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Effects on diversity of R&D sources and human capital on industrial performance

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ABSTRACT

This study conducts a 9-year longitudinal analysis on the effects of diversity of R&D sources, diversity of human capital, innovation infrastructure and academic knowledge on industrial performance. Here, I suggest there is an inverse U-shaped relationship between diversity of R&D sources and industrial performance. Industrial performance is also related to diversity of human capital in a curvilinear (inverted U-shaped) manner. Moreover, innovation infrastructure negatively moderates the effect of diversity of R&D sources on industrial performance, while academic knowledge also negatively moderates the effect of diversity of R&D human capital on industrial performance. The fixed- and random-effects regressions are used to test the hypotheses in a panel data of 315 industry-year cases and the findings support our prediction. The results of this study can help reconciling contradictory findings from previous studies by demonstrating the potential impact of diversity on industrial performance.

1. Introduction

Why do some industries increase their performance in overall production over time, while in others, performance gradually declines? Innovations have become an increasing important means of developing and maintaining industrial competitive advantage [1]. The accumulation of knowledge capital through research and development (R&D) could persistently strengthen industrial competitiveness. R&D is the core of innovation, and its importance is widely recognized. The scope and breadth of R&D activities are varied and evolve with the passage of time. To accumulate the necessary knowledge, industrial organizations turn to external activities from other R&D units [2]. Keeping pace with a dynamic and uncertain environment commonly requires combing knowledge from multiple sources. Knowledge sources and R&D human capital are important means by which industry managers identify and gain access to relevant knowledge. Successful firms may not only rely on internal developments within their boundaries, but also choose to acquire knowledge and capabilities from other institutions of R&D sources [3,4].

Thus, to cope with R&D uncertainty and to increase their productivity, firms increasingly rely on external partners to tap into sources of new knowledge. Previous research studies have shown that a broad search for different types of information from suppliers and customers allows firms to build a new knowledge stock within the firms [5,6]. Research has also shown that firms engaged in R&D activities with different types of partners are able to alleviate increasing costs of innovation [7] and are more likely to effectively capture the benefits of their innovative effort [8].

External R&D units allow firms to tap into sources of knowledge outside their own realm. They allow firms to access information and knowledge they lack without the cost of producing and developing solely themselves. Given the increasing costs of R&D activities, R&D sources have become increasingly important [9]. A changing competitive environment induces shorter technological life cycles and relatively higher development costs. For example, Taiwan has some disadvantages in developing its manufacturing industry because it has a shorter industrialized history, a smaller R&D scale, and weaker

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technical capabilities. Therefore, in the institutional context of Taiwan, the Taiwanese government controls the channeling of resources from society to industry by undertaking core R&D itself [10,11]. In order to promote industrial collaboration for information exchange while sharing the costs and risks of technological development, the Taiwanese government created a unique division for R&D between government and industry in the case of the IT industry [12]. With rich R&D partnerships in an industry, the variety and diversity of knowledge sources have also increased. Firms can establish multiple R&D partnerships simultaneously with a broad range of knowledge sources.

Established in 1987, TSMC (Taiwan Semiconductor Manufacturing Company Limited) is the world's first dedicated semiconductor foundry. Before the 1980s, suppliers of chips mostly spent large sums to design chips themselves and churn them out in their own factories. TSMC came up with a specialized foundry for companies willing to outsource manufacturing to an unknown Taiwan company. The option erased an enormous financial barrier to entry for engineer entrepreneurs, and created fortunes for Qualcomm and Boardcom. Older industry giants like Philips and AMD turned to TSMC, too [13]. As the founder and a leader of the dedicated IC foundry segment, TSMC has devoted significant resources and R&D investment to process technology development and has been able to develop advanced process technologies independently because of accumulated technological knowledge and competence. With a diverse global customer base, TSMC-manufactured microchips are used in a broad variety of applications that cover various segments of the computer, communications, consumer, and other electronics markets [14]. The foundry industry as characterized by its intensive capital expenditure, advanced technology investment, and cyclical market demand required agile and flexible strategies for production capacity planning and industrial growth [15]. If TSMC does not anticipate these changes in technologies and rapidly develops new and innovative technologies, they may be unable to remain a technological leader in semiconductor industry. In 2010 and 2011, the total R&D expenses were US$1020 million and US $1118 million, which represented 7.1% and 7.9% of net sales, respectively. TSMC will continue to invest significant amounts on R&D to maintain a leading position in the development of advanced process technologies. TSMC's dramatic increase in R&D investment is correlated with the company's increase in technological advance innovation and its employment of professional human capital. Because having the mainstream technology offerings and function-rich capabilities, TSMC will be the most advanced, innovative, and largest provider of foundry services for years to come [14].

