesler, 2007; Walsh & Maloney, 2007). However, in a climate of economic constraints on research and ever-increasing costs, such collaborations are common.

We believe three changes in the nature of science – team science, distributed science, and interdisciplinary science – illustrate how concepts and theories in organization theory are relevant. These changes have brought about an increased pace of work, difficulties in synchronizing activities and in the management of attention, and high costs of monitoring cooperation and accountability, each of which are problems for current organization theory (see Table 1). In the sections that follow, we describe the changing nature of scientific research and discuss how organization theory can be used to better understand how research organizations could be designed for increased effectiveness.

Table 1. Changing nature of science and its implications for organization theory

Level of Analysis	Changes in Scientific Practice	Effects on Organizational Processes	Illustrative Organization Theories
Scientists	Individual → teams	Task interdependence Team identification	Coordination theory Social identity theory
Projects	Collocated → distributed	Knowledge integration Weak tie formation	Knowledge-based view of the firm Social network theory
Institutions	Disciplinary→ interdisciplinary	Learning curves Creativity and innovation	Organizational learning theory Absorptive capacity theory
Cross-cutting issues: Temporal pace of work and the synchronization of activities Multiple projects and the management of attention Cooperation and the costs of monitoring			

CHANGING NATURE OF SCIENCE

It is difficult not to notice that scientific research is changing. Worldwide, there has been increasing technological innovation and development of complex computer-based methods and tools that necessitate the interaction and fusion of different technical disciplines and expertise (Gibbons et al., 1994). These changes have caused a rise in the significance of interdisciplinarity and team collaboration. For instance, advances in computational biology have depended on collaborations in computer modeling, statistics, and genetics. During the same period, and not without its detractors (e.g., Alberts, 1984), the need to share expensive research resources, to manage huge amounts of information, and to overcome disciplinary "silos" to solve social problems, has pushed science policy towards externally generated priorities (Inselt et al., 2004). Those goals have led to a tighter meshing of research with government-funded social missions, and a closer relationship between basic research and industrial application (Llerena & Meyer-Kranmer, 2003). To meet these priorities, agencies in the U.S., Europe, and Asia have sponsored a wide range of large research projects such as the European Large Hadron Collider to investigate particle physics, the multinational Antarctic Drilling project to investigate climate change, and the Human Genome project to investigate human DNA (Collins, Morgan, & Patrinos, 2003). Networks of relationships still motivate many interpersonal collaborations (Blau & Scott, 1962; Tichy, 1981), but these new investments, and the increasingly rapid application of science and technology to products and services in agriculture, finance, energy, health care, transportation, and entertainment have increased the size of the science enterprise, its costs, political prominence, and structural complexity.

As teams and project-based research organizations have begun to dominate production in science, scientific work has changed as well. Since Kraut, Galegher, and Egido (1987) published their original study of research collaborations that showed how personal relationships facilitated effective task completion and the importance of proximity for informal communication, scientific teams have grown larger and more dispersed across institutions and disciplines (Corley, Boardman, & Bozeman, 2006; Metzger & Zare, 1999; Olson, Zimmerman, & Bos, 2007). R&D labs are now spread across continents (Gassmann & Zedtwitz, 1999), open source software projects have contributors from around the world (von Hippel & von Krogh, 2003), and so-called "collaboratories" have formalized institutional alliances and have encouraged scientists in many geographic locations and fields to share common resources (Finholt & Olson, 1997; Kouzes, Myers, & Wulf, 1996).

These changes in science are associated with many theoretical and empirical questions that fall into the domain of organization theory. For instance, as research teams become larger, involve more institutions, and entail costs into the millions or billions of dollars, their organizational structures have become more formalized. Yet apart from scattered case studies (e.g., Moon & Sproull, 2002), little is known about the external environments, institutional arrangements, management strategies, norms and team processes, and labor markets for expertise that make some research organizations succeed and others, like the

Superconducting Super Collider, fail. Unfortunately, the evaluation of research programs has been *ad hoc* (Luukkonen, 1998). New organizational forms emerging in science present fascinating questions for organizational scholars. For example, how do traditional incentive structures built around tenure clash or adapt to new interdisciplinary imperatives? When ties are weak and spread over nations, how do teams find just the right expertise at a cost they can afford? To what extent can the open source movement facilitate scientific progress across institutional and disciplinary boundaries? How do new ways of publishing and presenting findings challenge the dominance of top journals and the traditions of peer review and self-policing of scientific quality?

As we noted, research on how science is organized is not new. It can be found especially in the literatures on the sociology of science and industrial organization. The journal, *Social Studies of Science*, publishes papers on the politics of science, epistemology of science, ethical issues, and social roles and processes. *Research Policy* publishes studies of organization relevant to government and R&D policy. Much of the work in industrial organization examines macro-level processes such as the relationship of investments in R&D to GNP. An emerging field of "scientometrics" (with its own journal by the same name) has contributed new methods, including types of network analyses, for understanding the spread of knowledge. Examinations of new organizational forms in science are beginning to emerge (e.g., Chompalov, Genuth, & Shrum, 2002). Yet by contrast with other domains and topics, changes in scientific practice and their impact on research organizations have been neglected by most organizational scholars. *Nature, Science*, and biotech news outlets have published commentaries on issues in the organization of science, such as the purported glut of postdocs (Philippidis, 2013). Problems like these should be of interest to those who study organizations, but so far, have not.

More Scientists Are Team Scientists

Research collaboration, also referred to as "team science" (National Academies, 2014), involves the cooperative teamwork of researchers to achieve a common goal of producing new scientific knowledge (Katz & Martin, 1997; Kraut, Galegher, & Egido, 1987; Stokols et al., 2008). Classic studies show that a few fields, such as physics and astronomy, have long depended on team science and were transformed in mid-twentieth century from "little science" to "big science" due to the complexity and cost of their equipment and infrastructure (de Solla Price, 1963). Division of labor also increased as professors took on graduate students, post-docs, and technicians to expand the scope of their work (Hagstrom, 1964). These changes now apply to most fields of science.

The change from individuals to teams, and from smaller to larger teams has benefits and costs. Teams benefit from more people to share the work and to solve problems, and more experts to contribute. One expert's departure is unlikely to doom an entire project. Larger groups experience many efficiencies of scale over smaller groups. Technologies and practices adopted or created by a few members can be readily used or copied by other members. Working with others can increase scientists' own expertise. Despite these benefits of scientific teams, there are costs. More people generally implies more layers of decision making. More people also means a greater need for planning – meetings, calendars, managers, committees, and staff to manage workflow and resources. Research sponsors and employer organizations also demand greater accountability for larger projects with bigger budgets and more control over the activities of participants, that is, bureaucratization (Weber, 1968). Bureaucratization involves more rules, reports, and oversight. In our research on large scientific teams (Cummings & Kiesler, 2007), researchers told vivid stories about lengthy institutional review board (IRB) procedures, detailed budgeting, frequent requests for progress reports, and arcane rules for equipment purchases that increase the administrative costs of research.

The shift from individuals to teams affects a key process familiar to organization theorists: task interdependence (Puranam, Raveendram, & Knudsen, 2012). In a scientific research team, task interdependence is typically high because what one subgroup does (or does not do) affects the work of others and the entire team. A high level of task interdependence leads to a high need for coordination and task integration. Bureaucratic procedures can impose even tighter coupling among tasks, complicating coordination. *Coordination theory* (Malone & Crowston, 1994; Van de Ven, Delbecq, & Koenig, 1976) provides an approach to the study of coordination processes within organizations. It has been used to suggest coordination improvements in project work (Crowston, 1997) and to evaluate factors that change coordination costs (Boh et al., 2007; Cummings & Kiesler, 2007; Olson & Olson, 2000). In large scientific teams, coordination costs may be exacerbated because division of labor, task specialization, and bureaucratic rules may be unsuited for some parts of the work. Science ultimately is a creative activity in which transformative discoveries can require changing goals, collaborators, or tasks midstream, each of which poses coordination challenges.

Coordination theory offers a productive lens for studying these challenges in scientific organizations and for advancing theory as well. The theory might help us understand the tradeoffs between formal organization, which rationalizes workflow and resources, versus creativity, which may not be readily rationalized. At what point do large organized projects, with their many strings that tie people together and coordinate work, sacrifice creative advances in research?

Another organizational process relevant to the shift from individuals to teams is team identification, in which members feel part of a social entity larger than themselves or their close associates. Scientists who work on a team can come to feel part of a community, making *social identity theory* (Hogg & Terry, 2000; Tajfel & Turner, 1986) potentially applicable to this process. Social identity theory generates a number of predictions relevant to scientific team attachment and success. For instance, the theory predicts that researchers who identify with a scientific project or team will see membership as comparatively interchangeable and will be less likely to leave if a favorite local colleague leaves (Turner, 1985).

Although topics such as team size and diversity (Cummings et al., 2013) and team stability and change (Guimera et al., 2005) are of great importance in science policy, these and other topics addressed by social identity theory need further development in the context of science. Social identify theory also could help clarify policy debates. For instance, “grand challenges” and other innovation contests that involve specific goals and competition with other scientific teams are increasingly popular in sciences ranging from agriculture to biometrics to computing (Boudreau, Lacetera, & Lakhani, 2011). Some have argued that team competitions (and other targeted initiatives) are inefficient and cause scientists to overemphasize short-term wins over long-term scientific progress (Dasgupta & David, 1994). We suggest that applying social identity theory to scientific organizations would improve not just the sophistication of science policy but extensions and boundary conditions of the theory.

More Research Projects Are Distributed, Geographically and Institutionally

Along with an increase in size, research projects are also becoming more distributed geographically and institutionally (Jones, Wuchty, & Uzzi, 2008). New computer-based communication technologies, especially, have made multi-institutional collaborations notably easier than was true when distant collaborators had to travel to each others’ labs and meet at research conferences. Researchers and their sponsors have taken advantage of this technological change. Investigators at institutions or departments specializing in one topic or technique seek colleagues located at other institutions, and networks of scientists cooperate and share news and know-how in their fields. Funding organizations, which need to satisfy many stakeholders, have an interest in supporting a diverse research portfolio, and have developed mechanisms for supporting multi-institutional collaborative projects. A new organizational form, exemplified in the open source model of software development (von Hippel & von Krogh, 2003) and adopted for research on a wide range of topics, such as personality measurement, machine translation, operations management, and protein interactions, involves investigators who work within an entirely virtual organization.

Distributed science has benefits and costs. On the benefits side, distributed researchers can collaborate with experts regardless of their location or prior ties. Transferring and fusing knowledge across expertise regardless of where people are located physically should improve innovation and creativity (Moon & Sproull, 2002). On the other hand, projects with dispersed members increase coordination costs and delays (Herbsleb et al., 2000), misunderstandings or outright conflict (Cramton, 2001), inconsistent procedures across locations (Curtis et al., 1988), and splinter groups (O'Leary & Mortensen, 2010). Dispersed projects also may grow larger as experts are added. The benefits of obtaining new expertise may be offset by costs associated with dispersion and larger size.

Organization theorists will recognize in these issues the considerable attention in recent years to the problem of how organizations can share and integrate knowledge. According to the *knowledge-based view* of the firm (Grant, 1996; Kogut & Zander, 1992), integrating the expertise of employees is a critical process in modern knowledge organizations, research organizations being in this category. Success depends on how those organizations combine their expertise, especially through teamwork and learning within teams (Grant, 1996; Teece, 1998). The knowledge-based view has implications for the extent to which organizations acquire expertise externally, establish boundaries, exchange tacit versus explicit knowledge, and utilize resources (Lepak & Snell, 1999). However, with recent exceptions (e.g., Boh et al., 2007), knowledge-based view research has been characterized by a high level of abstraction (Priem & Butler, 2001). Studying research organizations from the lens of the knowledge-based view could improve the empirical basis of this framework and help understand its tradeoffs. For example, we might ask how distributed scientific teams integrate knowledge when learning is mostly local but collaboration is mostly non-local. Scientific organizations offer an opportunity to apply the knowledge-based view in a context of great policy importance and to compare how the framework performs outside for-profit organizations.

Another recognizable organizational process in distributed teams is the role of weak ties in finding and recruiting experts and exchanging critical information (Granovetter, 1973; Hansen, 1999). Although researchers typically have extensive social networks that foster collaboration, they need to develop sufficient experience with one another to conduct research and co-author scientific papers. When research collaborations are distributed across institutions, investigators have to figure out how to best nurture those collaborations. Investigators need to balance meetings with local colleagues and students while at the same time managing meetings and other activities across institutions. The challenges to effective knowledge sharing across institutions are exacerbated further, for example, if one university follows a semester schedule while another follows a quarter schedule, or if one university has hurdles for evaluating intellectual property (e.g., a technology transfer office) while another has no hurdles.

Recent advances in *social network theory* identify mechanisms, such as homophily and reciprocity (Monge & Contractor, 2003), that apply to processes scientists use to form and sustain collaborations. However, we still lack detailed information on how dispersion affects collaboration through network ties, how local relationships compete with distant ones, and how researchers make tradeoffs regarding whether to collaborate with local versus distant colleagues (Bozeman & Corley, 2004). Interesting questions for organization scientists include why dispersed teams, on average, tend to be less efficient than collocated teams, and how to understand the role of leadership, resource allocation, and incentives in virtual organizations made up of weak ties (Ahuja & Carley, 1999).

Science Is More Interdisciplinary

By the end of the twentieth century, science had become increasingly interdisciplinary (Metzger & Zare, 1999). According to a cross-disciplinary citation analysis by van Leeuwen and Tijssen (2000), more than two-thirds of citations from 1985-95 crossed disciplinary (or sub-disciplinary) boundaries, although some fields like medicine were much more interdisciplinary than others, such as astronomy. Researchers themselves have begun seeking people from different disciplines to solve problems, and national governments have undertaken initiatives that combine different disciplines to address important social problems in domains such as health, national security, and agriculture. The National Cancer Institute in the U.S. has sponsored what the agency calls "translational medicine" by supporting staff, conferences, and papers on interdisciplinary research and team-based science. Traditional university organizations, built around disciplinary departments and professional schools, have struggled to accommodate interdisciplinary science (Rhoten & Parker, 2004). How can universities learn not merely to adapt to interdisciplinary work but to embrace it?

As with team science and distributed science, there are benefits and costs to interdisciplinary science. The value of interdisciplinary research to innovations in products and services has often been cited. For instance, the video recorder emerged from advances in control theory, magnetic and recording materials, and electronics (Schmoch et al., 1996). Other important discoveries based on interdisciplinary research include DNA, radar, and manned space flight. Nonetheless, a National Academies (2004: 1) report on interdisciplinary research claimed, "Despite the apparent benefits of interdisciplinary research, researchers interested in pursuing it often face daunting obstacles and disincentives. Some of them take the form of personal communication or 'culture' barriers; others are related to the tradition in academic institutions of organizing research and teaching activities by discipline-based departments – a tradition that is commonly mirrored in funding organizations, professional societies, and journals." Given such obstacles, universities may be slow, or even resistant, to change in spite of shifts toward interdisciplinary science.

Large projects typically display a mix of formal and informal organizational structures (March & Simon, 1958). They are created with formal administrative hierarchies and division of labor that frame goals and how work will be accomplished but evolve informally. Cultures within disciplines can clash across disciplines, sometimes creating silos and mistrust. Scientists sometimes initiate competing collaborations with multiple goals and objectives (Newman, 2001). A network of social scientists in the U.K. working within genetics projects have stimulated debate on topics such as animal-human hybrid embryos, raising some hackles, but they have also created links across fields. For instance, within the large Barcode of Life project, they mediated between groups using specialized methods, such as public health officials and the larger project, which needs global standards for genetic bar-coding (Macilwain, 2009).

Organization theorists familiar with *organizational learning theory* (Argote, 1999; Huber, 1991; March 1991) will recognize such situations. Although some organizational learning researchers have studied interdisciplinary learning in teams (e.g., Edmondson, 2003) and learning in distributed work (e.g., Lakhani & von Hippel, 2003), little is known about how (and if) universities create values, procedures, and structures wherein interdisciplinary science is central. Llerena and Meyer-Krahmer (2003) argue that external forces are increasing the incentives for this change, but organizational scholars rarely study these issues, although they often swirl around them in their own universities (Vural, Dahlander, & George, 2013). We believe there are interesting questions here for organization theorists. Is interdisciplinary work inherently more diverse, innovative, and risky, making organizational structures that support the cognitive and social aspects of the work more fragile (Paletz & Schunn, 2010)? What are the tradeoffs between exploitation and exploration (March, 1991), and what are their impacts on learning? Do the power asymmetries inherent in research organizations with junior and senior investigators inhibit or facilitate learning (Van der Vegt et al., 2010)?

Absorptive capacity theory (Cohen & Levinthal, 1990), which provides a framework for understanding the innovation capacity of an organization to use new knowledge, is another theory that would be useful in understanding changes toward interdisciplinarity. Most work in absorptive capacity has been focused on industrial organizations, but the concept applies to universities as well. In almost all universities, incentives and authority structures are discipline-based. Centers, networks, and other interdisciplinary units typically do not have the authority to hire tenure-track faculty, and they run on soft budgets. Thus, power and stability are held in disciplinary units, which may be resistant to recruiting faculty in different disciplines, creating interdisciplinary departments, pursuing proposals in new interdisciplinary areas, and helping faculty to learn new fields, thus undermining the university's capacity to acquire and utilize new knowledge. One interesting question here is whether universities that start interdisciplinary departments create more innovation capacity for bringing in new kinds of resources and people, and whether capacity on one side of campus spreads to other sides.

CROSS-CUTTING ISSUES

We have described how science is changing for scientists, the teams in which they work, and for universities and research institutions. We now highlight three cross-cutting issues apparent in the shift from individuals to teams, collocated to distributed work, and disciplinary to interdisciplinary research: (1) the increased temporal pace of work and pressures on synchronization of activities, (2) an increase in multiple projects affecting the management of attention, and (3) a greater need for cooperation, increasing the costs of monitoring.

Temporal Pace of Work and the Synchronization of Activities

Scientific work today, like other academic pursuits, is not a leisurely occupation. Aside from their regular duties in teaching and departmental activities, researchers face looming proposal cutoff dates and conference deadlines, websites to keep up to date, urgent queries from the press, progress and final reports, site visits, meetings, telephone and online conferences, and demanding travel schedules. Although some of what scientists do can be accomplished asynchronously, other critical work such as handling sudden resource or personnel crises, completing difficult analyses, getting help on a technique, or co-authoring a paper or proposal under deadline, requires synchronous planning, analysis, and discussion with others.

As the number of people in a team increases, member deadlines compete with one another, making synchronization more difficult. Distributed projects complicate deadlines further due to time zone differences and travel distances. Some globally distributed teams have to reserve a single daylight hour in which everyone is awake to discuss the work. Interdisciplinary science is a source of even more pressure because different disciplines run on different conference and publication time schedules. One of the authors was recently invited to an interdisciplinary program committee meeting, which had to be rescheduled twice to avoid conflicts with disciplinary conferences (of which the planners were unaware).

