# Technological Diversification and Firm Performance: The Contingency Effects of Independent Directors and Growth Opportunity

Review of Integrative Business & Economics Research

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**ABSTRACT**

The accumulated evidence is inconclusive concerning the performance effect of technological diversification, suggesting that further research is needed to unravel the complex relationship between technological diversification and firm performance. The purpose of this study is thus to explore the contingency factors underlying the technological diversification-performance pattern, i.e., the moderating effects of board independence and growth opportunity. This study focuses on Taiwanese publicly listed firms in high-tech industries because they are facing increasing innovation pressure. Panel data on 2,139 firm-year observations of 406 publicly listed Taiwanese high-tech firms in the period of 2008-2017 were used to test for our hypotheses. Based on the sample of Taiwanese high-tech firms, the findings show that there is an inverted U-shaped performance effect of technological diversification. Such a non-linear performance effect of technological diversification can be positively moderated by higher levels of board independence and growth opportunity.

Keywords: Technological diversification; Board independence; Growth opportunity; Taiwan.

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## 1. INTRODUCTION

Some corporate failures and losses remind us of the damage caused by technological obsolescence, such as Kodak, Blockbuster, and Nokia. The continued development of new technological competences has thus become an important corporate strategy for gaining new survival and competitive advantages (Leten *et al*., 2007). As Kim *et al*. (2016) suggest, technological diversification is a mechanism for generating new technological competences. Many studies have also tried to understand whether technological diversification can generate new competitive advantages and consequent financial benefits for enterprises (e.g., Lee *et al*., 2017; Lin and Chang, 2015). Nevertheless, the accumulated evidence does not result in a conclusive answer concerning the performance effect of technological diversification, suggesting that more research is needed to unravel


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the complex relationship between technological diversification and firm performance.

In addition to repeatedly verifying the relationship between technological diversification and firm performance, researchers have devoted their attention to a contingency or situational perspective for technological diversification because firms do not operate in an isolated environment; rather, they are situated in several diverse contexts. For example, Lee *et al*. (2017) investigated the moderating effects of firm size and financial slack associated with the performance effect of technological diversification. Lin and Chang (2015) found that absorptive capacity and environmental dynamism could enhance the relationship between technological diversification and performance. Leten *et al*. (2007) found a positive moderating effect of technological coherence on the performance of technological diversification. However, these studies are still unable to provide a complete picture of the performance of technological diversification and expect subsequent research to find more contingency factors. Therefore, the main purpose of this study is to explore the contingency factors underlying the technological diversification-performance pattern.

The literature on corporate innovation and strategy suggests a fit between technological and organizational conditions; however, studies have not explored the moderating roles of corporate governance arrangement and growth opportunity on the association between technological diversification and firm performance. Regarding the corporate governance arrangement, this study focuses on the impact of independent directors because not only do they play a role in monitoring corporate managers, but also as resource providers (Chen *et al*., 2016; Tian *et al*., 2011). Independent directors should be able to manage a company in a prudent and effective way; that is, it is plausible to assume that the performance effect of technological diversification can be moderated by independent directors. About the moderating effect of growth opportunity, high growth opportunity allows firms with greater availability to engage in exploiting existing resources, while also exploring new growth avenues (He and Wong, 2004; Teece, 2010). Firms with proactive corporate strategies are better able to capitalize on the benefits generated from a high growth opportunity (Wei *et al*., 2014). As such, the performance effect of technological diversification could vary in levels of growth opportunities. In short, this study aims to enrich the knowledge of technological diversification by examining the moderating effects of independent directors and growth opportunity.

To tackle the above research objectives, this study focuses on Taiwanese publicly listed firms in high-tech industries because they are facing increasing innovation pressure. The lessons generated from this study could be significant and pertinent not only regarding the performance effect of technological diversification but also to firms operating in a similar economy. The remainder of this article is structured as follows. Section 2 discusses the literature review and hypothesis development. Section 3 describes the data and measures. The empirical results are presented in Section 4, while the final section offers the discussion and conclusions.