This study investigates how the diversity of the R&D source base influences an industrial performance [15,16]. Previous studies have focused on the impact of specific types of R&D cooperation on firm performance; the paper examines the extent to which the level of diversity of external sources of knowledge in R&D affects the performance of the focal industry. Empirical research on the effect of diversity of R&D sources on performance is scarce and results have been contradictory. Nieto and Santamaria [17] found a positive relationship between the diversity of sources and the novelty of product innovation. This study provides an important contribution by examining the role of R&D resources on industrial performance.

The goal of this study is to explore the following research question: What is the nature of the relationship between diversity of R&D sources and human capital on industrial performance? Previous studies have used social identity theory and similarity/attention perspectives, particularly at the dyad and group levels of analyses, to explain the potential negative consequences of diversity on performance outcomes [18–23]. Knowledge-based views and decision-making perspectives have suggested that diversity promotes creativity and improves decision-making effectiveness and leads to superior performance [24,25].

2. Literature review and hypotheses

2.1. Diversity of R&D sources and industrial performance

Knowledge base research addresses internal and external knowledge transfer [26,27]. Knowledge learning and flow occur by organizations throughout cooperative systems. Most studies examine the effect of each type of R&D collaboration on performance like business enterprise sector, government sector, private non-profit sector, high education sector and sectors abroad. Instead, this study focuses on how such diversity in R&D sources affect industrial performance. To investigate these relationships, this paper adopts a knowledge-based perspective on the industry level [27,28].

Diversity of R&D sources refers to the portfolio of R&D expenditures in the R&D institutions of the industry. Industrial R&D sources are composed of business enterprise sector, government sector, private non-profit sector, higher education sector and sectors abroad. Engaging in external R&D activities creates an opportunity for the focal industry to enlarge its technology knowledge base by tapping into an external knowledge base. Prior research emphasizes on how the diversity of external knowledge is important to find new combinations of technological knowledge [29]. Since new knowledge is often created from firms outside [30], R&D partnerships are one of the primary means to access or to acquire knowledge [28,31]. By providing an industry with an increased stock of knowledge from diverse external sources, R&D sources help firms develop new products and increase its industrial growth. Firms in an industry engage in what March [32] refers to as “exploration” activities to increase their stock of knowledge. These activities allow firms to access diverse knowledge domains through partner collaboration and to transfer and absorb others' knowledge stock. Firms may also provide a form of knowledge sharing in which each member explores complementarities by giving access to knowledge base [28,33].

Why is the heterogeneity of knowledge sources important for organizations? Assuming that useful knowledge is widely distributed [30], the diversity of external sources allows firms to tap into diverse markets and technological knowledge. Thus, knowledge diversity facilitates the process of innovation by allowing firms to make new linkages and associations. Since novel innovations often depend on scientific effort from heterogeneous areas of science [34], firms seek complementary and new knowledge from a variety of sources to build up new knowledge domains or strengthen existing core knowledge [28,35]. A knowledge-base view suggests that the degree of heterogeneity in knowledge of potential sources is one of the reasons to engage in R&D collaboration with diverse types of partners. Collaborations with an onboard enterprise provide a

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