Organization theorists have long studied the temporal pace of work, including teams (Waller, Zellmer-Bruhn, & Giambatista, 2002) and organizations (Orlikowski & Yates, 2002). A generalization from this work is that teams and organizations use time to synchronize work and decision making, but time has psychological and social meaning well beyond the fixing of routines. In science, these routines and meanings are complex and challenging (Jackson et al., 2011). Scientists have been at the forefront of adopting technologies such as fast Internet access, smartphones, portable computing, and applications such as shared calendars, online voting, and instant messaging. These technologies have dramatically altered how scientists use their time and the technologies themselves. On the one hand, time seems more fungible since people can do more things at once (drive and talk by cell phone), but they also pack more activities into a given space of time (go through their email while at meetings). Because of their adoption of these new practices, scientific teams and organizations would seem to be prime places to study questions such as how researchers synchronize activities with individuals and groups.

Multiple Projects and the Management of Attention

Scientists often belong to several teams and projects with research relationships at different levels of closeness (Hudson et al., 2002; Newman, 2001). Managing time and attention across multiple teams, especially when members are in different geographic locations, can make working in teams challenging (Cummings & Haas, 2012). Social media websites such as GitHub are starting to make working on multiple projects easier (Tsay, Dabbish, & Herbsleb, 2012). However, the demands of being on multiple teams, along with those of teaching, administration, and graduate student training, increase the overall load on researchers' time and attention. Many different demands on attention keep work interesting and spark thinking about problems in new ways but also involve many interruptions, which can have cascading effects on interpersonal work relationships and a team (Leroy, 2009). Distraction negatively affects individuals' self regulation, communication, and thought processes (Gonzalez & Mark, 2004). However, research has shown that team members can learn vicariously from other teams, and that external learning activities are particularly valuable when members engage in internal learning activities (Bresman, 2010). In the context of science teams it would be interesting to know how external attention, as well as competing activities, affect productivity and member relationships. We expect that the management of attention would be further complicated by how much members vary in their level of commitment to the team (e.g., core versus peripheral members).

Having multiple task responsibilities and roles puts a premium on attention, including decisions about the allocation of people to projects and tasks (Ocasio, 1997). These decisions grow even more complex with the trend to create geographically distributed work arrangements, distributed collaborations, and organizations with multiple sites, each housing experts specializing in one or more facets of work (Becker, 2001). Although there has been considerable scholarly research on the management of expertise and attention within work teams (Polzer, Milton, & Swann, 2002), researchers have paid surprisingly little attention to the management of expertise and multiple task activities across distributed organizational and team environments (cf. Grinter, Herbsleb, & Perry, 1999). Many questions arise in the context of multiple-project work. For instance, what organizational strategy addresses the best structuring of expertise, attention, and workload in multiple project environments (Marks et al., 2005)? How do scientists regularize communication, prioritize tasks, and plan (or fail to plan) for expected and unexpected events? How do variations in the geographic and temporal distribution of work affect these decisions? Will new collaboration technologies help or make worse the trend in which scientists assume more tasks and join more projects?

Cooperation and the Costs of Monitoring

As the size of scientific teams continues to grow, as members are spread across a greater number of institutions, and as more disciplines are brought together to solve scientific problems, the need for cooperation among scientists intensifies. Researchers, who traditionally might have only needed to cooperate with members of their own labs, must now weigh the responsibility of cooperating with other labs and organizations in order to effectively achieve their scientific goals. Cooperation raises issues of trust and the costs of monitoring (Rousseau, Sitkin, Burt, & Camerer, 1998). Trust helps researchers organize their work and execute it successfully (McEvily, Perrone, & Zaheer, 2003), but working in large, geographically distributed, and/or multidisciplinary projects increases people's vulnerability and dependence on trust. Their perceptions of risk may inhibit their willingness to collaborate (Mayer, Davis, & Schoorman, 1995). As a way to mitigate the uncertainty associated with collaborating with people across institutions and disciplines, researchers are likely to spend more time monitoring what others are doing. The costs of monitoring are likely to increase as more cooperation is required in larger and more complex projects.

One interesting question that arises in the context of science is: to what extent does swift trust occur in distributed, interdisciplinary research projects (Jarvenpaa & Leidner, 1999)? Do members of these projects jump right into a large-scale collaboration, viewing distant colleagues benignly? Scientists who trust other participants are likely to experience lower costs of monitoring because they can focus on the work rather than on what others are doing. However, if the stakes are high, scientists may feel the need to verify the quality of the work and the progress made by other participants, and the costs of monitoring others could impede their efficiency on the task.

A related question for organization theorists interested in cooperation is how divergent incentives drive behavior in scientific collaborations. Incentives can differ within and across people and teams. For instance, there are different incentives for faculty with tenure compared to faculty without tenure, faculty who are on "hard" money hiring lines rather than "soft" money hiring lines, faculty with greater obligations to publish rather than to teach, and so on. Incentive differences can influence who is willing to join scientific projects and the cooperative behavior of those who do join. The willingness to cooperate and the amount of monitoring that researchers engage in should vary as a function of their position within the incentive structure of their organizations.

Another question concerns the cultures from which team members are drawn. Many scientific projects are global and require the cooperation of scientists from different nations.

For instance, the Global Seismographic Network is an open access project to monitor all seismic vibrations on Earth with high fidelity. Although science and scientists value objectivity, politically based funding and national differences, as well as value-laden social behavior, can affect such research projects (Easterby-Smith & Malina, 1999). For instance, researchers from more hierarchical and consensus-valuing Asian cultures may be more inclined to discuss issues fully with peers but to debate superiors less than their American colleagues. Thus far, little research has focused on answering questions about the influence of cross-cultural processes in scientific organizations.

Finally, Murray and O'Mahoney (2007) discuss the different rewards for sharing information and building on others' ideas within distinct fields, institutions, and communities. For instance, in the life sciences, researchers from academia and industry publish in venues with different implications for access (Murray & Stern, 2007). We believe their arguments for studying cumulative innovation are consistent with our call for applying organization theory to science. Just as there is variation in incentive structures across corporations engaged in science-based innovation (e.g., publishing, patenting, licensing), incentive structures for innovation vary across centers, institutes, universities, government laboratories, and other research organizations engaged in science. We need to gain a more systematic and empirically based understanding of these incentive structures to understand how they lead to more or less innovation.

DISCUSSION

Science has undergone major organizational changes over the past century and has embraced new ways of structuring incentives (e.g., million dollar prizes), collaborative relationships (e.g., virtual scientific networks), project governance (e.g., open source projects), scientific participation (e.g., citizen science), and knowledge dissemination (e.g., publicly accessible journals). These changes exemplify innovations in organizing that have both intended and unintended consequences, with implications for organization theorists, managers, and policy makers. For instance, the scientific value and efficiency of team science over solo science is so often taken for granted today that funding agencies, such as the U.S. National Science Foundation and E.U. Framework Programme, increasingly announce grant programs that require multi-investigator proposals. To pursue these projects, lead scientists must identify investigators who will be willing to participate, possibly at the expense of their personal research programs. They impel everyone to spend more time organizing proposals, getting to know other investigators involved, and otherwise shifting their attention towards larger scientific efforts.

Suppose one million dollars is available to address a particular scientific project. Is it always better to fund four investigators on the project rather than one investigator? Four investigators are likely to be more productive than one investigator, but this choice will have other unintended effects – on researchers (e.g., splitting budgets four ways may mean each researcher has to write more grants to cover his or her graduate students, lab, technicians, summer salary, and so forth, and thus spends more time writing proposals) and on the organization (e.g., faculty are led to write more proposals, but not necessarily with others in their own organization, thus they may increasingly look outside for collaborations). Perverse incentives arise as well (e.g., faculty hire post-docs so that they do not have to spend their research budgets on graduate tuition, even though their own departments rely on such graduate tuition payments). Organization theorists whose expertise is the organizational dimensions of coordination and group identity will find such phenomena a rich domain for study.

The prevalence of distributed science has risen, in part, because of technical advances that make possible virtual organizations (Olson, Zimmerman, & Bos, 2007). For example, one research organization based in California may have two scientists working on a problem, a second organization based in Illinois may have two scientists working on a related problem, and a third organization based in New York with two scientists working on yet another related problem. If the six scientists form a virtual organization that spans California, Illinois, and New York, each research organization has the potential to benefit from the distributed science. However, as with team science, there are both intended and unintended consequences. As research organizations participate in more virtual organizations, the boundary between the established organization and the new virtual organization becomes blurred in terms of how knowledge is controlled and appropriated. For instance, if the virtual organization becomes the focal organization for the two scientists in California in terms of sharing expertise and contributing new ideas, it is possible that the research organization in California will hire four scientists like those found in Illinois and New York to take advantage of their expertise. The knowledge-based view and social network theory may provide insight into the tradeoff between "making" (i.e., all scientists reside in a single research organization with informal ties outside) and "buying" (i.e., scientists in one research organization have a formal virtual organization with other scientists). By taking into account the costs of integrating expertise arising from the geographic dispersion of knowledge (likely higher for a formal virtual organization) and the weak tie benefits arising from having collaborators in different locations (likely higher for a single research organization with informal ties), organizational theorists could assess when making versus buying is preferred for a research organization. Down the road, the risk for research organizations relying too much on distributed science could be that they unintentionally increase the costs of integrating expertise because the virtual organization is outside the control of the research organization. Furthermore, the organization may incidentally reduce weak tie benefits because the virtual organization becomes a competitor and does not bring knowledge and new ideas back into the organization.

Interdisciplinary science presents an interesting domain for understanding how organizations evolve. All scientific disciplines that exist today were, at some point in history, something else. For instance, biochemistry, with many departments of its own today, is an intersection of biology and chemistry that was once considered undesirable territory for biology and chemistry departments. For research organizations that reside at the edge of formal organizational boundaries, there is uncertainty regarding the best approach to advance their agendas. Aside from dealing with institutional challenges such as existing departmental structures, research organizations seeking to bring investigators from different disciplines together must evaluate how to compose their organizations in a productive way. For example, bioinformatics combines biologists, medical scientists, and computer and information scientists. Often the proportions of each field represented are an unplanned consequence of who was unhappy in his or her "real" department and who was tempted by the chance to do something different (or any of a number of other individually based motivations). Organizational learning theory and absorptive capacity theory might help us better understand how interdisciplinary research organizations evolve, taking into account the learning costs associated with cross-discipline understanding, and the capacity benefits associated with assimilating outside ideas that are related to the task at hand.

As a whole, we think a better understanding of how science has changed and how it is being practiced could help resolve debates in science policy and lead to advances in organization theory. For example, a well-known research organization that exemplifies team science, distributed science, and interdisciplinary science is the Human Genome Project, which was primarily funded and coordinated by the U.S. National Institutes of Health and the U.S. Department of Energy. The goal of this project, which lasted from 1990 to 2003, was to identify the 20,000 - 25,000 genes in human DNA, while at the same time determining the sequences of the 3 billion base pairs that make up human DNA. Thousands of scientists worked in teams across centers and universities in the U.S. and abroad, representing disciplines ranging from evolutionary biology to nuclear medicine to physics. From a science policy perspective, it was not clear how to best organize this vast effort. As noted by Collins, Morgan, and Patrinos (2003: 286), "It took most centers awhile, however, to learn how to organize the most effective teams to tackle a big science project. John Sulston, director of the U.K.'s Sanger Centre (now the Sanger Institute) from 1993 to 2000, recalls that 'at first everyone did everything,' following the tradition of manual sequencing groups. However, it soon became apparent to Sulston and others that, for the sake of efficiency and accuracy, it was best to recruit staff of varying skills – from sequencing technology to computer analysis – and to allocate the work accordingly." A greater focus on science would put organizational scholars in a strong position to make evidence-based recommendations to science policy makers about how to best organize and structure these kinds of projects in the future.

Beyond policy, there are practical applications of organization theory for scientists who manage large, distributed, and/or interdisciplinary projects in research organizations. As several principal investigators of these kinds of projects have noted to us in interviews, most scientists are not trained in management or leadership, despite how important it is (Avolio et al., 2009). As a result, scientists often learn to manage and lead through trial and error, rather than through instruction about issues commonly found in the groups literature on how to best assemble a team, resolve conflict when it arises, and interface with external stakeholders. There are also practical applications for administrators of research organizations, such as provosts and deans, who are in a position to define the structure of organizational units. For example, drawing on organization theory, administers can make tradeoffs based on whether functional structures (e.g., organization with disciplinary departments), divisional structures (e.g., organization with interdisciplinary centers focused on different phenomena), or matrix structures (e.g., organization with institutes that cross disciplines by phenomena) provide the right mix of coordination and control (Burton, DeSanctis, & Obel, 2006).

CONCLUSION

Organization theory can contribute significantly to a better understanding of the world of science and technology through the application of theory to research organizations, and would itself profit from this work through the extension and redirection of existing theory. Organization theory would also gain insights from the many pioneering organizational structures, experiments in organizing, new ways of managing, and innovative applications of technology that one can find across the sciences today.

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REFERENCES

Ahuja M, Carley K. 1999. Network structures in virtual organizations. *Organization Science* 10(6): 741-757.

Alberts BM. 1984. Limits to growth: In biology, small science is good science. *Cell* 41: 337-328.

Argote L. 1999. *Organizational Learning: Creating, Retaining, and Transferring Knowledge*. Kluwer Academic Publishers, Norwell, MA.

Avolio B, Reichard R, Hannah S, Wallumbwa F, Chan A. 2009. A meta-analytic review of leadership impact research: Experimental and quasi-experimental studies. *Leadership Quarterly* 20: 764-784.

Becker MC. 2001. Managing dispersed knowledge: Organizational problems, managerial strategies and their effectiveness. *Journal of Management Studies* 38: 1037-1051.

Blau P, Scott W. 1962. *Formal Organizations: A Comparative Approach*. Chandler, San Francisco, CA.

Boh W-F, Ren Y, Kiesler S, Bussjaeger R. 2007. Expertise and collaboration in the geographically dispersed organization. *Organization Science* 18: 595-612.

Boudreau K, Lacetera N, Lakhani K. 2011. Incentives and problem uncertainty in innovation contests: An empirical analysis. *Management Science* 57(5): 843–863.

Bozeman B, Corley E. 2004. Scientists' collaboration strategies: Implications for scientific and technical human capital. *Research Policy* 33: 599-616.

Bresman H. 2010. External learning activities and team performance: A multimethod field study. *Organization Science* 21: 81-96.

Burton RM, DeSanctis G, Obel B. 2006. *Organizational Design: A Step-by-Step Approach*. Cambridge University Press, Cambridge, MA.

Chompalov I, Genuth J, Shrum W. 2002. The organization of scientific collaborations. *Research Policy* 31: 749-767.

Cohen W, Levinthal D. 1990. Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly* 35: 128-152.

Collins F, Morgan M, Patrinos A. 2003. The Human Genome Project: Lessons from large-scale biology. *Science* 300: 286-290.

Colyvas J, Powell W. 2006. Roads to institutionalization: The remaking of boundaries between public and private science. *Research in Organizational Behavior* 21: 305-353.

Corley E, Boardman C, Bozeman B. 2006. Design and the management of multi-institutional research collaborations: Theoretical implications from two case studies. *Research Policy* 35: 975-993.

Cramton CD. 2001. The mutual knowledge problem and its consequences in geographically dispersed teams. *Organization Science* 12: 346-371.

Crowston K. 1997. A coordination theory approach to organizational process design. *Organization Science* 8: 157-175.

Cummings JN, Haas MR. 2012. So many teams, so little time: Time allocation matters in geographically dispersed teams. *Journal of Organizational Behavior* 33(3): 316-341.

Cummings JN, Kiesler S. 2007. Coordination costs and project outcomes in multi-university collaborations. *Research Policy* 36(10): 1620-1634.

Cummings JN, Kiesler S, Zadeh R, Balakrishnan A. 2013. Group heterogeneity increases the risks of large group size: A longitudinal study of productivity in research groups. *Psychological Science* 24(6): 880-890.

Curtis B, Krasner H, Iscoe N. 1988. A field study of the software design process for large systems. *Communications of the ACM* 31(11): 1268-1287.

Dasgupta P, David PA. 1994. Towards a new economics of science. *Research Policy* 23: 487-521.

de Solla Price DJ. 1963. *Little Science, Big Science*. Columbia University Press, New York, NY.

Edmonson A. 2003. Speaking up in the operating room: How team leaders promote learning in interdisciplinary action teams. *Journal of Management Studies* 40: 1419-1452.

Easterby-Smith M, Malina D. 1999. Cross-cultural collaborative research: Toward reflexivity. *Academy of Management Journal* 42: 76-86.

Feldman M, Feller I, Bercovitz J, Burton RM. 2002. Equity and the technology transfer strategies of American research universities. *Management Science* 48(1): 105-121.

Finholt T, Olson G. 1997. From laboratories to collaboratories: A new organizational form for scientific collaboration. *Psychological Science* 8(1): 28-36.

Gittleman M. 2007. Does geography matter for science-based firms? Epistemic communities and the geography of research and patenting in biotechnology. *Organization Science* 18: 724-741.

Gassmann O, von Zedtwitz M. 1999. New concepts and trends in international R&D organization. *Research Policy* 28: 231-250.

Gibbons M, Limoges C, Nowotny H, Schwartzman S, Scott P, Trow M. 1994. *The New Production of Knowledge*. Sage, London, U.K.

Gonzalez VM, Mark G. 2004. Constant, constant, multi-tasking craziness: Managing multiple working spheres. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Vienna, Austria, April 24-29, 2004).

Granovetter M. 1973. The strength of weak ties. *American Journal of Sociology* 78: 1360-1380.

Grant RM. 1996. Toward a knowledge-based theory of the firm. *Strategic Management Journal* 17: 109-122.

Grinter RE, Herbsleb JD, Perry DW. 1999. The geography of coordination: Dealing with distance in R&D work. *Proceedings of SIGGROUP Conference on Supporting Group Work GROUP '99:* 306-315. ACM Press, New York, NY.

Guimera R, Uzzi B, Spiro J, Amaral L. 2005. Team assembly mechanisms determine collaboration network structure and team performance. *Science* 308(5722): 697-702.

Hagstrom W. 1964. Traditional and modern forms of scientific teamwork. *Administrative Science Quarterly* 9: 241-264.

Hansen M. 1999. The search-transfer problem: The role of weak ties in sharing knowledge across organization subunits. *Administrative Science Quarterly* 44: 82-111.

Herbsleb J, Mockus A, Finholt T, Grinter R. 2000. Distance, dependencies, and delay in a global collaboration. *Proceedings of the 2000 ACM Conference on Computer Supported Cooperative Work:* 319-328, Philadelphia, PA.

Hogg MA, Terry DJ. 2000. Social identity and self-categorization processes in organizational contexts. *Academy of Management Review* 25: 121-140.

Huber G. 1991. Organizational learning: The contributing processes and the literatures. *Organization Science* 2(1): 88-115.

Hudson JM, Christensen J, Kellogg WA, Erickson T. 2002. I'd be overwhelmed, but it's just one more thing to do: Availability and interruption in research management. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (April 20-25, 2002).