## 2. LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

### 2.1 Technological diversification and firm performance


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Technological diversification can be understood as the expansion of firms in a wide range of technology. Several theoretical perspectives have been employed to explain why technological diversification is important and beneficial for corporate growth and survival. For example, some researchers use the resource-based view (RBV) to posit that expanding firms' technological portfolio can add more functions for their existing products (Quintana-García and Benavides-Velasco, 2008) and create new attributes that could become patents (Huang *et al*., 2018), thereby helping them surpass their competitors. In addition, from the knowledge-based view (KBV), firms could efficiently exploit technological resources that lead to their synergy in a wide range of R&D projects (Kim *et al*., 2016; Leten *et al*., 2007; Fung and Chow, 2002); that is, more products, services, and progress can be created from a diversified technological portfolio (Garcia-Vega, 2006; Argyres, 1996; Hargadon, 1997; Kodama, 1992). Viewed in this light, technological diversification can generate economies of scope. Furthermore, based on the perspective of absorptive capacity, a firm with diversified technological competencies is better able to assimilate external knowledge and prevent adverse technological lock-ins (Kim *et al*., 2016). These perspectives suggest that expanding a firm's technological capabilities enhances its performance.

However, based on the conventional economies of scale view, some researchers argue that increasing the diversification of a firm's technological or other competencies could lead to negative performance (Chang and Wang, 2007). Namely, pursuing a diversified technological portfolio may dampen the efficiency-enhancing effects of instantiating and integrating diversified technological functionalities into a firm's products. Besides, by leveraging the notions of organizational ambidexterity, the simultaneous pursuit of exploration and exploitation could lead to organizational tension and conflicts (Lee *et al*., 2017). An argument made by Benner and Tushman (2003) supports the opinion mentioned above that the benefits of a specification are far superior to diversification.

In the literature, the empirical findings regarding the performance effect of technological diversification are varied and inconsistent. For example, in Lin and Chang's (2015) study, technological diversification was found to be positively associated with firm performance, while Chen *et al*. (2013) found the opposite result. Therefore, based on inconsistent theoretical inference and empirical results, researchers have recently begun to investigate an inverted U-shaped effect of technological diversification on firm performance (e.g. Chiu *et al*., 2008; Huang *et al*., 2018; Lee *et al*., 2017; Kim *et al*., 2009; Miller, 2006). Researchers with this view believe that at moderate levels of technological diversification, firms can maximize efficacy and minimize the side effects of pursuing a diversified technological portfolio. Some recent investigations also support that the performance effect of technological diversification is an inverted U-shape. Based on the above considerations and findings, this study proposes the following hypothesis:

*Hypothesis 1: There is an inverted U-shaped relationship between technological diversification and firm performance.*

## 2.2 The moderating effect of independent directors

The primary responsibility of a board is to monitor and discipline the top management


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team to work in the interests of shareholders (Fama and Jensen, 1983; Budiharta and Kacaribu, 2020). Increasing the proportion of independent directors on board has been widely regarded as an important way of enhancing a board's governance performance (Chen, 2011; Su and Lee, 2013; Ho *et al*., 2011). As Chen *et al*. (2016) suggest, from the integrated perspective of agency-resource dependence views, independent directors not only play the roles of monitors and resource providers but also bring human and social capital to a firm. Several recent investigations also empirically demonstrate that independent directors could play a facilitating or moderating role to assist a firm in achieving better organizational performance and outcomes. For example, Prabowo and Simpson (2011) found a significantly positive relation between independent directors and firm performance. Moreover, not only financial performance but some studies also point out that independent directors can help firms enhance corporate strategies, thereby achieving better performance (e.g., Pathak *et al*., 2014). These aspects and evidence suggest that independent directors could play a moderator role in the relationship between corporate strategy and performance. In this vein, the association between technological diversification and firm performance could be moderated by the presence of independent directors.

Some studies point out that the pursuit of diversification strategy is a result of managerial risk aversion. As Hill and Hansen (1991) suggest, risk-averse managers may adopt a diversification strategy to avoid the loss caused by a single field. That means, in addition to the concern of economies of scale, pursuing technological diversification could also imply the potential cost of the agency problem. Based on the role of corporate monitors, independent directors are expected to limit agency costs and ensure that the corporate conducts are by shareholders' interests (Raheja, 2005). That is to say, under the supervision of independent directors, the concern of agency costs derived from pursuing technological diversification could be eased. From the perspective of resource providers, independent directors could monitor information searches, analysis, and processing capabilities of top executives, thus enabling firms to integrate various perspectives (Kim *et al*., 2009). The evidence shows that independent directors may possess knowledge or expertise in different areas that can assist the top executives in identifying new business opportunities (e.g., Chen, 2011; Hillman and Dalziel, 2003). Dalziel *et al*. (2011) also indicate that via interlocks, independent directors can help managers to leverage the existing technology resources to meet new opportunities, suggesting that the economies of scope of a diversified technological portfolio could be enhanced. Judging from the above, we offer the following hypothesis:

