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Management of science, serendipity, and research performance: Evidence from a survey of scientists in Japan and the U.S.

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ABSTRACT

In science, research teams are increasing in size, which suggests that science is becoming more organisational. This paper aims to empirically investigate the effects of the division of labour in management and science on serendipity, which has been considered one of the great factors in science. Specifically, in examining the survey of scientists conducted in Japan and the U.S., this paper treats the following questions: Does pursuing serendipity really bring about better scientific outcomes? How does the division of labour in science influence serendipity and publication productivity? The empirical results suggest that serendipity actually brings about better research quality on average. It also finds that if the managerial role is played by a leading scientist in the team, this is positively associated with the quality of the paper through allowing researchers to pursue serendipitous findings. In contrast, if the managerial role and leading research role are played by different members, this has a positive association with the number of papers published, as the project size becomes larger. These results indicate there is a trade-off between serendipity and publication productivity in science via who plays the leading role in research and management.

1. Introduction

Would Alexander Fleming have discovered penicillin if he had been part of a large research team? Would he have changed his research plan on influenza to explore a culture contaminated with a fungus in 1928, if his research project had been managed by an efficient project manager? By focusing on serendipity and productivity in science, this paper aims to explore the relation between the management of science and its research outcomes, in three steps.

The first step explores the nature of serendipity in science. Serendipity is regarded as one of the most important aspects of science. Fleming's discoveries of the enzyme lysozyme in 1923 and penicillin from the mould Penicillium notatum in 1928 are frequently cited examples of serendipity. The cosmic background radiation identified by the Bell Lab scientists Arno Penzias and Robert Wilson; the circular structure of benzene discovered by Friedrich Kekulé; X-rays developed by Antoine Henri Becquerel; and Hans Christian Ørsted's finding that electric currents create magnetic fields, are also well-quoted examples of serendipity. It seems that many major discoveries have been made by people who were looking for something very different.

Much of the anecdotal evidence suggests that serendipity does indeed have a positive effect on the quality of research. However, is serendipity a good thing to pursue? One might think that serendipity does not necessarily bring about better results because unintended findings occur randomly. Or one might think that serendipity brings about better results because a scientist does not change their research plan and pursue unintended findings unless they expect that the change would be worth pursuing. This might also be thought because such anecdotes in the history of science only illustrate successful results. Thus, considering serendipity as a significant factor in science might be biased. It is therefore necessary to make a neutral definition of serendipity, and conduct empirical investigations which specify its relations to the quality of research; such studies have been lacking in the literature. By following the definition of serendipity provided by Stephan (2010) as "the act of finding answers to questions not yet posed," this paper investigates whether pursuing serendipitous findings has a positive effect on the quality of research.

The second step considers the effect of the division of labour in research and management on serendipity. How can unintended findings be explored when management and coordination are of importance in science? As will be reviewed in the next section, the

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size of research projects has been increasing. Inter-disciplinary and inter-organisational research has been of significance to the performance of research and development (Agrawal and Goldfarb, 2008). Prioritising in scientific discovery has also increased (Ellison, 2002; Stephan and Levin, 1992). Research is increasingly accomplished in teams across nearly all fields (Wuchty et al., 2007). This indicates that management, such as setting a research goal, planning the research procedure, organising the research team, coordinating the members' efforts, and managing a research schedule, is increasingly important so as to achieve the research goals effectively and efficiently.

Serendipity apparently happens in a random manner, implying that it is not manageable. However, management studies have indicated that certain managerial settings, such as a close relation between a corporate R&D laboratory and the business divisions, transferring managerial power to the on-site manager, and the use of external managerial resources, can promote exploration and allow the flexible pursuit of business opportunities (Chesbrough, 2003; Nonaka and Takeuchi, 1995). This suggests that a certain managerial setting in science can promote a flexible pursuit of serendipitous findings.

When a scientist encounters a serendipitous finding, they are faced with an important choice: to be flexible and change the research plan to pursue the serendipitous event, or to stick closely to the initial plan. A serendipitous finding comes unexpectedly in the form of a very crude and nascent condition. Thus, the scientist is forced to make an intuitive decision whether to pursue it or not. As is reviewed in the following section, this choice is difficult, particularly when the scientist is working as part of a research team managed by a competent and efficient project manager. This situation is seen not only in science but also in business management. This issue is related to the classical managerial challenge of whether to use top down or bottom up management. If managerial power is transferred to the immediate director, they can fully desterilise uncodified and tacit knowledge, and use managerial resources in the context of the actual situation. However, if a hierarchical managerial role is played top down, findings based on ground level intuition are seldom used. A centralised bureaucracy cannot readily adopt new ideas or easily adapt to environmental changes, due to its formalisation (Gouldner, 1954; Merton, 1957; Selznick, 1949). Directing its attention to the allocation of managerial and leading research roles, this paper explores the effects of the division of labour on serendipity.