Inselt TR, Volkow ND, Landis SC, Li T-K, Battey JF, Jr., Sieving P. 2004. Limits to growth: Why neuroscience needs large-scale science. *Nature Neuroscience* 7: 426-427.

Jackson SJ, Ribes D, Buyuktur A, Bowker G. 2011. Collaborative rhythm: Temporal dissonance and alignment in collaborative scientific work. *Proceedings of the ACM Conference on Computer Supported Cooperative Work*. ACM Press, New York, NY.

Jarvenpaa S, Leidner D. 1999. Communication and trust in global virtual teams. *Organization Science* 10(6): 791-815.

Jones B, Wuchty S, Uzzi B. 2008. Multi-university research teams: Shifting impact, geography, and stratification in science. *Science* 322: 1259-1262.

Katz J, Martin B. 1997. What is research collaboration? *Research Policy* 26: 1-18.

Kogut B, Zander U. 1992. Knowledge of the firm, combinative capabilities, and the replication of technology. *Organization Science* 3: 383-397.

Kouzes R, Myers J, Wulf W. 1996. Collaboratories: Doing science on the Internet. *IEEE Computer* 29: 40-46.

Kraut R, Galegher J, Egido C. 1987. Relationships and tasks in scientific research collaboration. *Human-Computer Interaction* 3: 31-58.

Lakhani KR, von Hippel E. 2003. How open source software works: "Free" user-to-user assistance. *Research Policy* 32: 923-943.

Lepak D, Snell S. 1999. The human resource architecture: Toward a theory of human capital allocation and development. *Academy of Management Review* 24(1): 31-48.

Leroy S. 2009. Why is it so hard to do my work? The challenge of attention residue when switching between work tasks. *Organizational Behavior and Human Decision Processes* 109: 168-181.

Llerena P, Meyer-Krahmer F. 2003. Interdisciplinary research and the organization of the university: General challenges and a case study. In A. Geuna, A. Salter, and W. Steinmuller (eds.), *Science and Innovation: Rethinking the Rationales for Funding and Governance*. Edward Elgar Publishing, Northampton, MA.

Luukkonen T. 1998. The difficulties in assessing the impact of EU framework programmes. *Research Policy* 27: 599-610.

Macilwain C. 2009. Genetics: Watching science at work. *Nature* 462: 840-842.

Malone T, Crowston K. 1994. The interdisciplinary study of coordination. *ACM Computing Surveys* 26: 87-119.

March J. 1991. Exploration and exploitation in organizational learning. *Organization Science* 2: 71-87.

March J, Simon HA. 1958. *Organizations*. Wiley, New York, NY.

Marks M, DeChurch L, Mathieu J, Panzer F, Alonso A. 2005. Teamwork in multi-team systems. *Journal of Applied Psychology* 90(5): 964-971.

Mayer R, Davis J, Schoorman F. 1995. An integrative model of organizational trust. *Academy of Management Review* 20(3): 709-734.

McEvily B, Perrone V, Zaheer A. 2003. Trust as an organizing principle. *Organization Science* 14(1): 91-103.

Metzger N, Zare R. 1999. Interdisciplinary research: From belief to reality. *Science* 283: 642-643.

Monge P, Contractor N. 2003. *Theories of Communication Networks*. Oxford University Press, New York, NY.

Moon JY, Sproull L. 2002. Essence of distributed work: The case of the Linux kernel. In Pamela Hinds and Sara Kiesler (eds.), *Distributed Work*: 381-404. The MIT Press, Cambridge, MA.

Murray F, O'Mahony S. 2007. Exploring the foundations of cumulative innovation: Implications for organization science. *Organization Science* 18(6): 1006-1021.

Murray F, Stern S. 2007. Do formal intellectual property rights hinder the free flow of scientific knowledge?: An empirical test of the anti-commons hypothesis. *Journal of Economic Behavior and Organization* 63(4): 648-687.

National Academies. 2004. *Facilitating Interdisciplinary Research*. National Academies Press, Washington, DC. http://newton.nap.edu/catalog/11153.html.

National Academies. 2014. *Science of Team Science*. National Academies Press, Washington, DC. http://sites.nationalacademies.org/dbasse/bbcss/currentprojects/dbasse_080231.

Newman M. 2001. The structure of scientific collaboration networks. *Proceedings of the National Academy of Sciences* 98(2): 404-409.

Ocasio W. 1997. Towards an attention-based view of the firm. *Strategic Management Journal* 18: 187–206.

O'Leary M, Mortensen M. 2010. Go (con)figure: Subgroups, imbalance, and isolates in geographically dispersed teams. *Organization Science* 21: 115-131.

Olson GM, Olson J. 2000. Distance matters. *Human-Computer Interaction* 15: 139-179.

Olson GM, Zimmerman A, Bos ND. 2007. *Science on the Internet*. The MIT Press, Cambridge, MA.

Orlikowski WJ, Yates J. 2002. It's about time: Temporal structuring in organizations. *Organization Science* 13: 684-700.

Paletz S, Schunn C. 2010. A social-cognitive framework of multidisciplinary team innovation. *Topics in Cognitive Science* 2: 73-95.

Pelz D, Andrews F. 1966. *Scientists in Organizations: Productive Climates for Research and Development*. Wiley, New York, NY.

Philippidis A. 2013. Ph.D.s need not apply: Will the glut of docs and postdocs ever shrink? *Genetic Engineering & Biotechnology News* 33(19): 6-7.

Polzer JT, Milton LP, Swann WB, Jr. 2002. Capitalizing on diversity: Interpersonal congruence in small work groups. *Administrative Science Quarterly* 47: 296-324.

Priem RL, Butler J. 2001. Is the resource-based "view" a useful perspective for strategic management research? *Academy of Management Review* 26: 22-40.

Puranam P, Raveendram M, Knudsen T. 2012. Organization design: The epistemic interdependence perspective. *Academy of Management Review* 37(3): 419-440.

Rhoten D, Parker A. 2004. Risks and rewards of an interdisciplinary research path. *Science* 306: 2046.

Rousseau D, Sitkin S, Burt R, Camerer C. 1998. Not so different after all: A cross-discipline view of trust. *Academy of Management Review* 23(3): 393-404.

Schmoch U, Hinze S, Jackel G, Kirsch N, Meyer-Krahmer F, Munt G. 1996. The role of the scientific community in the generation of technology. In G. Reger and U. Schmoch (eds.), *Organisation of Science and Technology at the Watershed:* 3–138. Physica-Verlag, Heidelberg, Germany.

Stokes D. 1997. *Pasteur's Quadrant: Basic Science and Technological Innovation*. Brookings Institution Press, Washington, DC.

Stokols D, Hall K, Taylor B, Moser R. 2008. The science of team science: Overview of the field and introduction to the supplement. *American Journal of Preventive Medicine* 35(2S): 77-89.

Tajfel H, Turner JC. 1986. The social identity theory of intergroup behaviour. In S. Worchel and W.G. Austin (eds.), *Psychology of Intergroup Relations:* 7-24. Nelson-Hall, Chicago, IL.

Teece D. 1998. Research directions for knowledge management. *California Management Review* 40(3): 289-292.

Tichy, N. 1981. Networks in organizations. In P.S. Nystrom and W.H. Starbuck (eds.), *Handbook of Organizational Design:* 225-249. Oxford University Press, New York, NY.

Tsay J, Dabbish L, Herbsleb J. 2012. Social media and success in open source projects.

Proceedings of the ACM Conference on Computer Supported Cooperative Work: 223-226. ACM Press. New York, NY.

Turner JC. 1985. Social categorization and the self-concept: A social cognitive theory of group behavior. In E.J. Lawler (ed.), *Advances in Group Processes: Theory and Research:* 2: 77-122. JAI Press, Greenwich, CT.

Van der Vegt G, de Jong S, Bunderson JS, Molleman E. 2010. Power asymmetry and learning in teams: The moderating role of performance feedback. *Organization Science* 21 (2): 347-361.

Van de Ven A, Delbecq A, Koenig R. 1976. Determinants of coordination modes within organizations. *American Sociological Review* 41: 322-338.

van Leeuwen T, Tijssen R. 2000. Interdisciplinary dynamics of modern science: Analysis of cross-disciplinary citation flows. *Research Evaluation* 9(3): 183-187.

von Hippel E, von Krogh G. 2003. Open source software and the "private-collective" innovation model: Issues for organization science. *Organization Science* 14: 209-223.

Vural M, Dahlander L, George G. 2013. Collaborative benefits and coordination costs: Learning and capability development in science. *Strategic Entrepreneurship Journal* 7(2): 122-137.

Waller MJ, Zellmer-Bruhn M, Giambatista RC. 2002. Watching the clock: Group pacing behavior under dynamic deadlines. *Academy of Management Journal* 45: 1046-1055.

Walsh JP, Maloney NG. 2007. Collaboration structure, communication media, and problems in scientific work teams. *Journal of Computer-Mediated Communication* 12(2): 712-732.

Weber M. 1968. *Economy and Society*. G. Roth and C. Wittich (eds). Bedminister Press, New York, NY.

Wood C, Sullivan B, Iliff M, Fink D, Kellig S. 2011. eBird: Engaging birders in science and conservation. *PLoS Biology* 9(12): e1001220.

Wuchty S, Jones B, Uzzi B. 2007. The increasing dominance of teams in production of knowledge. *Science* 316: 1036-1039.

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WILL ORGANIZATION DESIGN BE AFFECTED BY BIG DATA?

GILES SLINGER • RUPERT MORRISON

Abstract: Computing power and analytical methods allow us to create, collate, and analyze more data than ever before. When datasets are unusually large in volume, velocity, and variety, they are referred to as "big data." Some observers have suggested that in order to cope with big data (a) organizational structures will need to change and (b) the processes used to design organizations will be different. In this article, we differentiate big data from relatively slow-moving, linked people data. We argue that big data will change organizational structures as organizations pursue the opportunities presented by big data. The processes by which organizations are designed, however, will be relatively unaffected by big data. Instead, organization design processes will be more affected by the complex links found in people data.

Keywords: Organization design, big data, organizational structure, organization design process

We participated in the Big Data and Organization Design conference in Paris, May 2013, as representatives of Concentra, our consulting firm which specializes in design, data analytics, and technology. Many speakers at the conference discussed the various impacts of big data, defined as "high-volume, -variety, and -velocity information assets that demand cost-effective, innovative forms of information processing for enhanced insight and decision making" (Laney, 2001). With respect to business organizations, big data allows more accurate customer segmentation in marketing. In health care, big data supports more targeted diagnosis and treatment. In employee recruiting, big data allows employers to screen more accurately. In the supply chain, big data reduces inventory wastage. And big data promises to alter the shape of organizations in many as yet unknown ways.

At the enterprise level, Galbraith (2012) proposes that big data will change organization structure, as large multinational firms will restructure to add a (fifth) structural dimension. Some new functions will engage in big data operations, which will distinguish themselves from the rest of the organization, just as the previous four structural emphases divided the organization according to (1) functions, (2) product divisions, (3) international units, and (4) customer segments. Big data will also change roles and power structures (Galbraith, 2014).

At the moment, big data is a promising technological innovation that may affect many business models. Is it really a step change, however, in its effects on how organizations are structured? Further, is big data going to change the processes by which we design organizations? Based on our experience from working with clients on organization design projects, we believe that big data will affect how organizations are structured more than how they are designed. In this article, we explore three propositions:

1. Organizations will be restructured to take advantage of big data opportunities.
2. Processes of organization design are unlikely to change because of big data.
3. The organization design process is not based on the volume, variety, and velocity of data; it is based on the slow-moving, linked nature of people data.

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ORGANIZATIONS WILL BE RESTRUCTURED BECAUSE OF BIG DATA

This proposition looks like an open-and-shut case – organizations are already restructuring to deal with big data. Galbraith (2014) discussed the example of Proctor & Gamble, which has created "control towers" to maintain continuously updated control of its supply chain. He also highlighted Amazon, which says it wants to be the world's most customer-centric organization, mostly by understanding its customers' data in great depth. And he described Nike, which created its Nike Digital Sports division in 2010, putting sensors in shoes, clothes, and watchbands, and setting up virtual athletics communities.

Why should companies restructure themselves to deal with big data? Resource allocation becomes much more flexible in organizations that can apply big data. With visibility of demand levels and supply volumes, they find it easier to move people, capital, and other resources across sites, functions, roles, and positions. For example, a theme park can reallocate staff quickly to busy areas, or a supermarket can respond rapidly to forecasts of changing weather conditions. Today, we find it normal that a supermarket chain should seek detailed insights on the impact that weather conditions have in different store locations and at different times on customers' behavior. Yet analyses as recent as Starr-McCluer (2000) could find only modest impact of weather on sales. Such an analysis seems almost to be from a different era because data available at that time was only available in aggregated forms. Starr-McCluer's data sources, for example, were average monthly temperature data across the whole of the U.S. and average monthly sales data across ten types of retail operations. This compares with modern sales data, which are minute-by-minute, and modern weather metrics, which are hour-by-hour, both types of data allowing for real-time analytics and decision-making.

It is clear that the volume and granularity of big data opens up possibilities that have never previously existed to track the supply chain and customer-company interaction. That will mean opportunities to deliver better services which, in turn, will require different kinds of organizational structures. Interestingly, Galbraith (2012) argues that this will also generate new tensions, and the most successful organizations will be those that manage the conflicts of direction and interest that will inevitably arise from having up to five different structural emphases in the business. Galbraith's (2012) observation echoes that of McAfee and Brynjolfsson (2012), who point out that big data will alter the sources of influence in the organization. The location of decisions will change, for example, as HiPPOs (the "Highest Paid People in the Organization") find that they need to allow their judgment-based decision-making to be modified, and at times overruled, by data-driven insights.

PROCESSES OF ORGANIZATION DESIGN ARE UNLIKELY TO CHANGE BECAUSE OF BIG DATA

Proposition 2 is much harder to affirm than Proposition 1. The overall process of organization design is typically described in stages, moving from the outside in: (a) environmental (external) analysis, (b) definition of the organization's purpose and mission, (c) assessment of the existing organization (internal analysis), (d) detailed design, and (e) implementation and review. An example of the overall design process is shown in Figure 1.

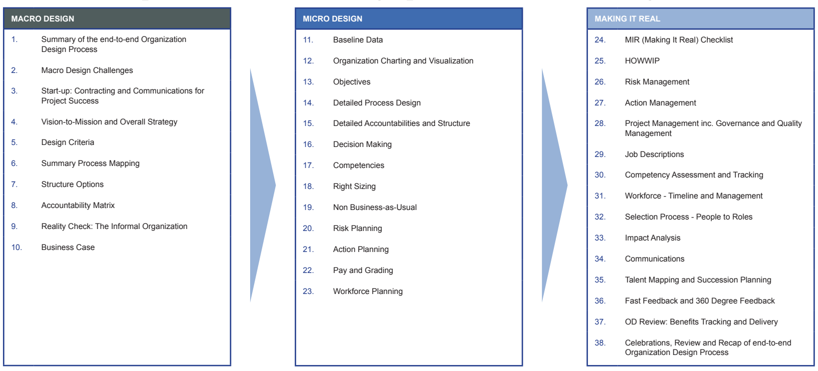

Fig. 1. Organization Design Process

Will the processes of organization design, as illustrated in Figure 1, change as a result of big data? Our firm has asked many academics and businesspeople how they think big data will change the process of designing organizations. A few predictions have emerged – crowd-sourcing of ideas for process change (a new source of data), data-mining CV or LinkedIn text for information on competencies (a new use of unstructured data), fast adjustment of organizational objectives in response to changing market conditions (a new use of high-velocity data) – but no clear patterns are evident. Therefore, we gathered examples of big data's impact that we could find in the literature and assessed whether each one would change the *structure* of organizations or the *process* of designing organizations (see Table 1).

Table 1. How Big Data Affects Organizational Structure and Design Process

What Makes it Big data?	Example	Change Organizational Structure?	Change Design Process?	Comments
Volume of data	Crowdsourcing of ideas for change in products or processes	Potentially by altering the products or services provided	No	Data mostly used for product and service re-design. Could indirectly impact the shape of organization needed, e.g., Sainsbury's: (a) Colleague Feedback panel has 3000 members; (b) "Tell Justin" gave >30,000 ideas during 2006–2010.[1]
Variety of data	Data on behavior, capabilities, personality profile, performance, absence, ENPS, NPS, mood, text, image data, etc.	Yes—could affect allocation of people to roles	Does not affect the method for designing roles	Many data types used historically for individual performance assessment and development are now available for analytics of large groups.
Velocity of data (1)	Staffing in response to changing external demand levels	Yes—alters the number of roles in the organization continuously	No—the structures are designed in the same way	The organization does not have to restructure itself formally. It uses a more effective right-sizing process to allocate staff where needed.
Velocity of data (2)	Internal fast feedback, as opposed to annual surveys	No—is about quality control, not structural change	Faster data—if linked to structures, clients or skills—can make responses more rapid but not different in type	Monthly data on management performance allows more rapid intervention. Fast feedback can help the organization respond to managers' training needs, but does not affect the organization structure.
Velocity of data (3)	Ability to respond in real time to customer needs or security issues	Only if organization needs new structures to respond	No—the design process is unchanged	Structural change required only if organization cannot "increase its clock speed" through current structural forms.

Our conclusion, based on assessing examples from the literature, is that the conventional big data factors (volume, variety, velocity) will affect how organizations are structured but not the process by which they are designed. To support this assertion, we documented the sizes of the largest datasets that Concentra has used in its various organization design projects (see Table 2). It is notable that the "macro" design stage – which is often the focus of organization design theory – generally uses smaller datasets. It is only for the very largest organizations, and for very detailed feedback or planning, that dataset sizes are larger than a million data points. Larger datasets occur in the "micro" design and implementation stages when the organization is making detailed evaluations of accountabilities, objectives, decisions, and competencies associated with individual employees.