> *Hypothesis 2: A firm's independent directors positively moderate the relationship between technological diversification and firm performance; that is, the performance effect of technological diversification will shift upward when the firm has more independent directors on the board.*

### 2.3 The moderating effect of growth opportunity

Audretsch *et al*. (2014) argue that not all firms have the same level of opportunity to achieve success or survive by adopting the same corporate actions because of their different levels of growth opportunity. A firm's growth is a heterogeneous, complex and dynamic process that encompasses economic, social and cultural factors (Wong *et al*.,


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2005), suggesting that the level of growth opportunity represents a critical contingency situation of corporate strategy and consequent performance. Delmar *et al*. (2003) argue that under different growth opportunities, firms should adopt heterogeneous strategies to attain the desired outcomes, such as organic growth, creation of new firms, the concentration of existing firms (mergers or acquisitions) and growth through innovation and diffusion of new products and processes. In other words, the outcome of any corporate strategy would be affected by the growth opportunities of the company.

As expanding the diversity of a firm's technological portfolio is a strategy to increase the availability of internal technological resources, the performance effect of technological diversification should be associated with the context of growth opportunity. In the opinion of Coad and Rao (2008), the impact of innovation activities on organizational growth is highly subject to growth opportunity; the innovation activities can lead to superior performance only when firms have a higher growth opportunity. Choi *et al*. (2015) also argue that the growth potential of a firm is dependent on the outcome of technological investment. These facts suggest that firms with different growth opportunities may not be able to obtain the same benefits from pursuing technological diversification; namely, the benefits from pursuing technological diversification could be enhanced when a firm's growth opportunity is high. We thus have the following hypothesis:

*Hypothesis 3: A firm's growth opportunity positively moderates the relationship between technological diversification and firm performance; that is, the performance effect of technological diversification will shift upward when the firm has a higher level of growth opportunity.*

## 3. METHOD AND DATA

### 3.1 Data

Publicly listed Taiwanese high-tech companies were chosen as the sample in this study. In the past two decades, Taiwan has relied on the development of high-tech industries to raise its competitiveness in the global tech arena, especially in computers, panels, and semiconductors. However, as time goes by, technologies change or become obsolete. This leads Taiwanese high-tech firms to the necessity to develop new technological innovations to sustain their competitive advantages. For example, Acer and Asus, two world-renowned technology brands rooted in Taiwan, have actively expanded their technological competencies to maintain the sustainability of their companies. Therefore, the high-tech firms in Taiwan could provide an adequate research context to test the proposed hypotheses in this study. The data for testing hypotheses were collected from the Taiwan Economic Journal (TEJ) and Taiwan's Intellectual Property Office (TIPO), which can separately provide the data on firm characteristics and patents. As Huang *et al*. (2018) suggest, a 10-year observation period is sufficient to gain precise and generalizable results. In this vein, after removing the observations without information on the variables, a panel data on 2139 firm-year observations for 406 publicly listed Taiwanese high-tech firms in the period of 2008-2017 were used to test our hypotheses.

### 3.2 Dependent variable


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Firm performance: The return on assets (ROA), the ratio of net income to total assets, is the most common measure of firm performance in management studies (Gomez-Mejia and Palich, 1997). By reviewing the literature on technological diversification (e.g., Chen *et al*., 2013; Miller, 2004), ROA is also a relevant indicator used to investigate the performance effect of technological diversification. Hence, this study uses ROA as a measure of firm performance.

### 3.3 Independent variables

As prior studies suggest, a patent portfolio can be used to determine the technological fields in which a firm may operate (Argyres, 1996; Huang *et al*., 2018; Huang and Chen, 2010; Lee *et al*. (2017); Lin and Chang, 2015). The technological fields a firm's patents belong to can reflect the technological domains where a firm has already developed. However, according to Katila and Ahuja (2002), the value of new technology will be greatly reduced after five years. The patents filed in the period of t-4~t, where t is the focal year, were used to estimate a firm's technological diversification in the year t. As Huang *et al*. (2018) suggest, 4-digit IPC (international patent classification) subclasses can be used to categorize a patent's technological field. After defining the technological field of each patent, the Herfindahl index measure was then used to measure the extent of a firm's *technological diversification* (TD). The calculation formula is as follows: $1 - \Sigma i Pi^2$, where Pi represents the proportion of a firm's patent portfolio in the technological field i. The value range of technological diversification is from 0 to 1. The greater value means that technological diversification is higher. *Board Independence* (BI) was measured by the percentage of independent directors to total board members (Su and Lee, 2009). The higher value represents a firm's board having more independent directors. *Growth opportunity* (GO) was measured by the sales growth rate in the focal year t. This measure was also adopted by several recent studies, such as La Rocca *et al*. (2018) and Wu *et al*. (2012). The higher value indicates that a firm has a greater opportunity for growth.