The third step concerns the effect of the division of labour in research and management on research productivity. One of the advantages of the division of labour is the increased efficiency resulting from specialisation and concentration on a single subtask. Thus, if a leading scientist is separated from a managerial role, they can focus on research and increase productivity. A specialised project manager can also be fully responsible for the progress of a research project. Top down hierarchical management facilitates the completion of the original research goal. In other words, the second and third steps touch on the dilemma that exists in management: exploration versus exploitation (March, 1991).

Through exploring a survey of scientists, this paper reports the following results. First, serendipity has a positive association with citation of papers. This suggests that the management of science needs to seriously take serendipity into consideration because it is one of the important factors in scientific discovery. Secondly, the integration of a managerial and leading research role has a positive association with serendipity. This is consistent with the coordination cost framework, which indicates that integration reduces the costs of the coordination between management and actual research, and provides scientists with flexibility in their research. Thirdly, the separation of management from research has a larger, positive association with the number of papers, as the project size becomes larger. It must be noted that our empirical results are patterns of associations between serendipity, research quality, and management. However, our empirical results suggest a trade-off between serendipity and productivity in science via considering who plays the managerial and leading research roles in research management. The findings of this paper provide managerial and policy implications for the management of science. Since the size of research projects in science has been growing, the role of the research manager is of increasing importance to research performance. The findings of this paper suggest that a bureaucratic and formalistic research manager can block a leading scientist from approaching an initial research plan flexibly and pursuing serendipitous findings, which are a source of quality scientific discoveries.

The remaining part of this paper is organised as follows. Section 2 defines serendipity and reviews the previous literature on the management of science, serendipity, and productivity. In Section 3, we introduce the hypotheses, data description, definitions of the variables, estimation models, and some estimation issues. Section 4 presents the estimated results and robustness checks. Section 5 summarises the findings, considers managerial and policy implications, and discusses three limitations for future research.

2. Management and serendipity

Research is rarely undertaken in isolation; it is increasingly carried out by a team. The mean number of authors per paper has increased from 2.8 in 1981 to 4.2 in 1999 and team size in science has increased by 50% over a 19-year period (Adams et al., 2005).

There are several factors behind this trend in increasing team size. Several studies have shown that collaborative research produces better outcomes with higher citation rates (Andrews, 1979; Presser, 1980; Sauer, 1988; Wuchty et al., 2007). The internet and institutional change have decreased communication costs and promoted increasing team size (Agrawal and Goldfarb, 2008). The increase of team size in scientific research in the U.S. has been attributed to the deployment of the National Science Foundation's NSFNET and its connection to networks in Europe and Japan after 1987 (Adams et al., 2005). Advances in research equipment (e.g., cyclotron, particle accelerators, and high-flux research reactors) have increased both collaboration and team size. Experimental design has also changed from table-top experiments to large-scale projects. This, too, accompanies changes in the pattern of collaboration among researchers because the use of one of these new experimental tools requires several different sets of expertise simultaneously.

Another trend in science, discussed in the literature on the management of science, is related to diversity. Many researchers have suggested that diversity in a research team can lead to a greater level of creativity (Allen, 1977; Garvey, 1979; Kasperson, 1978; Pelled et al., 1999). Singh and Fleming (2010) argued that collaboration reduces the probability of very poor outcomes due to more rigorous selection processes and greater recombinant opportunities in the creative searches. Zuckerman (1977) showed that nearly two-thirds of the 286 Nobel Prize winners named between 1901 and 1972 were honoured for work they did collaboratively. By investigating the conditions under which major discoveries or fundamentally new knowledge occur in science, Hollingsworth (2006) demonstrated that scientists are likely to develop new and alternative ways of thinking when they interact with other scientists with diverse areas of expertise and backgrounds. With the advances in information and communication technology, and institutional changes, scientists can obtain relevant but different knowledge by collaborating with other scientists in areas outside their own specialties. Accessing external complementary knowledge and expertise through networking becomes significant when