1 Allen (2010) and Transparent Consulting interviews with Sainsbury's HR team, 2010.

Table 2. Data Requirements for 20 Organization Design Activities, Sorted by Stage of Implementation

Design Activity	Phase	Data Used	Data Points Per Size of Org (FTE)		
			1,000	10,000	100,000
Start-up: Contracting and Communications for Project Success	Macro Design	For informal network mapping: n employees * at most (5 * influence ratings from syrveys + 12 * email traffic mapping outputs + 3 * mapped expert references)	20,000	200,000	2,000,000
High-Level Process Design	Macro Design	List of outputs and 100-10,000 processes	100	1,000	10,000
Vision-to-Mission and Overall Strategy	Macro Design	List of company's stated mission, strategy items	20	20	20
Design Criteria	Macro Design	5-10 design criteria	10	10	10
Structure Options	Macro Design	3-6 structure options	10	10	10
Objective Mapping	Micro Design	n employees * 10 objectives * 12 datapoints	120,000	1,200,000	12,000,000
Detailed Accountabilities and Structure	Micro Design	n employees * 10 items responsible + 50 items supporting + 10 items approving	70,000	700,000	7,000,000
Decision Making	Micro Design	n employees * up to 50 decisions	50,000	500,000	5,000,000
Organization Charting and Vissalization	Micro Design	ID, Manager ID * n employees	2,000	20,000	200,000
Baseline Data	Micro Design	Summary business data - headount, orles, key outputs, objectives, KPIs	22	22	22
Right Sizing via Benchmark Comparisons	Micro Design	Up to 100 key comparisons vs. own data (e.g. % headcount in core function)	200	200	200
Fast Feedback	Implementation	Monthly feedback on 5 questions on implementation effectiveness for up to 3 years from n employees	180,000	1,800,000	18,000,000
Selection Process - People to Roles	Implementation	Mapping of 50 skills vs. 5 roles for n/10 candidates	25,000	250,000	2,500,000
Competency Assessment and Tracking	Implementation	n employees * 10-50 competencies * periodic updates	20,000	200,000	2,000,000
Impact Analysis	Implementation	Mapping of impact of To-Be vs As-I on e.g. 5 dimensions for each employee (e.g. line manager, location, role, pay, hours)	10,000	100,000	1,000,000
Talent Mapping	Implementation	Map n employees into 9 categories (for 9 box grid)	9,000	90,000	900,000
Succession Planning	Implementation	Map up to 5 employees into each role needing successor	5,000	50,000	500,000
Workforce Planning - Timeline and Management	Implementation	Plan for up to 1000 roles* periodic headcount per role (e.g. monthly for 3 years), plus tracking actual vs. plan	720	7,200	72,000
Pay and Grading	Implementation	Analysis of job complexity on 10 dimensions * number of distinct roles	100	1,000	10,000
Job Descriptions	Implementation	10-1000 standard role descriptions	10	100	1,000

Source: Concentra Consulting, OrgVue, Slinger (2014)

In short, it appears that the scale of data is not the major challenge in the processes used for designing organizations. Nor is it the speed of change in the data. Instead, it seems that the primary data challenge in the design process is how to deal with the slow-moving, linked nature of people data.

THE PROCESS OF ORGANIZATION DESIGN WILL BE BASED ON SLOW-MOVING, LINKED PEOPLE DATA

To understand the organization design process, we believe it is useful to focus on a particular type of data: people data. We define people data as data that has the worker – the current, potential, or former employee or contractor – as a key unit of analysis. People datasets are more often available, and they are richer today than in the past. Employers can, in principle, collect extensive information on daily productivity, working time, location, and even e-mail exchanges and other forms of social interaction. However, the most common elements of people data used for organization design are the same as they have been for a long time: current and forecasted headcount, fully loaded personnel costs, skills and experience, project preferences, and so on.

Why the Individual Matters as a Unit of Analysis

Using the individual as the unit of analysis puts a constraint on a full optimizing approach to organization design. In principle, organizations should be designed by "pull" – as a flow from the products and services that customers will buy, through the activities required, through the competencies needed, through the roles that cluster the competencies, to the teams that bring together the roles, and lastly, to the organizational structures that bring the teams together. The model that could exist in principle, however, hits a conceptual stumbling block. Competencies do not link directly to roles. They are clustered in people. People do not change very fast, and they are not divisible. Working hours and salaries are, by law, difficult to alter. New skills take time to learn. Relationships between peers and across hierarchical levels take time to build. Creativity and commitment influence the quality of output. In sum, the embodiment of organizational characteristics in units of people changes the nature of the design problem.

People Data Are Not "Big"

People data have always posed challenges for organizational analysis, but we should not overestimate that analytical challenge. People data are sparsely populated and slow moving. The actual number of links between organizational components is low. For example, imagine an organization of 1,000 people in 1.1 roles each, ten activities each, and ten products and twenty clients handled by each. The organization has, at most, a total of 2.2 million connections – still a lot in absolute terms, but not an especially big number for analytical purposes. The data in this "small" people dataset are usually incomplete, changing, and linked in complex ways that makes the organization design process challenging.

Dealing with People Data: Iteration and Simplification

Organization designers have responded to the challenge of optimizing the performance of the organization as a complex system by iteration and simplification. The iterative approach reminds us to treat the organization as a system. Interdependencies and linkages within the organization mean that change must be tested and cascaded layer by layer. This approach has the benefit of reducing risks caused by unexpected complex interactions within the system but will result in local variations from the preferred overall design. Some of those variations may be appropriate, and some may be costly, but no systemically optimal design exists. The simplifying approach may view the overall organization as a system, but typically it intervenes on one aspect such as demographics, competencies, talent, succession, or activity costs. This can provide consistency of treatment across the organization (e.g., standard processes, standard ratios, standard pay rates, standard spans of control), but the resulting design may be susceptible to unexpected consequences. Both approaches are adaptations to deal with the challenge of optimal organization design, but neither approach models the organization as a system.

How People Data Affect the Design Process

People data affect both the organization's design and the process of design itself. By employing some of the newer uses of people data, designers can come closer to optimizing their designs. We discuss some of these newer uses below, and they are summarized in Table 3.

Table 3. Where People Data Might Affect the Organization Design Process

Uses of People Data	Example	Impact on Organization Structure	Impact on Design Process	Implications
Informal Networks Data	Data on social capital—influence, communications, importance to the organization through informal networks	Yes—could lead to simpler structures if it showed formal hierarchies not needed	Yes—supporting an evolving organization design with leaders emerging through interaction	Extends mapping of the organization into data on new types of relationships—not just hierarchical or matrixed, but informal and influence. Offers additional “capability” variable(s) per person.
Data Visualization	People data particularly relevant for expressing via color, size, shapes, and hierarchical structures	No direct impact on structure	Adjustment more likely if managers see where costs, skills, and customer impacts are	Visualization could affect organization design—by giving a sense of the organization more intuitively, it might be more possible to achieve an organization design that makes sense to more people.
Incomplete Data	People data might be incomplete, but might still be necessary for organization design	Could allow simpler and more flexible structures	Incomplete data could be used for incomplete design—x% adaptable	Organizations have always been re-designed on the back of napkins. However, it would be innovative if organizations were designed consciously to cope with incomplete data.
Data Reflexivity	People datasets can affect themselves—as expressed in the feedback loops in Silverman Research’s Social Media Garden	Does not change structure directly	Yes—the organization design process can evaluate its own progress and adapt	An exciting extension of the idea of group training environments where the group is explicitly invited to reflect on its own process, take ownership of it, and improve how it operates (Silverman, 2012).
Linked Relationships	People data are unusually highly linked—to processes, costs, customers, skills, services, objectives, etc.	Potential new role for strategy team / MI team	Yes—design and monitor systemic impact during the change process	It has always been hard to link and process the data. As this becomes possible on an ongoing basis, people will be more able to reconfigure their organizations as needed.

Informal networks data. Stephenson and Lewin (1996), Farmer (2008), Cross (2009), and others have investigated the informal networks that exist within and outside formal hierarchical structures. For example, an individual’s influence (or social capital) can be mapped onto networks of innovation, knowledge, and collaboration, amongst others. Informal network analysis can be used during an organizational redesign as a reality check by asking, for instance, are our nominated leaders really people of influence? An example of informal networks analysis is shown in Figure 2, where managerially nominated influencers who may hitherto have been “over-recognized” (red) are contrasted with peer-nominated influencers who may have been “under-recognized” (green).

Informal networks data can also be used to plan for how an organization will evolve flexibly, as in the design of the U.K. government’s transport innovation network (Transport Catapult, 2014). It has been designed to include innovation teams with individuals selected both for their capabilities and for their personal innovation networks. Collaboration levels are measured monthly on internal team working, inter-team working, and interactions with key innovators in parent organizations. Project manager roles are filled by emergent leaders from within each project team, typically within the first six weeks of the project team’s life. The “health” of these networks is a key leading indicator of innovation success or failure (Farmer, 2013).

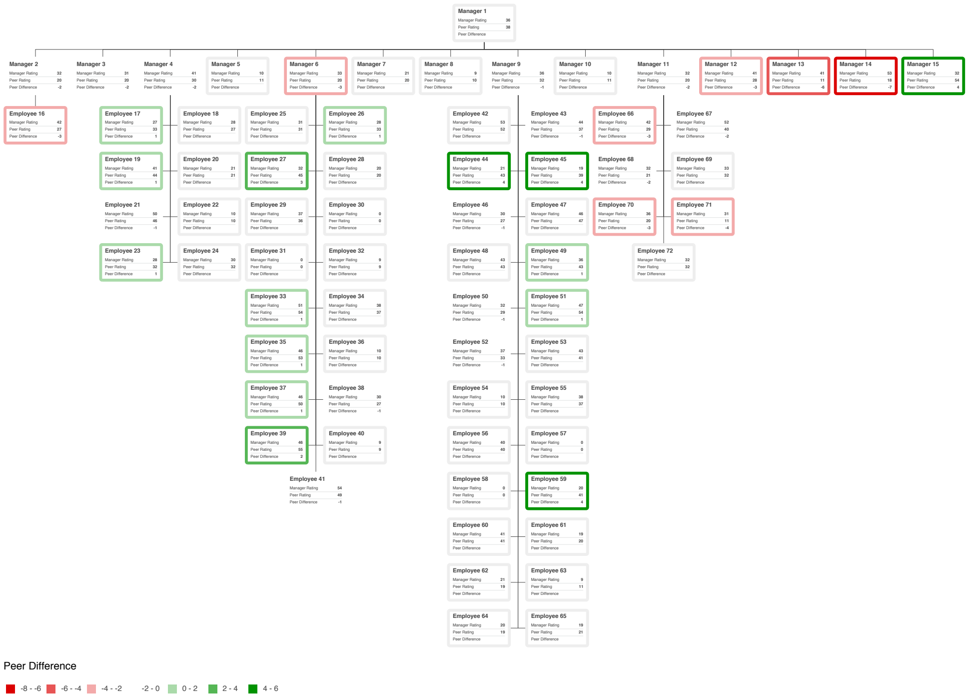

Fig. 2. Mapping Informal Networks on Hierarchical Structures

Data visualization. Davenport and Patil (2012) have argued that data cleansing, organization, and visualization will be critical skills for managing big data. Our recent consulting work has shown us that visualization also works well for people data. Figure 3 shows a business firm which had historically visualized its cost in tables of numbers or bar charts per division. It mapped people to processes using linking software to see the cost per process for everything it did. The impact was that at a single click the organization could change between seeing itself as a hierarchy and seeing itself as a set of processes. This made it easier to facilitate staff discussions around processes that needed to improve – in effect, the organization re-designed itself.

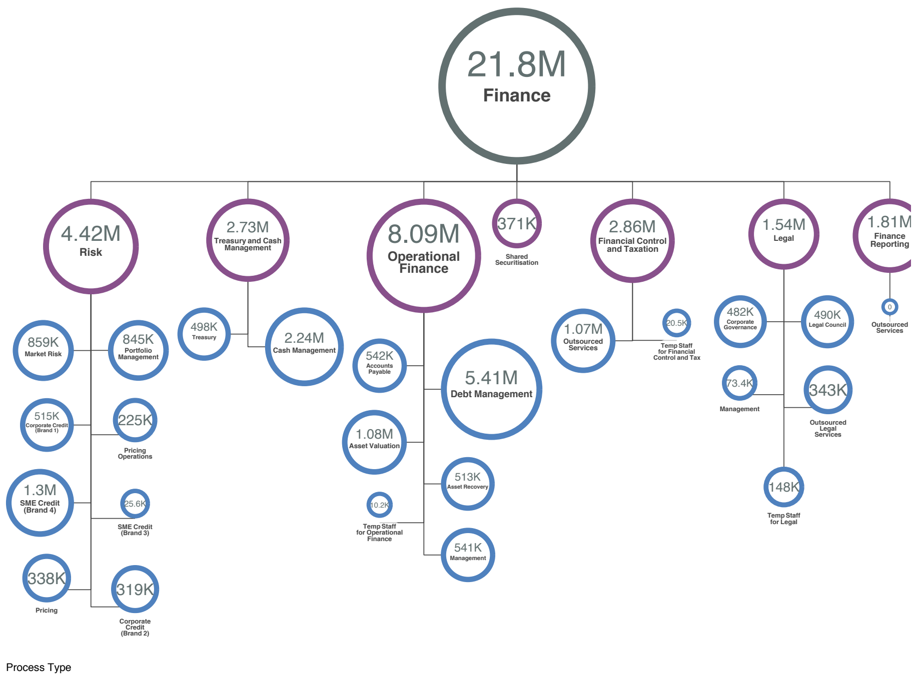

Fig. 3. Process Cost Visualization.
Source: Concentra

Incomplete data. Incomplete data might be seen as a problem for organization design. After all, an organization design is meant to treat the whole organization as a system – linking people to roles, to processes, to competencies, to client deliverables, and to objectives. Linked datasets are valuable in addressing incomplete data because they expose gaps. For example, a company may understand 100% of its costs. But in a changing world, can we link costs to processes? Can we link costs to clients? We have listed our organization's risks, but do we know who is responsible for handling each one? As people's roles change and outside factors alter risk levels, can we track who is overloaded? It is easier to sense-check this kind of analysis through linked datasets than it is through simple "one-aspect" datasets.

Data incompleteness also may be used deliberately. Google's 70-20-10 work system is based on the idea that the most valuable innovations may come from unexpected areas. Google has empowered its employees to spend up to 30% of their time on whatever seemed to them to be the most valuable use. It can be argued that this "unstructured" time is actually structured and managed very effectively. Peers review the work done, the choices made, and the results achieved in briefing sessions. Google's unstructured work time is an example of how organizations can be designed flexibly to include information gaps, to convert unstructured innovation into structured value.

Data reflexivity. Silverman Research's Social Media Garden allows a large group of people in an organization to consider ideas reflexively. Reflexive consideration means that people not only give their suggestions, but as Figure 4 shows, can view a bubble map of each other's suggestions – including size, color, and location indicating others' interest and agreement – and can respond. This design tool encourages ideas to develop over several rounds, allowing the socially constructed mass of ideas to influence its own evolution.

Fig. 4. Idea Mapping and Rating in Silverman Research's Social Media Garden.
Source: Silverman Research (www.silvermanresearch.com)

This methodology for gathering group ideas genuinely differs from surveying due to its looped nature and differs from a "town hall" meeting because of its greater potential scale and anonymity. It can be used as a step in the process of organization design, to surface issues and evaluate options.

Linked data. During the organization design process, we have found it critical to be able to link aspects of the organization to one another, so that impacts throughout the system can be understood properly. Linking is necessary because the many-to-many relationships between one aspect of the organization (e.g., people) and another aspect (e.g., responsibilities) are difficult to model and maintain in normal datasets. Linking is vital because it helps the organization to be conscious of where it has specified its activities, skills, deliverables, and risks, and where it still has gaps.

Figure 5 gives a conceptual model of an IT infrastructure supply company in which OrgVue was used to map (a) clients into client segments, (b) services to client segments, and (c) people to the services that they carry out for clients. Such a mapping allows designers to understand the connections between the client segments and the true underlying cost, either at the client level or the service level. This is vital for understanding the true cost to serve per client and redesigning the organization's structure and workflow.

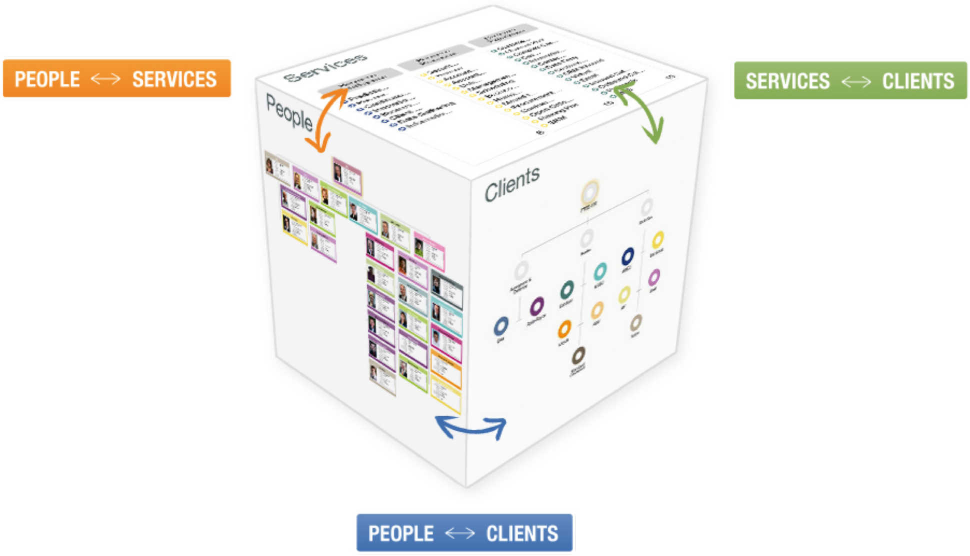

Fig. 5. Image Representing a Linked Model of People-Clients-Services.
Source: OrgVue (OrgVue.com)

Linking different aspects of people in an organization reflects the reality of organizational life. Linked connections, often mapped through graph databases (Webber, 2013), are fundamental to understanding organizations because:

- They are how humans work – but not how we are trained to think. We find it very hard to think in two connected dimensions at once, so we need systems that will let us agree on actions in one dimension and see their impact on other dimensions.
- They reflect reality. People may carry out multiple roles, have multiple skills, and deal with multiple customers or multiple products.
- They deal with the connectedness of change. When change occurs, organizations have to adapt as elements that are linked together. And those connected elements end up with a clustered, connected item: people.

CONCLUSION

The structures of organizations will certainly be different because of big data. We prefer goods that arrive on time, services on which we can give feedback, and recommendations that are tuned into our wants and needs. Big data can help with all of these desires. But the process of organization design is not a big data problem. The process of organization design is fundamentally driven by the bundled, reflexive, and linked nature of people data. People data are multiple-aspect with many-to-many links. Successful organization design in the future will make use of all the traditional tools, but it can avoid having to build enormous data warehouses. Instead, it will supplement the existing databases with graphing, visualization, and linking tools and methods that at last will let us treat organizations properly as systems.

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REFERENCES

Allen K. 2010. Companies that put employee engagement into practice. *Observer* 22 August 2010.

Cross R. 2009. *Driving Results through Social Networks: How Top Organizations Leverage Networks for Performance and Growth*. Jossey-Bass, San Francisco, CA.

Davenport TH, Patil DJ. 2012. Data scientist: The sexiest job of the 21st century. *https://hbr.org*.
Farmer N. 2008. *The Invisible Organization: How Informal Networks Can Lead Organizational Change*. Ashgate Publishing Company, Burlington, VT.
Farmer N. 2013. E-mail to the authors, Informal Networks Ltd.
Galbraith JR. 2012. The evolution of enterprise organization designs. *Journal of Organization Design* 1(2): 1–13.
Galbraith JR. 2014. *Designing Organizations: Strategy, Structure, and Process at the Business Unit and Enterprise Levels*. Jossey-Bass, San Francisco, CA.
Laney D. 2001. Gartner definition of big data. https://www.gartner.com (Accessed on October 17, 2014)
McAfee A, Brynjolfsson E. 2012. Big data: The management revolution. *https://hbr.org*.
Silverman M. 2012. Social Media Garden, *Silverman Research Online*.
Slinger G. 2014. Dataset size for organization design. blog.orgvue.com, Concentra, February 2014.
Starr-McCluer M. 2000. The effects of weather on retail sales. Working Paper. Federal Reserve Board of Governors, Washington, DC.
Stephenson K, Lewin D. 1996. Managing workforce diversity: Macro and micro level HR implications of network analysis. *International Journal of Manpower* 17(4/5): 168–196.
Transport Catapult. 2014. *https://ts.catapult.org.uk/* (Accessed on February 8, 2014).
Webber J. 2013. A little graph theory for the busy developer. *SkillsMatter.com*, May 29.