### 3.4 Control variables

Several control variables were also included in the analyses to eliminate alternate explanations and increase the generalizability of our study findings. By referring to the extant literature and considering the data availability (e.g., Huang *et al*., 2018; Lee *et al*., 2017), some firm- and board-level control variables were incorporated into the analytical models: firm age, firm size, debt ratio, current ratio, quick ratio, R&D intensity, patent stock, and board size. *Firm age* was measured by the number of years the firm has been in existence. The natural logarithm of total assets was used to measure *firm size*. Debt ratio, current ratio, and quick ratio were included to control for the potential confounding effects of a firm's financial conditions. *Debt ratio* was measured by the ratio of total long-term debt to total assets, *current ratio* was computed by the ratio of current assets to current liabilities, and *quick ratio* was measured as the difference between current assets and inventories divided by the current liabilities. *R&D intensity* was measured as expenditures on R&D divided by total sales. The natural logarithm of the number of a firm's patents granted in the period of t-4~t was used to proxy for *patent stock*. *Board size* was measured by the total number of directors on the board.


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## 4. RESULTS

Table 1 shows the descriptive statistics and correlation matrix. The correlation coefficients among the three main variables are modest so that the multicollinearity of main and moderating variables should be not a problem. Given that the data used in this study were a panel in nature, the ordinary least squares regression model could result in biased estimations, because each firm has its characteristics and each sample year may have heterogeneous macroeconomic conditions (Wu and Tu, 2007). This implies that without controlling firm- and year-effects, the estimations could be biased. By using a Hausman test, the result also suggests that using a panel data regression model with fixed effects is suitable for the estimation. Furthermore, according to the previous studies (e.g., Faccio et al., 2016; Soytas et al., 2019; Vella and Verbeek, 1998), a panel data regression model with fixed effects also could ease the impact of endogeneity. In other words, the results generated by a panel data regression model could be more robust. The results of the regression analyses with fixed-effects are reported in Table 2.

Model 1 is the baseline model with constant and control variables only. The results show that all selected control variables were significantly associated with firm performance. Firm age, firm size, current ratio, patent stock, and board size were positively associated with firm performance, while debt ratio, quick ratio, and R&D intensity negatively impact firm performance. To confirm that the relationship between technological diversification and firm performance is not linear, the direct effect of technological diversification on firm performance was tested in Model 2. The result indicates that the relationship between technological diversification and firm performance is not linear.

The linear and quadratic effects of technological diversification were simultaneously included in Model 3. The results reveal that the linear effect of technological diversification was significantly positive in relation to firm performance (coef. = 6.445, $p<0.01$) while the quadratic effect of technological diversification has a negative significant effect on firm performance (coef. = -7.527, $p<0.01$), indicating that the performance effect of technological diversification is inverted-U-shaped. We further plotted the technological diversification-firm performance association in Figure 1. The evidence strongly supported Hypothesis 1. In Model 4, the direct effect of board independence was tested. The result shows that board independence has a significantly positive effect on firm performance (coef. = 3.375, $p<0.05$). The moderating effect of board independence on the performance effect of technological diversification was tested in Model 5. The results indicate that "technological diversification × board independence" has a significantly positive effect (coef. = 36.272, $p< 0.01$), and "technological diversification$^2$ × board independence" has a significantly negative effect on firm performance (coef. = -35.054, $p< 0.01$). The regression results are plotted in Figure 2. According to the regression results and interaction plot, the performance effect of technological diversification was found to be positively moderated by board independence.

The direct effect of growth opportunity was tested in Model 6. Growth opportunity


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was found to be significantly positive related to firm performance (coef. = 0.041, p<0.001). The results revealed in Model 7 show that "technological diversification × growth opportunity" has a significantly positive effect (coef. = 0.113, p<0.1), and "technological diversification$^2$ × growth opportunity" has a significantly negative effect on firm performance (coef. = -0.136, p<0.1). These analytical results were also applied to plot the interaction effect, as shown in Figure 3. The regression results and the plot both reveal that growth opportunity can positively moderate the relationship between technological diversification and firm performance. Model 7 was performed to see whether the results would remain the same when all the variables were simultaneously entered into the model. The direction of the main variables remains the same, suggesting that our findings are consistent and stable.