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UNTANGLING THE AMBIDEXTERITY DILEMMA THROUGH BIG DATA ANALYTICS

TOR BØE-LILLEGRAVEN

Abstract: Ambidexterity theory suggests that the ability to simultaneously explore and exploit is linked to firm performance, but the empirical evidence to date is mixed. In this study, I review existing research on firm performance in the newspaper industry in order to identify the main causal factors in a single industrial context. Three broad categories emerge: media convergence, organizational ambidexterity, and business model innovation. By incorporating variables and arguments from these categories into a basic performance model, I develop a multi-dimensional conceptual framework of explore and exploit value chains. The article concludes with a discussion of how the explore/exploit framework can be operationalized using big data analytics, and recommendations for future research are offered.

Keywords: Ambidexterity, exploration-exploitation, organizational performance, big data, analytics capability, organization design

The "ambidexterity premise" suggests that organizations capable of exploiting existing businesses while simultaneously[1] exploring new opportunities may achieve superior performance compared to firms emphasizing one at the expense of the other (Raisch & Birkinshaw, 2008; Tushman & O'Reilly, 1996). But despite hundreds of studies over the past 15 years, the empirical evidence linking ambidexterity and firm performance remains mixed. Junni et al. (2013), in their recent meta-analysis of ambidexterity research to date, found that exploitation was linked to profits whereas exploration was linked to growth, but they point out that it is not clear *when* and *how* ambidexterity affects firm performance. They recommend that future studies should consider multiple, fine-grained measures within specific industry contexts to further our understanding of the ambidexterity-performance relationship (Junni et al., 2013: 19).

In this study, I follow their recommendation by examining ambidexterity in the empirical context of the newspaper industry. This is an appropriate context for studying the relationship between ambidexterity and firm performance, given that newspaper firms over the past

1 I would like to thank an anonymous reviewer for pointing out the ambiguity of the word "simultaneously" – does it exclude a cyclical emphasis on exploration and exploitation over time? In their original 1996 article, Tushman & O'Reilly introduce the idea of the ambidextrous organization, where exploration and exploitation are undertaken at the same point in time by structurally independent units, each having its own processes, structures, and culture. In a later study, the authors specifically emphasized that ambidextrous organizations do not switch between exploration and exploitation – they do both simultaneously (Tushman et al., 2002: 9). However, in their 2013 review of the ambidexterity literature, O'Reilly and Tushman expand the concept to include the idea of sequential/temporal ambidexterity, which suggests firms may in fact shift their emphasis between exploration and exploitation over time. I would add that this issue might be dependent on the level of analysis. At the level of the firm, a structural separation of organizational resources may allow for simultaneous exploration and exploration. However, this may not be feasible at lower levels of analysis – i.e., for individuals. See, for example, Gupta et al. (2006: 698), who argue that exploration and exploitation should be conceptualized as mutually exclusive when confined to a single domain (i.e., individual or subsystem), and that individuals accordingly must shift their attention and efforts between exploration and exploitation over time.

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two decades have embarked on a digital transformation of their business to explore the value potential offered by the Internet, social media, and mobile devices while relentlessly exploiting the legacy print business (Lawson-Borders, 2006; O'Reilly & Tushman, 2013; Quinn, 2005; Tameling & Broersma, 2013). I investigate whether recent advances in big data analytics – the process of collecting, organizing, and analyzing large sets of data to discover patterns and other useful information – may hold the power to untangle explore-exploit complexities, providing firms with real-time insights into the trade-offs between pursuing new and old business, and potentially reduce the risks and uncertainties involved in exploring dynamic business environments in particular.

The article is structured as follows. First, I systematically review past research on the newspaper industry to synthesize what we know about firm performance in the digital age. Three categories of potential causal factors emerge from this review: media convergence, organizational ambidexterity, and business model innovation. Next, I use these factors to develop a multi-dimensional conceptual framework of explore and exploit value chains in the newspaper industry. This allows for an in-depth examination of the relationship between ambidexterity and firm performance. The article concludes with a discussion of how this framework can be operationalized using big data analytics and derives implications for future ambidexterity research.

LITERATURE REVIEW: FIRM PERFORMANCE IN THE NEWSPAPER INDUSTRY

To identify relevant literature on firm performance in the newspaper industry, I used the EBSCO host database to conduct a systematic literature review by accessing Academic Search Elite, Business Source Alumni Edition, Business Source Complete, Communication & Mass Media Complete, eBook Collection (EBSCOhost), EconLit, ERIC, PsycARTICLES, PsycCRITIQUES, PsycEXTRA, PsycINFO, Regional Business News, and SocINDEX with Full Text. To ensure research quality, the search was limited to peer-reviewed scholarly journals published in English over the period 1994-2013. Table 1 is a summary of the search terms used and the number of articles found.

Table 1. Search terms used and number of articles found

Newspaper performance	*109*
Newspaper explore-exploit	*0*
Newspaper ambidexterity	*0*
Newspaper business	*235*
Newspaper innovation	*43*
Newspaper organization	*134*
Newspaper management	*84*
Newspaper multimedia	*23*
Newspaper convergence	*25*
Newspaper organization online	*4*
Newsroom management	*19*
Newsroom organization	*26*
Newsroom convergence	*51*

This search process yielded a total of 593 articles. When duplicates were removed, 358 articles remained. To identify articles that specifically focused on the newspaper industry, I examined each of the 358 articles for its industry context. The industry filter reduced the number of potentially relevant articles to 197. Each of those articles was content analyzed, looking at factors such as type of newspaper, firm performance, organization theories used for analysis, research methodology, empirical sample, and relevant findings (where applicable). The content analysis further reduced the sample of articles to 33 that specifically addressed firm performance in the context of the newspaper industry. The content analysis suggested three streams of research involving firm performance in the newspaper industry: media convergence, organizational ambidexterity, and business model innovation.

Media Convergence

One prominent media research stream concerns convergence – the integration of technologies, products, organizations, and business models among the previously distinct provinces of print, television, and online media. In the early 2000s, this stream of research theorized how integrated news organizations would provide superior news coverage and capture lucrative new audiences (Boczkowski, 2004; Deuze, 2004; Fioretti & Russ-Mohl, 2009; Kolodzy, 2006; Lawson-Borders, 2006; Quinn, 2005; Quinn & Filak, 2005; Singer, 2004). Much of the research focus has been on providing a normative, step-wise model to describe how newspaper firms can "become" convergent. Tameling and Broersma (2013), in their review of the convergence literature, note that the current research presents a "fuzzy picture of a confused profession," suggesting that convergence is not an end-goal for organizations but rather a continuous struggle to balance journalistic aims and profitability through a fundamental technological disruption. Legacy newspaper firms want to embrace the opportunities offered by digital technologies but have to "balance the certainties of their present business model with the uncertainties of a digital future" (Tameling & Broersma, 2013: 20). My review indicates that most convergence studies are found in the social sciences, rely on qualitative data, and offer limited insights into the specifics of newspaper firm performance – in particular, across print/online business domains. One notable exception is Graham and Greenhill (2013), who examined the influence of print/online convergence on the rate of print circulation change for 100 regional newspapers in the U.K. Their regression analysis suggested that established firms with premium pricing, multiple-platform distribution, and free online content had print circulations that declined less than other newspapers. Also, in a study of the relationship between organizational changes and performance in newspaper firms, van Weezel (2009) found that integration and outsourcing positively affect financial performance.

Organizational Ambidexterity

Ambidexterity suggests that the simultaneous exploration of new business opportunities and exploitation of existing businesses results in superior firm performance (Tushman & O'Reilly, 1996). Juggling new and old business is crucial for firm survival over time, but competition for attention and resources still means that explicit and implicit choices have to be made between new and old, as "exploration of new alternatives reduces the speed with which skills at existing ones are improved" (March, 1991: 72). A number of ambidexterity studies have used case studies from the newspaper industry as a context for studying the tensions between exploration and exploitation (Boumgarden, Nickerson, & Zenger, 2012; O'Reilly & Tushman, 2004, 2013; Tushman et al., 2002). These studies define the print business as exploitation and digital ventures as exploration. In one often-quoted case study, Tushman et al. (2002) examined how *USA Today*, a legacy newspaper firm, established an independent online operation in the mid-1990s to explore new business opportunities. Due to its poor performance, however, online was later integrated back into the parent print organization, where resources could be leveraged across explorative and exploitative domains. This case is used as an example of a successful ambidextrous organizational design and suggests that *USA Today* improved its performance as a result. It is not clear, however, how the ambidextrous organizational design specifically contributed to firm performance. Despite the proliferation of interest in the construct – including hundreds of empirical studies where ambidexterity has been positively linked with sales growth, subjective ratings of performance, innovation, and firm survival – the empirical evidence is still mixed. Junni et al. (2013), in their meta-analysis of 69 empirical studies, found that most of the empirical evidence to date was linked to subjective measures of performance through cross-sectional survey designs, and they recommend that future studies consider multiple performance measures and longitudinal data to further examine the mechanisms through which ambidexterity influences performance on multiple levels. Also, ambidexterity scholars are divided on whether exploitation and exploration involve "unavoidable tradeoffs" (March, 1991) or if the two factors are orthogonal to each other and firms can choose to engage in high levels of both at the same time (Burton, Obel, & DeSanctis, 2011; Cao, Gedajlovic, & Zhang, 2009).

Business Model Innovation

A third stream of research on firm performance in the newspaper industry concerns business model innovation (Bakker, 2002; Carter, 2009; Eppler & Hoffmann, 2012; Holm, Günzel, & Ulhøi, 2013; Lewis, 2004; Sullivan, 2006; Tang et al., 2011). Disruptive technologies, such as the Internet, have triggered changes in the prevailing business models of newspaper firms. The case studies of two Danish newspaper firms showed these incumbents "opening" their business models to ideas from outside the company or even the industry (Holm et al., 2013). The flipside of openness is increased complexity and involves a number of trade-offs, as more openness can help drive innovation and diversify revenue streams, but it also makes a firm more dependent on third parties. Although this study is well done, it does not address a key issue for legacy newspaper firms – namely that of managing two or more possibly conflicting business models simultaneously (Markides, 2013), and how this balancing act affects total firm performance. Difficulties in operationalizing the business model concept have led to its being used inconsistently, even as it has been applied to a wide range of situations (Harren, 2012; Holm et al., 2013). One notable exception is Tang et al. (2011) who examined how investment in "bricks" (i.e., the newsroom staff and resources that produce news content) helps build "clicks" (i.e., more online visitors and, subsequently, online advertising revenue). The authors conducted an econometric analysis of 12 years of longitudinal data from one multi-channel newspaper. The findings show that the basic success of the online business model ("clicks") depends on the investment in newsroom resources ("bricks").

EXPLORE AND EXPLOIT VALUE CHAINS

In this section, I synthesize factors and arguments from media convergence, organizational ambidexterity, and business model innovation to develop a conceptual framework of explore and exploit value chains in the context of the newspaper industry. This framework allows for a discussion of the various relationships involving ambidexterity and their implications for firm performance.

In the digital era, performance management has expanded from using only financial indicators to include complex non-financial measures as well (Bititci et al., 2012). My literature review suggested a similar evolution of performance measures in the newspaper business. For newspaper companies, financial performance is based on a 200-year old business model in which revenues come from two main sources: sales and advertising. Newspaper sales ("circulation") are typically either subscription-based (home delivery) or single-copy sales (at newsstands). The estimated number of total readers typically determines the advertising rates. Conversely, digital revenues for newspaper firms are based almost solely on advertising: the more readers your online site (or other digital products) attract, the higher online ad rates you can charge. Online performance measures have evolved significantly from the advent of the Internet until today, from simple measures of online page impressions (how many times a web page is displayed by a hosting server) to complex measures involving the browsing patterns of individual online users on multiple digital platforms.

A resource-based view of the firm suggests that firm resources determine financial performance relative to the competition (Barney, 1991; Otto & Aier, 2013). Several studies have shown a positive correlation between key resources and revenues in the newspaper industry (Blankenburg, 1989; Cho, Thorson, & Lacy, 2004; Mantrala et al., 2007; Tang et al., 2011). To differentiate themselves from the competition, and attract large enough print and online audiences to sustain their business, newspaper firms make investments in key resources, which in turn produces high-quality content, which improves market penetration and yields higher revenues (Lacy, 1992). I propose that this basic financial performance model be updated to include factors associated with media convergence, organizational ambidexterity, and business model innovation.

First, consider factors suggested by the business model innovation literature. Holm et al. (2013) suggested that in the digital age, newspaper firms must manage the co-existence

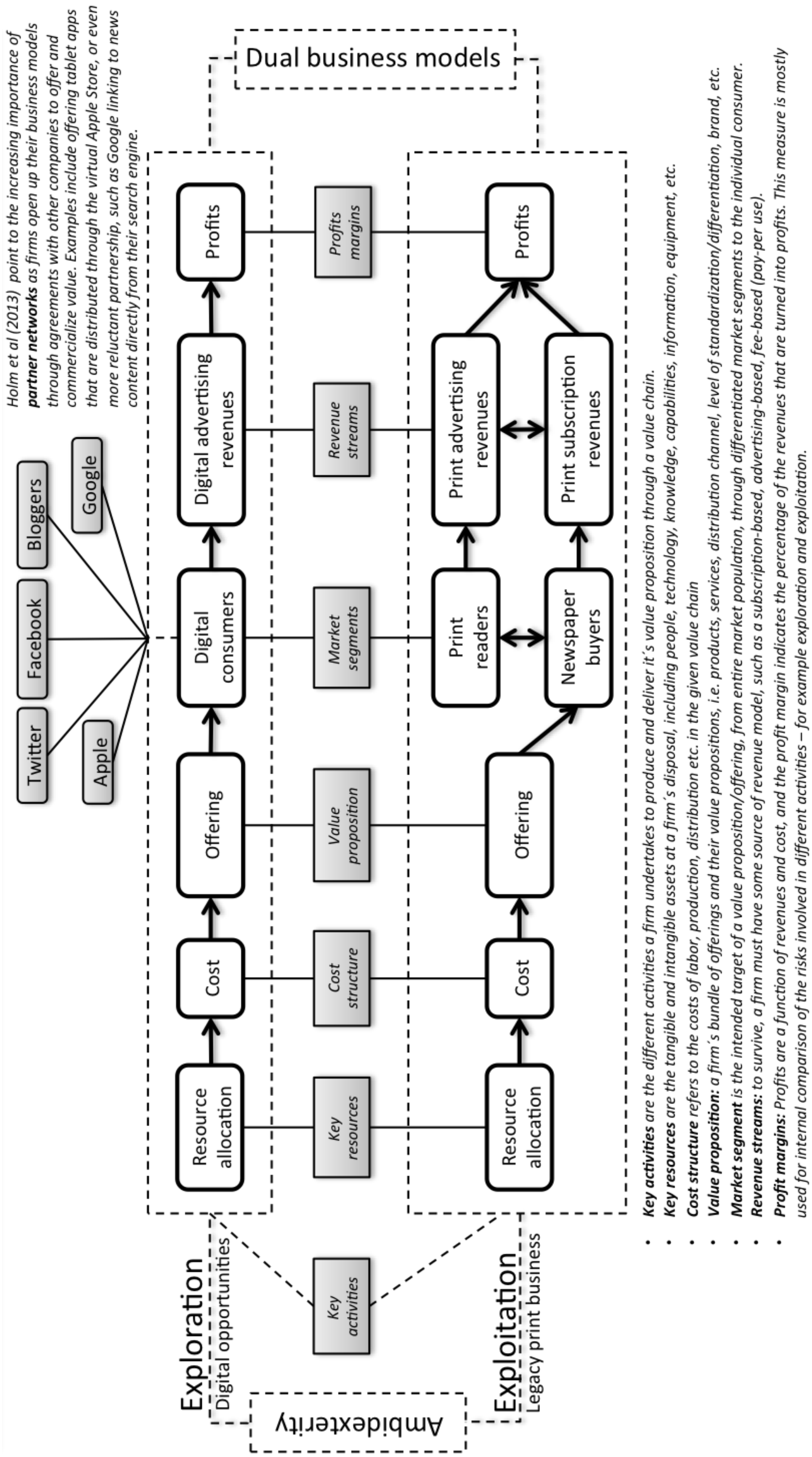

Fig. 1. Explore and exploit value chains

of their traditional print business model with emerging and potentially disruptive digital business models. They suggest that business model "building blocks" include key activities, key resources, cost structure, market/customer segments, and revenue model.

Second, consider the recent theoretical linkages between business model innovation and ambidexterity (Markides, 2013), particularly how the ambidexterity framework can be used to guide research in the industry and address the challenge of managing dual business models simultaneously.

Third, acknowledge the conflicting demands ambidexterity places on the explore and exploit value chains. These include allocating resources between explorative and exploitative activities; managing diverse product offerings across multiple market segments; and potentially cannibalizing returns from the subscription-based legacy business.

Fourth, consider the link between organizational ambidexterity and performance, where previous empirical studies have broadly linked exploration to growth and exploitation to profits, but how and when ambidexterity affects the firm's value chains remains unclear.

Consolidating all of these variables into a single conceptual framework leads to the multidimensional model of explore and exploit value chains shown in Figure 1. This model takes into account the argument that the ambidexterity dilemma is a "nested" issue (Birkinshaw & Gupta, 2013; March, 1991; Markides, 2013; O´Reilly & Tushman, 2013) that transpires at multiple levels in a firm and its ecosystem.

UNTANGLING AMBIDEXTERITY-FIRM PERFORMANCE COMPLEXITIES WITH BIG DATA ANALYTICS

The "ambidexterity premise" suggests that digital exploration and print exploitation can be aligned for superior performance, but this balancing act is complicated by differences in the distribution of costs and returns across the two value chains. Moreover, outcomes associated with digital exploration are more uncertain than the outcomes associated with print exploitation. I propose that big data analytics can help practitioners as well as researchers untangle these explore/exploit complexities. Big data analytics offers practitioners and scholars the opportunity to dynamically track and measure the outcomes of organizational strategies through two distinct but interrelated performance dimensions: "On the one hand, (big) data is used for the incremental improvement and optimisation of current business practices and services…On the other hand, new products and business models can be innovated based on the use of data" (Hartmann et al., 2014: 5).

There is already some empirical evidence linking big data analytics with firm productivity and profitability (e.g., McAfee & Brynjolfsson, 2012), but most of the research to date is anecdotal and case-based, leaving a research gap in regards to exactly how big data can improve firm performance. I propose that these two performance dimensions – optimization of current business and innovation in products and business models – can be framed through the theoretical lens of organizational ambidexterity. Such a framing allows for the use of well-established ideas and concepts from the ambidexterity literature, and it builds on existing industry-specific research to further our understanding of performance management in the era of big data analytics.

Big Data Implications for Exploration

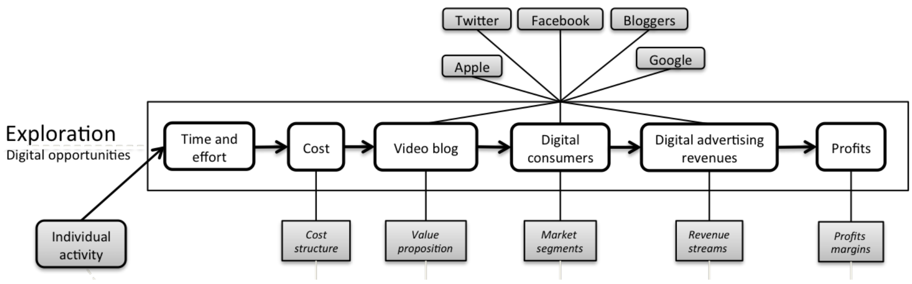

Fig. 2. Big data implications for digital exploration: access to ubiquitous, high velocity real-time data and continuous feedback mechanisms

Access to ubiquitous, high-velocity data allows for the continuous analysis of the micro-foundations of explorative activities as they "…evolve on a minute-to-minute, day-to-day basis, rather than being constrained to assessing snapshots such as quarterly inputs and outcomes or sales cycle trends" (George, Haas, & Pentland, 2014: 325). For example, in the newspaper industry, big data analytics could track in real-time the efforts of individual reporters creating different types of content (text, video, photos, blogs, etc.), thereby giving insights and continuous feedback into firm and individual productivity as well as the specific cost-structure of each piece of content as it is being produced. Such content objects could then be combined into a particular offering aimed at existing (exploitative) or new (explorative) market segments, which in turn may have very different revenue streams and profits.

The defining quality of big data is the granularity and the velocity of the data, which allows for the focus to shift from the number of resources (traditionally measured as FTE or full-time employees) to providing fine-grained, concurrent information about individual behavior, giving insights into the micro-foundations of organizational ambidexterity (Rogan & Mors, 2014) as well as allowing for real-time decision making (Galbraith, 2014). A whole range of advanced analytics can be used to gain further insights from big data, including A/B testing, cluster analysis, forecasting, data mining, visualization of large data sets, content analysis, and network analysis. For example, a reporter working for the legacy print newspaper could a spend a full workday experimenting with making a digital interactive video-blog for the web edition of the newspaper, which is subsequently shared on Facebook and Twitter. Through network analysis, it is possible to track in real-time how this particular blog is re-posted and viewed by individuals across social media. This information can then be combined with data from Google analytics to determine the exact amount of ad revenues this particular digital blog generates as it drives traffic to the newspaper web site. Through content analysis, A/B testing, and cluster analysis, it can be determined which blog framings or formats yield the most Twitter "re-tweets," or web-site traffic, but also which Facebook users generate the most story "shares" and "comments" through their individual networks. In another example, the reporter could engage in the recent trend of native advertising by writing sponsored stories (e.g., praising a particular product) which are then published online in a format very similar to an actual news story but in fact is a form of paid advertisement. This practice is quite controversial, as readers sometimes have a hard time telling the difference between sponsored stories and "the real thing." At the firm level, there is also the danger of losing credibility by engaging in paid journalism, but that cost may be outweighed by the potential ad revenues generated from the native ads. Through big data analytics, the impact of such explorative ventures can be tracked in real-time.

Big data analytics thusly offers the ability to link resource allocation, cost structure, value proposition, market segments, revenue streams, and profits (see Figure 2) – and, as indicated in the example above, give feedback regarding the return on investment of a full day´s work on making a digital story. For firm management, such individual data can then be aggregated to assess the viability of explorative ventures and thereby systematically reduce the risk and uncertainty involved in digital exploration, making the returns on alternative resource investments more predictable. The rich data also allows for the examination of "outliers" that may represent the innovation frontier (George et al., 2014).

Big Data Implications for Exploitation

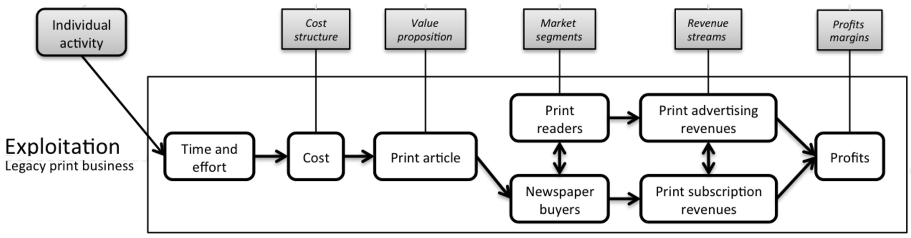

Fig. 3. Big data implications for print exploitation: Limited access to sample-based, low-velocity data with limited feedback

Paradoxically, the richness of real-time insights into the effects of digital exploration may actually complicate decision making in the legacy (print) part of the business, where the available performance data remains largely static, and events traditionally unfold at a much slower pace. Even though resource allocation, productivity, and cost structures presumably can be measured in real-time in the exploitative value chain, tracking and measuring market performance of the printed offerings in real-time is not possible. Instead, that is done through surveys of representative samples of individuals from different market segments to assess if they have read the newspaper or particular sections of it such as advertisements. Such surveys are conducted at regular intervals and are representative of the general population as such, and they allow for comparison to competing products as well as the identification of general trends and average tendencies.

Similarly, the revenue streams from the print business are often based on long-term, pre-paid subscriptions. Print advertisers traditionally commit to buying large volumes of advertising space in the printed newspaper, often a year at a time. In the digital space, in contrast, advertisers may literally bid for advertising space in real-time as an attractive consumer is loading a web page on an online news site. The slower velocity of the data from print exploitation implies that there is no direct linkage and feedback mechanism between individual effort and effect. If we return to the example of the print reporter who spent a full workday making a digital interactive blog or a native advertisement, then let´s assume this effort came at the cost of him or her making one less story for the printed newspaper. The incremental effect of this on the print side of the business may be tricky to measure. Most likely, another print story took its place, and newspaper readers are none the wiser for it – unless they discovered the interactive blog and decided to spend their time reading it instead of the printed newspaper.[2]

The arguments above suggest that when considering the context of the newspaper industry, big data analytics holds the power to reverse the logic of the explore/exploit framework (March, 1991) by actually making returns from experimentation with new digital opportunities more positive, proximate, and predictable. Conversely, the returns from exploiting the existing print business have become more uncertain, distant, and often negative. The process is modeled in Figure 3.

SUMMARY AND RECOMMENDATIONS

The purpose of this study was to address the gap in our understanding of when and how ambidexterity creates value for firms. Synthesizing arguments from theories of media convergence, organizational ambidexterity, and business model innovation, I proposed a value chain framework that allows for a more in-depth understanding of the interrelations between exploration and exploitation. The empirical evidence to date suggests that ambidexterity (the simultaneous pursuit of print exploitation and digital exploration in the newspaper industry) is linked to superior firm performance, but this evidence is based mostly on subjective measures of financial performance. My model allows for a more granular analysis of when and how ambidexterity affects firm performance in the context of the newspaper industry. Previous ambidexterity studies have shown that exploration is linked to growth whereas exploitation is linked to profits. I go beyond these arguments, furthering our understanding of the interaction mechanisms between six dimensions of the explore/exploit value chains: resource allocation, cost structure, value proposition, market performance, revenues, and profits.

I would like to see future empirical studies use big data analytics to test the proposed model on both the individual and firm level of analysis (e.g., by means of A/B testing). It would be useful to examine how the ambidexterity-performance link is moderated on the firm level by alternative resource allocations. For example, what are the specific performance implications of having individuals divide their time between print exploitation and digital exploration, as opposed to specializing in one or the other? Also, what are the firm performance implications

2 I would like to thank an anonymous reviewer for pointing out that the blog and the print story need not be substitutes, but rather that the writing of the blog might subsequently lead to the reporter writing a better print story. That is, the two might potentially be complementary. If so, a given investment or action might yield positive returns in both the explorative and exploitative value chains. This is a good example of how insights from big data analytics could have theoretical implications for the ambidexterity concept.

of investing in content creators versus advertising/sales resources, web traffic managers, pricing specialists, conversion rate optimization experts, or data scientists? What is the distribution of costs and returns of such alternative resource investments over time?

Big data analytics offers the opportunity to consider the micro-foundations of both ambidexterity strategies and activity by allowing for the examination of how business opportunities are exploited and/or explored in real-time as well as longitudinally. However, I would argue that the *sine qua non* of big data analytics is the potential to move ambidexterity research beyond its current focus on survey-based industry studies and selected case studies (which yield a great deal of detail but offer limited generalizability) towards more rigorous research designs where voluminous and diverse sources of data from multiple time-periods are analyzed to find patterns that our current theoretical models cannot.

O'Reilly and Tushman (2013) note that as the innovation frontier increasingly moves outside incumbent firms, the explore/exploit balancing act becomes more complex. In the context of the newspaper industry, the logic of open innovation is fundamentally different from the traditional business paradigm that has sustained the newspaper industry for almost three centuries. Future studies should consider how both incremental and disruptive innovations are distributed in the larger ecosystems in which firms reside. And, as George et al. (2014) point out, once such correlative linking patterns are identified, the next big data challenge is to explore causality. Hopefully, the model proposed here offers a theoretical and operational starting point for future studies investigating the impact of ambidexterity as well as big data analytics on multiple levels, from the individual and organization to the larger industrial context.

REFERENCES

Bakker P. 2002. Free daily newspapers – business models and strategies. *International Journal of Media Management* 4(3): 180-187.

Barney J. 1991. Firm resources and sustained competitive advantage. *Journal of Management* 17(1): 99–120.

Birkinshaw J, Gupta K. 2013. Clarifying the distinctive contribution of ambidexterity to the field of organization studies. *Academy of Management Perspectives* 27: 287-298.

Bititci U, Garengo P, Dörfler V, Nudurupati S. 2012. Performance measurement: Challenges for tomorrow. *International Journal of Management Reviews* 14(3): 305-327.

Blankenburg WB. 1989. Newspaper scale and newspaper expenditures. *Newspaper Research Journal* 10: 97–103.

Boczkowski PJ. 2004. *Digitizing the News: Innovation in Online Newspapers*. The MIT Press, Cambridge, MA.

Boumgarden P, Nickerson J, Zenger TR. 2012. Sailing into the wind: Exploring the relationships among ambidexterity, vacillation and organizational performance. *Strategic Management Journal* 33: 587-610.

Burton RM, Obel B, DeSanctis G. 2011. *Organizational Design: A Step-by-Step Approach*. Cambridge University Press, New York, NY.

Cao Q, Gedajlovic E, Zhang H. 2009. Unpacking organizational ambidexterity: Dimensions, contingencies and synergistic effects. *Organization Science* 20: 781-796.

Carter AY. 2009. Global perspective: Seeking a new business model for newspapers. *Journal of Communications Research* 4(2): 80-92.

Cho S, Thorson E, Lacy S. 2004. Increased circulation follows investments in newsrooms. *Newspaper Research Journal* 25(4): 26–39.

Deuze M. 2004. What is multimedia journalism? *Journalism Studies* 5(2): 139-152.

Eppler MJ, Hoffmann F. 2012. Does method matter?: An experiment on collaborative business model idea generation in teams. *Innovation: Management, Policy & Practice* 14(2): 217-232.

Fioretti N, Russ-Mohl S (eds). 2009. *Merging Media, Converging Newsrooms*. Giampiero Casagrande Editore, Lugano, Italy.

Galbraith JR. 2014. Organizational design challenges resulting from big data. *Journal of Organization Design* 3(1): 2-13.

George G, Haas M, Pentland A. 2014. From the editors: Big data and management. *Academy of Management Journal* 57(2): 321-326.

Graham G, Greenhill A. 2013. Exploring interaction: Print and online news media synergies. *Internet Research* 23(1): 89-108.

Harren H. 2012. Management of multiple business models: Determining the optimal organizational strategy. Unpublished Doctoral Dissertation, Technical University of Berlin.

Hartmann PM, Zaki M, Feldmann N, Neely A. 2014. Big data for big business? A taxonomy of data-driven business models used by start-up firms. Working Paper, Cambridge Service Alliance.

Holm AB, Günzel F, Ulhøi JP. 2013. Openness in innovation and business models: Lessons from the newspaper industry. *International Journal of Technology Management* 61(3/4): 324–348.

Junni P, Sarala M, Rikka TV, Tarba SY. 2013. Organizational ambidexterity and performance: A meta-analysis. *Academy of Management Perspectives* 27(4): 299-312.

Kolodzy J. 2006. *Convergence Journalism: Writing and Reporting across the News Media*. Rowman and Littlefield, Lanham, MD.

Lacy S. 1992. The financial commitment approach to news media competition. *Journal of Media Economics* 5(2): 5–21.

Lawson-Borders G. 2006. *Media Organizations and Convergence: Case Studies of Media Convergence Pioneers*. Lawrence Erlbaum, Mahwah, NJ.

Lewis KJ. 2004. Australian newspapers online: Four business models revisited. Media International Australia Incorporating Culture and Policy. *Quarterly Journal of Media Research and Resources* 111: 131-144.

Mantrala MK, Naik P, Sridhar S, Thorson E. 2007. Uphill or downhill? Locating your firm on a profit function. *Journal of Marketing* 71(2): 27–43.

March J. 1991. Exploration and exploitation in organizational learning. *Organization Science* 2: 71-87.

Markides C. 2013. Business model innovation: What can the ambidexterity literature teach us? *Academy of Management Perspectives* 27(4): 311-323.

McAfee A, Brynjolfsson E. 2012. Big data: The management revolution. *Harvard Business Review* 10 (October).

O'Reilly CA, Tushman ML. 2004. The ambidextrous organization. *Harvard Business Review* April: 74-83.

O'Reilly CA, Tushman ML. 2013. Organizational ambidexterity: Past, present, and future. *Academy of Management Perspectives* 27(4): 324-338.

Otto B, Aier S. 2013. Business models in the data economy: A case study from the business partner data domain. *Proceedings* of the 11th International Conference on Wirtschaftsinformatik (WI 2013) 1: 475–489.

Quinn S. 2005. Convergence's fundamental question. *Journalism Studies* 6(1): 29–38.

Quinn S, Filak VF (eds.). 2005. *Convergent Journalism: An Introduction*. Elsevier, Burlington, MA.

Raisch S, Birkinshaw J. 2008. Organizational ambidexterity: Antecedents, outcomes, and moderators. *Journal of Management* 34: 375-409.

Rogan M, Mors ML. 2014. A network perspective on individual level ambidexterity in organizations. *Organization Science* 25: 1860-1877.

Singer JB. 2004. More than ink-stained wretches: The re-socialization of print journalists in converged newsrooms. *Journalism and Mass Communication Quarterly* 8(4): 838–856.

Sullivan D. 2006. Business service model promotes better newspapers. *Newspaper Research Journal* Fall 2006.

Tameling K, Broersma M. 2013. De-converging the newsroom: Strategies for newsroom change and their influence on journalism practice. *International Communication Gazette* 75(1): 19-34.

Tang E, Sridhar S, Thorson E, Mantrala MK. 2011. The bricks that build the clicks: Newsroom investments and newspaper online performance. *International Journal of Media Management* 13(2): 107-128.

Tushman ML, O'Reilly CA. 1996. The ambidextrous organization: Managing evolutionary and revolutionary change. *California Management Review* 38: 1-23.

Tushman ML, Smith W, Wood R, Westerman G, O'Reilly, CA. 2002. Innovation streams and ambidextrous organizational designs: On building dynamic capabilities. Working Paper 03-106, Harvard Business School, Boston, MA.

van Weezel A. 2009. Organizational changes in newspaper firms and their relation to performance. *International Journal of Media Management* 11(3-4): 144-152.

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FIT - THE KEY TO ORGANIZATIONAL DESIGN

LEX DONALDSON • GREG JOFFE

Abstract: The design of an organization needs to fit its situation. Designs that fit produce higher organizational performance than designs that do not. This article uses the concept of fit to show how to align organizational designs to three important situational factors: competitive strategy, organization size, and task uncertainty.

Keywords: Fit, misfit, organization design, strategy, organization size, task uncertainty, contingency theory, multinational organizational structures

The concept of fit is central to modern organizational design. The core idea is that the design of an organization needs to fit its strategy and other contingency factors. Designs that fit deliver better financial performance; misfit produces disorganization and consequent lower performance (Schlevogt, 2002). As organizations evolve, their existing strategies and structures tend to lose fit and become a drag on performance. Managers have to be alert to emerging misfits and adjust the organization to the changed contingencies in order to restore performance. The objective of this article is to translate research-based organizational design knowledge for managers, specifically to show them how to achieve a fit between structural features and the key contingencies of competitive strategy, organization size, and task uncertainty.

CONTINGENCY 1: COMPETITIVE STRATEGY

The process of achieving fit with competitive strategy is driven by the organization's level of diversification – a continuum that ranges from single business to multiple businesses to multinational. Low diversification, such as a single-business firm with homogeneity in products, services, and customers, is best fitted by a functional structure, in which the managers who report directly to the CEO are specialized by function – engineering, manufacturing, marketing, etc. (Galbraith, 1973). For example, AustralianSuper, a large, successful Australian superannuation (pension) fund, uses a functional structure (see Figure 1). Although AustralianSuper is large, it has only a single product (pensions) and a single geography (Australia), and therefore is best supported by a functional structure.

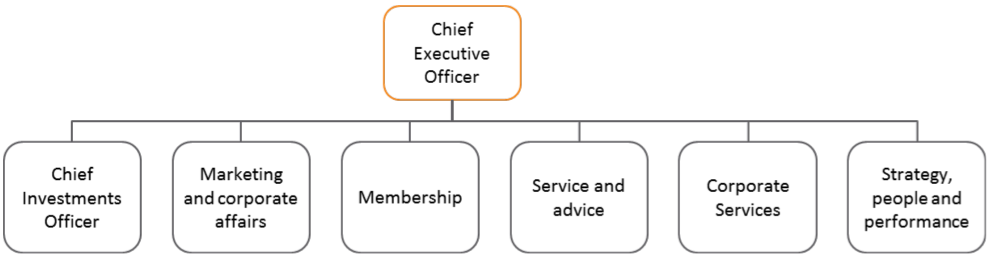

Fig. 1. AustralianSuper: single-business strategy, functional organization structure
Source: www.australiansuper.com

When an organization begins to diversify – to add products, services, production technologies, markets, and geographies – it must adopt a divisional structure (Chandler, 1962). An example is Sony Corporation (see Figure 2). As the firm added entertainment and financial services

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to its original line of electronics products, each product category was grouped into its own division. When products or services are unrelated (according to production methods or customers), the fitting structure is for each division to be run as an autonomous business, each with its own set of functions (Hill, Hitt, & Hoskisson, 1992; Rumelt, 1974). Each division is responsible for its own profitability, and division managers may receive bonuses based on divisional profitability. When the products or services are related, however, then some functions and services can be centralized, resulting in increased corporate synergy. In such cases, divisional autonomy declines. In the case of related diversification, collaboration among divisions can be encouraged by having managers and employees receive bonuses based on overall corporate profitability (Rumelt, 1974). When products are vertically integrated, such as in oil companies and other continuous processing firms, the fit is centrally coordinated planning of production rates and inventories across the corporation. The corporate head office, accordingly, is larger and contains more functions. In this structure, upstream divisions are cost centers and downstream divisions are profit centers (Lorsch & Allen, 1973), and general managers' bonuses include more weighting on corporate profitability.

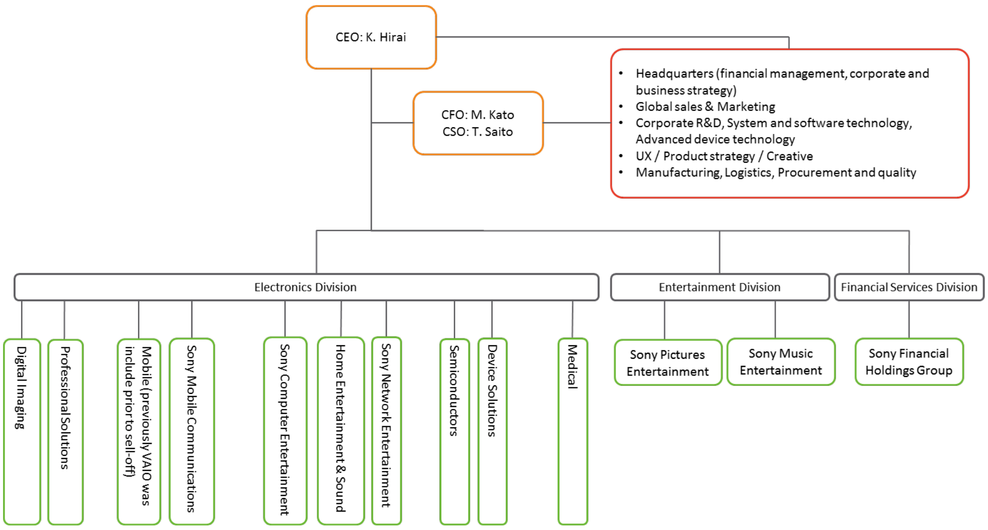

Fig. 2. Sony Corporation: multi-business strategy, divisional organization structure
Source: Sony Group Annual Report 2012 (http://visiblebusiness.blogspot.com.au/2013/06/sony-organizational-chart-2012.html)

Much of this strategy-structure fit model has been well researched and is widely understood. Nevertheless, firms sometimes wait more than ten years after diversifying before moving to a divisional structure (Donaldson, 1987), so that they are in misfit for a considerable period, which adversely affects their performance. Hence, there is a need for managers to be more aware of the benefits of moving to a divisional structure as the organization begins to diversify. Moreover, even when the firm has moved to a divisional structure, it may not install the entire suite of structural and process elements that make the divisional model work, such as divisional autonomy, measurement of divisional profitability, and reallocation of capital between divisions (Hill, 1985). Each of these is an element of fit and so adds to performance.

Diversification on Two (or More) Axes

When firms are diversified on two axes – for example, functions and products – the matrix structure becomes the fit, because it is necessary to have a manager responsible for each major diversification dimension (Galbraith, 1973). Matrix structures are complex and may become difficult for managers and employees to operate, so it is important to pre-specify which managers have final decision rights on which decisions (Davis & Lawrence, 1977). In cases where there are diverse projects that draw on shared central functions for resources, a project-functional matrix may offer benefits of speedy innovation and cost containment. Project managers ensure the impetus for speed and innovation while functional managers oversee efficient use of resources shared across projects.

From the original two-dimensional matrices defined by functions and products, matrix structures have become increasingly complex as large multinational companies strive to emphasize multiple diversification dimensions. Three-dimensional matrix structures appeared in the 1970s as multinational companies emphasized country and regional geographies, and four-dimensional matrices appeared in the 1980s as companies put heavy emphasis on customers. Recently, a five-dimensional matrix structure has been predicted, in which companies try to take advantage of the opportunities presented by "big data" (Galbraith, 2014).

Fit for Multinational Corporations

For multinational corporations (MNCs), strategic considerations include not only the level of diversification but also the relative importance to the MNC of local responsiveness (LR) and global integration (GI). High local responsiveness means the MNC responds in-depth to local environments, such as customizing products to local tastes and working cooperatively with the host government. High global integration means the MNC is primarily concerned with global economies of scale, such as standardized products and integrated global supply chains (Bartlett & Ghoshal, 2002). A typology of international strategies and their best-fit organizational structures is shown in Figure 3.

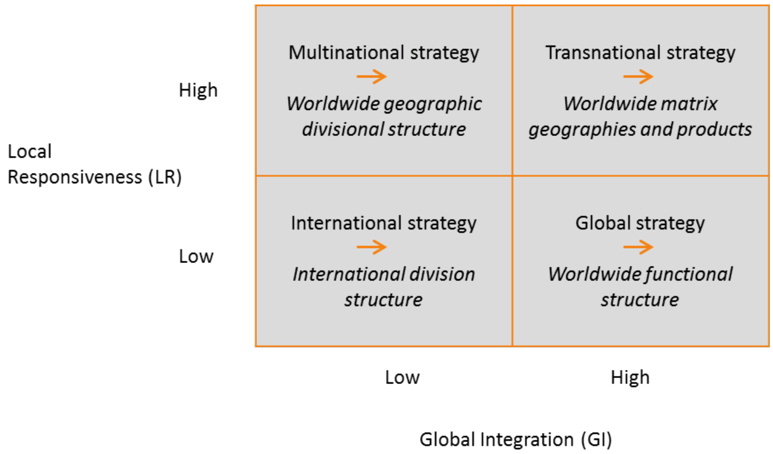

Fig. 3. Multinational strategies and supporting structures

As indicated in the figure:

- An MNC pursuing an international strategy (low LR and low GI) is best fitted with an international division structure (Donaldson, 2009). The international division, housed in the domestic organization, coordinates the foreign subsidiaries. Although this structure has limited cross-national information-processing capacity, it is appropriate for an MNC with limited foreign operations.
- A global strategy (low LR and high GI) is fitted by having a worldwide functional structure which provides detailed coordination among foreign subsidiaries and the domestic organization.
- A multinational strategy (high LR and low GI) is fitted by a worldwide geographic divisional structure, which provides autonomy to foreign subsidiaries so that they can cater to local tastes.
- A transnational strategy (high LR and high GI) is fitted by geographies matrixed with functions; however, if there are diverse products, then the fit is geographies matrixed with product divisions, the functions being within each product division. The transnational strategy requires coordination by the geographies balanced by functions or products.

These designs refer to the enterprise level of the organization, indicating the major building blocks of the organization and the responsibilities of the managers who report directly to the CEO (Qiu & Donaldson, 2010). Accordingly, fitting structure to strategy is straightforward when strategies change. For example, in an MNC pursuing a global strategy and presently supported by a worldwide functional structure, if its managers decide to change to a multinational strategy, they would attain a new and better fit by changing to a worldwide geographic divisional structure. This would be accomplished by changing the senior managers (or the focus of those senior managers) who report directly to the CEO from functional to geographic. There will be other details to be decided, such as which countries are grouped in the same geographic division, but these issues can be managed by working through the options against agreed criteria.

Fitting Centralization, Formalization, and Shared Values to Strategy

An MNC's competitive strategy will also guide choices regarding centralization, formalization, and shared values as shown in Figure 4 (Ghoshal & Nohria, 1993).

	International	Global	Multinational	Transnational
Enterprise Structure	Domestic	Worldwide functional	Worldwide geographic	Matrix
Degree of Centralization	Low	High	Low	High
Degree of Formalization	Low	High	Low	High
Shared Values	Low	High	Low	High

Fig. 4. How structures and shared values fit MNC strategies

As indicated in the figure:

- An international strategy requires little coordination and so is fitted by minimal structure that avoids unnecessary costs. Therefore, an MNC pursuing an international strategy can be low on centralization, formalization, and shared values.
- Global strategy requires tight control over foreign subsidiaries in order to reap global synergies, so an MNC pursuing this strategy needs to be high on at least one of centralization, formalization, or shared values. Here the challenge is to control lower-level managers, either by the head office making the decisions, or by rules, or by shared values, respectively.
- The multinational strategy seeks local responsiveness and therefore the foreign subsidiaries must fit their local environments, especially the local resources and level of complexity. The degree of centralization, formalization, and shared values is typically low.
- The transnational strategy seeks both global integration and local responsiveness, so it is fitted by high levels of at least one of centralization, formalization, and shared values, while the foreign subsidiaries must also fit their local environments.

It involves a significant amount of work to assess the levels of centralization, formalization, shared values, and foreign subsidiary fits of an MNC and to make appropriate adjustments. However, Ghoshal & Nohria (1993) found that most of the MNCs they studied were in misfit, which resulted in lower profitability and revenue growth (an average of 35% in ROA, 64% in ROA growth, and 31% in revenue growth). Given such magnitudes of lost profitability and lost revenue growth due to misfit, it is clearly worth the effort to assess fit and ensure that the organization structure fits the strategy.

CONTINGENCY 2: ORGANIZATION SIZE

As an organization grows, the fitting structure becomes more complex. The expanding structure has more hierarchical levels, more decentralized decision-making, more functional departments, more specialist jobs, and more standard operating procedures (Child, 1975). An example is the Australian management consulting firm, Nous Group. When the organization had only 10-20 staff in the early 2000s, the Managing Director made most of the important decisions. As the organization grew to approximately 150 people in 2014, more decisions were delegated to lower-level managers and to personnel who made decisions guided by their job descriptions, policies, standard operating procedures, and norms. The more complex structure included a people and culture team, an IT support team, practice groups, and industry groups.

Some managers fear that greater organizational size may produce structures that are overly complex and costly. Structures, however, become more complex at a lesser rate than size increases. Consider, for example, the growth of hierarchy as size increases. An organization is a pyramid, so there are more people at the bottom than at the top. Adding a level at the bottom accommodates many more people when the organization is large than when it is small. Hence, size growth leads to less of an increase in hierarchy in large organizations than it does in small organizations. If the CEO of a small organization has seven subordinates, then the size is eight and there are two hierarchical levels. If each of these subordinates were to gain seven subordinates, then the size becomes 57 and there are three hierarchical levels. The increase of one hierarchical level, from two to three, is caused by size growth of 49 people, whereas an earlier increase of one level, from one to two, was caused by size growth of only seven people. Similarly, as size grows, specialization and other structural features become more complex, but complexity increases at a lesser rate than size.

This is a hopeful message about fit for managers of growing organizations. Managers should respond to size growth incrementally, adding an additional hierarchical level and a little more delegation, a specialist here and a rule there, as challenges due to growth highlight the need for more sophisticated organizational designs.

CONTINGENCY 3: TASK UNCERTAINTY

Task uncertainty determines how formalized the organization, or parts of the organization, need to be. Uncertainty about how to perform tasks stems from both inside and outside the organization. Generally speaking, organizations in dynamic industries, and organizations that are highly innovative, require less formalized structures so that they can respond quickly to threats and opportunities (Burns & Stalker, 1961). Task uncertainty can be thought of as a continuum. Where task uncertainty is low, the fit is a standard operating procedure. Where the task is somewhat more variable, the ability to plan tasks is the fit. Where the task is of intermediate uncertainty, a manager using his or her information and experience is the fit. Where task uncertainty is high, the fit may require a team of specialists from different functions. They mutually adjust their activities, as each uses their professional expertise to contribute to task accomplishment. In some cases, the fit for high task uncertainty also involves an integrator, who is independent of the functional departments and uses a problem-solving approach to coordinate between the functions (Lawrence & Lorsch, 1967).

Where there is a strong focus on innovation, the fit is for each product or service line to be a division with its own resources. Here co-located functions are focused on one group of products under its own division manager. If there are cross-division opportunities, these can be targeted using cross-division business teams and/or a head office integrator.

FITS TO MULTIPLE CONTINGENCY FACTORS

So far we have considered the fit of organizational designs to the three major contingencies – strategy, size and task uncertainty – separately. But there can be more than one contingency factor that together shape which structure is the fit. For example, strategy and task uncertainty can jointly shape structural fit. In a company with a strategy of related products or services, the best fit for innovation and so high task uncertainty is to have a divisional structure with each division focused on optimizing innovation for its own products and customers. In contrast, if that company had a strategy of related products or services, but had cost containment as its priority, so task uncertainty would be low, the fit would be a functional structure, to achieve economies of scale. Hence for a company with a related strategy, it's fitting structure depends upon whether it wants to prioritize innovation or cost containment. Thus, which structure fits it is affected by two contingencies simultaneously: strategy and task uncertainty.

The fit prescribed by one contingency may sometimes differ from that fit prescribed by another contingency. For example, an organization that has a high need for innovation would be fitted by low formalization, yet if the organization were also large that would be fitted by high formalization. Organizational designs often cope with this through structural differentiation. This means that the R&D department has low formalization, to deal with the high uncertainty of its tasks, while the administrative aspects of the organization (e.g., Accounting) have high formalization to fit the large size of the organization.

This idea of structural differentiation can be carried further to yield the ambidextrous organization (March, 1991; O'Reilly & Tushman, 2004; Tushman & O'Reilly, 1996). A firm with a mature product that also has a related product in the innovation stage may structure them as separate divisions, each with its own distinct internal structure fitted to the task uncertainty of the division. The divisions have their own strategies and are held accountable by the head office on different performance criteria, e.g., profit for the mature product division versus attaining innovation deadlines for the innovative product division. Integration of the two divisions is dealt with by a shared vision of the future under the leadership of the CEO. The main structural differentiation options for ambidextrous organizations are discussed by Carroll (2012).

DEVELOPING FITS

Of course, the environments of organizations can change often. This makes the perfect organizational design elusive and attaining it an unrealistic goal. Organizational design is a dynamic process (Nissen, 2014), in which managers recurrently seek to close the gap between the newly needed organizational design and the existing design. Such reductions in misfit improve organizational performance. To succeed competitively, a firm and its managers only have to do this redesign of their organization in a more effective and timely manner than their competitors.

IDENTIFYING MISFITS

A common question of business owners and managers is how to identify organizational designs that misfit key contingencies. Although it is logically possible that in an organization every design variable could misfit its contingency, in practice there is in an organization often only one or a few large misfits of structural variables and contingencies that is causing most of the performance loss (Burton, Lauridsen, & Obel, 2002). Thus, in the typical organization there is some "low hanging fruit" that a manager can pluck by identifying the big misfit in his or her organization and changing it to a fit. In theory, the search for such a misfit could entail examining all combinations of the structural variables and contingencies in the organization, and identifying those that are mis-fitted to their contingencies. But often the largest misfit in an organization is the result of a change in a contingency (e.g., competitive strategy) that has not yet been accommodated by a new, fitting organizational design. Experienced, vigilant managers are probably aware of the large misfits in their own organizations already and can determine the appropriate adjustments to make.

CONCLUSION

This article provides an application of contingency theory to organizational structures that managers can consider when designing and redesigning their organizations. For managers seeking guidance on the organization design process, see Burton, DeSanctis, and Obel (2011). For those interested in the research base underlying the concept of fit, see Burton and Obel (2004). This book comes with a computer program, *Orgcon*, which analyzes an organization's design and recommends the appropriate fits. By identifying misfits and making the appropriate adjustments, managers can significantly improve the performance of their organizations.

REFERENCES

Bartlett CA, Ghoshal S. 2002. *Managing Across Borders: The Transnational Solution*. 2nd ed. Harvard Business School Press, Boston, MA.

Burns T, Stalker GM. 1961. *The Management of Innovation*. Tavistock, London, UK.

Burton RM, DeSanctis G, Obel B. 2011. *Organizational Design: A Step-By-Step Approach*.

2nd ed. Cambridge University Press, New York, NY.
Burton RM, Lauridsen J, Obel B. 2002. Return on assets loss from situational and contingency misfits. *Management Science* 48(11): 1461-1485.
Burton RM, Obel B. 2004. *Strategic Organizational Diagnosis and Design: The Dynamics of Fit*. 3rd ed. Kluwer, Boston, MA.
Carroll TN. 2012. Designing organizations for exploration and exploitation. *Journal of Organization Design* 1(2): 64-68.
Chandler AD Jr. 1962. *Strategy and Structure: Chapters in the History of the American Industrial Enterprise*. The MIT Press, Cambridge, MA.
Child J. 1975. Managerial and organizational factors associated with company performance, part 2: A contingency analysis. *Journal of Management Studies* 12: 12-27.
Davis SM, Lawrence PR. 1977. *Matrix*. Addison-Wesley, Reading, MA.
Donaldson L. 1985. Organization design and the life-cycles of products. *Journal of Management Studies* 22: 25-37.
Donaldson L. 1987. Strategy and structural adjustment to regain fit and performance: In defence of contingency theory. *Journal of Management Studies* 24: 1-24.
Donaldson L. 2009. In search of the matrix advantage: A reexamination of the fit of matrix structures to transnational strategy. In J.L. Cheng, E. Maitland, and S. Nicholas (eds.), *Managing Subsidiary Dynamics: Headquarters Role, Capability Development, and China Strategy*: 3-26. Emerald Group Publishing, London, UK.
Galbraith JR. 1973. *Designing Complex Organizations*. Addison-Wesley, Reading, MA.
Galbraith JR. 2014. Organization design challenges resulting from big data. *Journal of Organization Design* 3(1): 2-13.
Ghoshal S, Nohria N. 1993. Horses for courses: Organizational forms for multinational corporations. *Sloan Management Review* 34(2): 23-35.
Hill CWL. 1985. Internal organization and enterprise performance: Some UK evidence. *Managerial and Decision Economics* 6: 210-216.
Hill CWL, Hitt MA, Hoskisson RE. 1992. Cooperative versus competitive structures in related and unrelated diversified firms. *Organization Science* 3: 501-521.
Lawrence PR, Lorsch JW. 1967. *Organization and Environment: Managing Differentiation and Integration*. Division of Research, Graduate School of Business Administration, Harvard University, Boston, MA.
Lorsch JW, Allen SA. 1973. *Managing Diversity and Interdependence: An Organizational Study of Multidivisional Firms*. Division of Research, Graduate School of Business Administration, Harvard University, Boston, MA.
March JG. 1991. Exploration and exploitation in organizational learning. *Organization Science* 2: 71-87.
Nissen M. 2014. Organization design for dynamic fit: A review and projection. *Journal of Organization Design* 3(2): 30-42.
O'Reilly CA, Tushman ML. 2004. The ambidextrous organization. *Harvard Business Review* April: 74-81.
Qiu XJ, Donaldson L. 2010. The cubic contingency model: Towards a more comprehensive international strategy-structure model. *Journal of General Management* 36: 81-100.
Rumelt RP. 1974. *Strategy, Structure and Economic Performance*. Division of Research, Graduate School of Business Administration, Harvard University, Boston, MA.
Schlevogt KA. 2002. *The Art of Chinese Management: Theory, Evidence and Applications*. Oxford University Press, Oxford, UK.
Tushman ML, O'Reilly CA. 1996. Ambidextrous organizations: Managing evolutionary and revolutionary change. *California Management Review* 38: 8-30.

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COMPETITION-BASED INNOVATION

THE CASE OF THE X PRIZE FOUNDATION

MOKTER HOSSAIN • ILKKA KAURANEN

Abstract: The use of competition-based processes for the development of innovations is increasing. In parallel with the increasing use of competition-based innovation in business firms, this model of innovation is successfully being used by non-profit organizations for advancing the development of science and technology. One such non-profit organization is the X Prize Foundation, which designs and manages innovation competitions to encourage scientific and technological development. The objective of this article is to analyze the X Prize Foundation and three of the competitions it has organized in order to identify the challenges of competition-based innovation and how to overcome them.

Keywords: Radical innovation, breakthrough innovation, competition-based innovation, innovation competition, modularity, X Prize Foundation

A recently developed approach for creating radical or breakthrough innovations is taking clear shape: competition-based innovation. In competition-based innovation, innovations are created by engaging entities or individuals to submit solutions for specified challenges within a stipulated time frame. Then, the best solutions are selected and rewarded by the organizers of the innovation competition. Competition-based innovation is not a new concept (MacLeod, 1971), but the Internet and other advances in information technology have made its use significantly easier and consequently more widespread (Kalil, 2006). The currently popular concept of open innovation (Chesbrough, 2003) has helped to focus the attention of scholars and practitioners on competition-based innovation. Similar terms used to describe competition-based innovation are design competition, idea contest, innovation contest, innovation jam, and tournament-based innovation (Adamczyk, Bullinger, & Möslein, 2012).

Some scholars have argued that modularity is necessary in order to create innovations based on ideas obtained from external experts (Baldwin & Henkel, 2014; Henkel, Baldwin, & Shih, 2013). In the modular approach, the original problem is partitioned into smaller sub-problems, termed modules (Baldwin & von Hippel, 2011). Each module is then separately presented as a challenge in an innovation competition. One drawback of modularity is that protecting intellectual property rights can be more difficult for the innovator, and imitation can be easier for competitors (Ethiraj, Levinthal, & Roy, 2008). An alternative approach to modularity is the unitary approach. When this approach is used in competition-based innovation, the original challenge is submitted to external experts without partitioning it into smaller modules.

Because of the strong belief in the requirement of modularity, competition-based innovation has not been frequently used to achieve breakthrough innovations. Only recently have successful examples of competition-based innovation in advancing the development of science and technology challenged the traditional belief in the value of modularity. One of the pioneering organizations founded to design and manage innovation competitions to advance scientific and technological development is the X Prize Foundation.

The objective of this article is to show how competition-based innovation can be used in creating breakthrough innovations. We describe the X Prize Foundation and three innovation

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competitions organized by the Foundation. Based on the X Prize Foundation case, we discuss how innovation competitions should be designed in order to support successful breakthrough innovation.

X PRIZE FOUNDATION

The X Prize Foundation is a USA-based organization established in 1996. The Foundation was established in cooperation with several large companies, including Cisco, Google, Nokia, Qualcomm, and Shell Oil. Its mission is to bring about "radical breakthroughs for the benefit of humanity" through incentivized competition. The Foundation organizes high-profile competitions that motivate individuals, groups, companies, and organizations across all disciplines to develop innovative ideas and technologies to overcome challenges that restrict humanity's progress. According to the CEO of the X Prize Foundation, each competition aims to tackle previous failures and to create a new approach to achieve breakthroughs once thought to be impossible. The duration of competitions ranges from a few years to a decade. The first competition, for example, started in 1996 and ended in 2005. X Prize rules allowed contestants to retain the intellectual property and other commercial rights related to their inventions and discoveries. Further, competitions are based on unifying principles so modularity is not a relevant issue to the X Prize Foundation.

The X Prize Foundation is widely recognized as a forerunner in facilitating prize competitions that motivate innovators to solve pressing challenges facing the world. The Foundation's vision is to dramatically change the innovation spectrum by presenting an alternative to traditional modes of innovation. It organizes competitions in five categories: education, global development, energy and environment, life sciences, and exploration. So far, the X Prize Foundation has successfully completed four competitions, has cancelled one, has four that are active, and has approximately a dozen in the development stage. The X Prize Foundation organizes two types of competitions: the X Prize and the X Challenge. In the X Prize competition, an award of $10 million or more is rewarded to the first team to accomplish a task specified by the Foundation. In the X Challenge competition, a prize of up to $2.5 million is given for the solution of a well-defined technical problem for which there is no known solution. The aim of both competitions is to bring breakthrough technical or behavioral solutions to the market. The competitions stimulate innovation through tapping into the competitive and entrepreneurial spirit of the contestants.

The X Prize Foundation has completed four competitions: Ansari X Prize, Progressive Insurance Automotive X Prize, Wendy Schmidt Oil Cleanup X Challenge, and Northrop Grumman Lunar Lander Challenge. The Archon Genomics X Prize was cancelled in the middle of the competition process. The four active projects are Google Lunar X Prize, Qualcomm Tricorder X Prize, Nokia Sensing X Challenge, and Wendy Schmidt Ocean Health X Prize. To better understand the process of competition-based innovation, we briefly describe an example from each category.

The Ansari X Prize

The Ansari X Prize was announced in 1996 and was the first competition organized by the X Prize Foundation. The name of the competition was changed from its initial name following a multimillion-dollar donation from the Ansari family. The competition offered a $10 million cash prize to the first non-government organization that could build and launch a reusable three-passenger vehicle into space, reaching over 100 kilometers in altitude, and repeating this feat twice within two weeks. The closing date for the competition was January 1, 2005 (Hoyt & Phills, 2007).

The competition received extensive press coverage. Eventually, 26 teams from seven different countries entered this competition. It is estimated that the participating teams allocated a cumulative total of $100 million in their development work for winning the prize (Brunt, Lerner, & Nicholas, 2012). The participating teams were from all around the world, ranging from hobbyists to corporate-backed groups. One-third of the teams were new startups, formed specifically to go after the prize, another third were already working towards spaceflight, and the final third came from different fields to try to win the prize (Hoyt & Phills, 2007).

SpaceShipOne, a USA-based aircraft design company, won the competition after eight years of work. SpaceShipOne made an agreement with Virgin founder Richard Branson to supply the new vehicle to Virgin Galactic, which aimed to develop a business selling trips to space. Even though the idea of space tourism was not new, the X Prize competition changed attitudes towards space tourism and gave new belief in its potential. The first-ever tourist space trip was made in 2001 with a price tag of $20 million. Although some people are willing to pay a hefty price for a space tour, high costs are still a major hindrance for this business. The Ansari competition shows the high potential of space tourism since the price of space tourism is expected to come down significantly.

Archon Genomics X Prize

Two years after completing the first Ansari competition, the X Prize Foundation announced its second competition on October 4, 2006: the Archon Genomics X Prize. The Archon Genomics X Prize was a competition awarding $10 million to the first team that could sequence 100 human genomes in 30 days. One hundred centenarians (people who are over 100 years old) around the world were expected to donate samples of their genes for each contestant in this competition. The objective was to provide valuable new insight about human longevity. It was expected that breakthrough innovations and technologies on genome sequencing would be attained and that these would lead to improved medical diagnosis and treatment. With a $25,000 fee, a legal entity could register for the competition by May 31, 2013. The formal competition period was from September 5, 2013 to October 5, 2013. The award ceremony was scheduled to be held on October 31, 2013. Several external research organizations collaborated with the Foundation to develop the validation protocol. Researchers were expected to produce valuable clues of human longevity, impacting future healthcare. Thus, the Archon Genomics X Prize competition was expected to bring breakthrough innovations and technologies on genome sequencing and, consequently, a radically new approach to personalized medicine.

After careful consideration, however, the Foundation decided that this competition was not incentivizing technological changes. Many companies, meanwhile, were able to sequence genomes at low cost and in a few days. Hence, the Archon Genomics X Prize was cancelled just before entering a master team agreement. Yet, this competition resulted in two valuable outcomes: (1) collection of blood samples and creation of cell-lines to preserve the DNA of over 100 centenarians whose genomes will be sequenced and put into the public domain and (2) creation of a validation protocol, the first analytical tool for assessing the overall quality of whole genome sequences (Diamandis, 2013). Thus, the global genomics community benefited tremendously, though the participating X Prize teams were highly disappointed.

The Google Lunar X Prize

This is a space competition sponsored by Google. The competition looks for a privately funded space flight team which will launch a robotic spacecraft that can land on the moon and travel on its surface for more than 500 meters and send images back to earth. The competing teams have to have at least 90 percent of their funding from private sources. This challenge offers prizes totaling $30 million. The first successful team will receive $20 million, and the second most successful team will receive $5 million. Teams can earn additional money by performing more than the basic required tasks. These additional tasks include travelling on the surface of the moon at least ten times as much as the minimum requirement of 500 meters, capturing images of the Apollo program hardware, and verifying the recently discovered water ice on the moon. Furthermore, a $1 million award may be given to teams that make significant progress in promoting ethnic diversity in the fields of science, technology, engineering, or mathematics. A company named Space Florida has offered a $2 million bonus to teams that launch the mission from the state of Florida. If this competition turns out to be a success, the world will witness a new frontier of discovery on the surface of the moon.

The Google Lunar competition will end when all necessary prize requirements are fulfilled or at the end of 2015. However, the closing date of this competition has been changed three times. Initially, it was at the end of 2012 with an offer of $20 million to the first successful team. After that, the deadline was moved to 2014 and, finally, to the end of 2015. The registration for the Google Lunar X Prize was closed at the end of 2010, and 25 teams registered for the competition.

MAJOR CHALLENGES AND HOW THE FOUNDATION HAS OVERCOME THEM

The X Prize Foundation has faced many challenges in a variety of areas. We discuss the major challenges and how the Foundation has dealt with them.

Financing

Financing mega prizes is challenging for the X Prize Foundation since it does not have its own budget for prizes. It needs to find a sponsor for each competition. The CEO has approached approximately 200 CEOs and CTOs in the past five years in attempts to secure financing. Despite many setbacks, the CEO did not give up and took a creative approach to funding. With an aerospace insurance broker, he negotiated a multimillion-dollar policy payment against a $10 million payout if space flights were successfully made by January 1, 2005. The underwriters were convinced that no one could make it. Anousheh Ansari, an Iranian-born software entrepreneur from Texas, then agreed to pay the insurance premium, and the competition became the Ansari X Prize. The Archon Genomics X Prize is funded by philanthropists Stewart and Marilyn Blusson. The Google Lunar X Prize is sponsored by Google. Thus, the X Prize Foundation has been able to attract funding from philanthropists, an insurance policy paid for by a philanthropist, and large companies.

Competition Design

Designing an innovation competition involves a lot of work and many tough decisions. On one competition, the Foundation spent about a year developing a set of competition rules that could be easily understood and verified. Also, the Foundation set a requirement that it should organize all competitions at minimum cost, implying that money and other resources should not be wasted. Lastly, setting a time frame for a competition is a design challenge. The Foundation must work with appropriate scientists and other experts to settle on a specific time frame because, ideally, it is desirable not to have to change deadlines during a competition.

Attracting Contestants

Breakthrough innovations need visionary and creative people. Traditional research funding favors those who have solid credentials and successful track records. This, however, may inhibit thinking outside the box. To overcome such problems, innovation competitions need to attract individuals and teams outside the problem area so that they bring different ideas, perspectives, and ways of thinking to the competition (Jeppesen & Lakhani, 2010). The Foundation has been quite successful in this regard. For example, it restructured its board of directors, inviting top-notch entrepreneurs and visionaries such as one of the founders of Google and of Pay Pal to provide guidance and help make decisions.

Trust

Building trust with all stakeholders is a key condition in competition-based innovation. For example, the contestants take a big risk when they start to invest their resources in development work, so contestants must have confidence that the competition organizer will not change the nature of the competition while it is in progress and will have the means to pay the winner. By successfully organizing multiple competitions, the X Prize Foundation has been able to gain the necessary credibility and trust.

Competition Visibility

Visibility of a competition is important. The ability to attract funding and advance an innovation depends largely on visibility. One of the competitions organized by the Foundation, the Progressive Insurance Automotive X Prize, had over 12 billion media hits, providing large and positive visibility to the field of competitors, their financial backers, and the prize sponsor.

University Alliances

The X Prize Foundation has initiated close collaboration with several universities. Research on competition-based innovation has helped to further develop the innovation competitions organized by the Foundation. University cooperation has also attracted more talent to participate in the competitions.

LESSONS LEARNED: HOW TO DESIGN COMPETITIONS FOR BREAKTHROUGH INNOVATION

Funding Sources

The X Prize Foundation's way of organizing competition-based innovation has expanded the potential sources of funding for breakthrough innovation. An imaginative example is that one of the X Prize innovation competitions was funded by an insurance policy. The Foundation has also been successful in attracting funding from philanthropists. Some of the innovation competitions have been funded by large companies without the companies getting any direct return from their investments. All of these are alternative ways to bypass the traditional sources of funding for breakthrough innovation.

Patenting

Traditionally, in innovation competitions, there have been two ways to deal with the intellectual property rights of inventions. One has been that the contestants have been required to give the intellectual property rights to the competition organizer. Another approach is that the innovations have been made public without any protection of intellectual property rights. The X Prize Foundation has implemented a third way: each contestant has been able to keep the intellectual property rights to its innovations. Consequently, the X Prize Foundation's system has turned out to be very motivating for contestants, as the winners of the Foundation's competitions have received the monetary prize and been able to patent their inventions. At the same time, the winning innovations have received a lot of publicity which has enhanced the commercialization process.

Resource Allocation

Competition-based innovation characteristically increases resources that are allocated to solve challenges. In the competitions organized by the X Prize Foundation, the solvers' total allocation of resources significantly exceeded the total value of the prizes. The contestants bear the costs of developing their solutions, whereas only the winning solutions are rewarded. Contestants must calculate the risks associated with a competition and decide if they want to participate. Thus, self-selection plays an important role in competition-based innovation.

Staging

The X Prize innovation competitions have shown that it is usually advantageous to organize the competition in stages. At certain stages, teams are eliminated from the competition so that the most promising teams can get more and better support. Another staging consideration is that premature rewarding may not bring forward full solutions.

Cooperation between Contestants

A downside of innovation competitions is that they lead to duplication of effort when various contestants work on the same challenge. It is not clear how much sharing of information between the contestants there should be during innovation competitions or how cooperation might enhance solutions. However, post-competition collaboration among the contestants is an option to accelerate breakthrough innovation.

Diversity of Participants

Innovation competitions with mega prizes, like those organized by the X Prize Foundation, are a way of attracting contributions from people in different sectors. Such competitions can offer a large number of potential solvers from across the world an opportunity to participate and utilize their expertise. The X Prize competitions have had interdisciplinary and cross-national teams participate.

Media Coverage

Innovation competitions typically garner significant media coverage. The organizers intentionally try to attract media attention. This is advantageous because when more people become aware of the competition, the number of contestants in the competition increases accordingly. Also, innovation development does not end when the winners of the competition are announced. Breakthrough innovations have a long way to go before they become widely utilized in society, and positive media coverage can help in the market penetration of the final products and services.

Contestant Motivation

For contestants, the incentive to participate in innovation competitions is the prize money, but the motivation of contestants can be very broad. In the case of competitions organized by the X Prize Foundation, motivations have included positive public attention, media coverage, the desire to show that one is able to solve the problem, and testing the limits of one's personal abilities. In order to create and sustain the motivation of contestants, certain factors are important to keep in mind. The rules of the competition and the selection of winners must be clear and fair, with no disputable issues. Selection of the winner should be done without delay. Contacts to companies that potentially can commercialize the breakthroughs should be established, even prior to the competition if possible.

Risk and Commercialization

Innovation development inherently bears risk and uncertainty, and developing breakthrough innovations is associated with even higher degrees of risk and uncertainty (Teirlinck & Spithoven, 2008). In comparison to other forms of innovation development, breakthrough innovations take longer to develop, and the market analyses associated with the commercialization process are more challenging (McDermott & Handfield, 2000). The X Prize Foundation's innovation competitions have produced several products of high potential, but developing those into commercial products has been challenging.

CONCLUSION

The X Prize Foundation case provides insight into how competition-based innovation can be used to create radical or breakthrough innovations. Many scholars have argued that modularity is necessary in order to create breakthrough innovations based on ideas obtained from external experts. The X Prize Foundation's competition-based process, as illustrated with three of its examples, shows that a unitary approach can work equally well.

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REFERENCES

Adamczyk S, Bullinger AC, Möslein KM. 2012. Innovation contests: A review, classification and outlook. *Creativity and Innovation Management* 21(4): 335-360.

Baldwin CY, Henkel J. 2014. Modularity and intellectual property protection. Working Paper 14-046, Harvard Business School, Boston, MA.

Baldwin CY, von Hippel E. 2011. Modeling a paradigm shift: From producer innovation to user and open collaborative innovation. *Organization Science* 22(6): 1399-1417.

Brunt L, Lerner J, Nicholas T. 2012. Inducement prizes and innovation. *Journal of Industrial Economics* 60(4): 657-696.

Chesbrough HW. 2003. *Open Innovation: The New Imperative for Creating and Profiting from Technology*. Boston, MA, Harvard Business School Press.

Diamandis P. 2013. Outpaced by innovation: Cancelling an X Prize
http://www.huffingtonpost.com/peter-diamandis/outpaced-by-innovation-ca_b_3795710.html (Accessed on June 6, 2014)

Ethiraj SK, Levinthal D, Roy RR. 2008. The dual role of modularity: Innovation and imitation. *Management Science* 54(5): 939-955.

Henkel J, Baldwin CY, Shih WC. 2013. IP modularity: Profiting from innovation by aligning product architecture with intellectual property. *California Management Review* 55(4): 65-82.

Hoyt DW, Phills JA. 2007. X Prize Foundation: Revolution through competition. Case # SI90-PDF-ENG. Stanford Graduate School of Business.

Jeppesen LB, Lakhani KR. 2010. Marginality and problem-solving effectiveness in broadcast search. *Organization Science* 21(5): 1016-1033.

Kalil T. 2006. Prizes for technological innovation. Working Paper, http://www.brookings.edu/research/papers/2006/12/healthcare-kalil (Accessed on June 10, 2014)

MacLeod RM. 1971. Of medals and men: A reward system in Victorian science, 1826-1914. *Notes and Records of the Royal Society of London* 26(1): 81-105.

McDermott C, Handfield R. 2000. Concurrent development and strategic outsourcing: Do the rules change in breakthrough innovation? *Journal of High Technology Management Research* 11(1): 35-57.

Teirlinck P, Spithoven A. 2008. The spatial organization of innovation: Open innovation, external knowledge relations and urban structure. *Regional Studies* 42(5): 689-704.

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