## 5. DISCUSSION

The tension between economies of scale and scope of pursuing a diversified technological portfolio leads to the performance effect of technological diversification being uncertain. This study, therefore, aimed to re-address this issue by examining contingency factors that may moderate the association between technological diversification and firm performance. In a sample of Taiwanese high-tech firms in the period of 2008-2017, we found that technological diversification has an inverted U-shaped effect on firm performance and that this relationship is positively moderated by independent directors and growth opportunity. The findings generated from this study may not only contribute to the knowledge and literature of technological management but also shed light on the importance of contingency in understanding the complexities of technological choices. The theoretical and managerial implications are as follows.

The finding regarding the inverted U-shaped effect of technological diversification on firm performance supports the recent notion that a moderate level of technological diversification allows firms to obtain the benefits and suppress the costs derived from increased technological diversification (e.g., Huang *et al*., 2018; Lee *et al*., 2017; Leten *et al*., 2007). Compared with the extant research, this study confirms the nonlinear performance effect of technological diversification in non-western countries. In other words, the inverted U-shaped effect of technological diversification on firm performance should be closer to the ideal situation (Kim *et al*., 2016; Leten *et al*., 2007). In terms of the findings regarding the positive moderating effects of independent directors and growth opportunity, they echo the argument of contingency theorists that firms do not operate in a vacuum (Fosfuri and Tribó, 2008); rather, they occur in several situations of varying complexity. The moderating effect of independent directors is consistent with the prior evidence that a firm's innovation activities can be influenced by the corporate governance arrangement (Chen and Hsu, 2009). Our study further indicates that independent directors can assist a firm to find possible opportunities and avoid improper agency problems resulting from increased diversity of a firm's technological portfolio. The finding of growth opportunity reflects the significance of appropriate organization-environment fit (Venkatraman and Camillus, 1984); that is, without considering a firm's unique business and economic environments, a firm's intended technological strategy might not function properly. This finding also suggests that passive technological strategies taken by firms could cause them to fall short of desired profitability in an environment filled with growth potentials.


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Table 1. Descriptive statistics and correlation matrix

| | | Mean | S.D. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Firm performance | 1.804 | 6.525 | | | | | | | | | | | |
| 2 | Firm age | 20.122 | 9.127 | 0.034 | | | | | | | | | | |
| 3 | Firm size | 15.714 | 1.576 | 0.076 | 0.176 | | | | | | | | | |
| 4 | Debt ratio | 38.623 | 16.674 | -0.152 | 0.141 | 0.376 | | | | | | | | |
| 5 | Quick ratio | 203.503 | 183.157 | 0.102 | -0.132 | -0.282 | -0.680 | | | | | | | |
| 6 | Current ratio | 267.695 | 202.741 | 0.095 | -0.146 | -0.340 | -0.722 | 0.975 | | | | | | |
| 7 | R&D intensity | 7.410 | 9.956 | -0.191 | -0.171 | -0.300 | -0.388 | 0.441 | 0.459 | | | | | |
| 8 | Patent stock | 2.530 | 1.583 | 0.026 | 0.009 | 0.602 | 0.132 | -0.065 | -0.098 | 0.078 | | | | |
| 9 | Board size | 6.942 | 1.723 | 0.026 | -0.071 | 0.279 | 0.020 | -0.022 | -0.045 | -0.042 | 0.202 | | | |
| 10 | TD | 0.569 | 0.264 | 0.015 | 0.015 | 0.184 | 0.024 | 0.035 | 0.032 | 0.165 | 0.471 | 0.109 | | |
| 11 | BI | 0.240 | 0.165 | 0.097 | -0.304 | -0.112 | -0.042 | 0.051 | 0.056 | 0.050 | -0.017 | 0.050 | 0.023 | |
| 12 | GO | 5.842 | 21.021 | 0.253 | -0.103 | 0.080 | 0.072 | -0.037 | -0.051 | -0.132 | -0.032 | -0.002 | -0.063 | 0.057 |

TD: Technological diversification, BI: Board independence, GO: Growth opportunity


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Table 2. Regression results with fixed effects

| | Model 1 | | Model 2 | | Model 3 | | Model 4 | | Model 5 | | Model 6 | | Model 7 | | Model 8 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Coef. | S.E. | Coef. | S.E. | Coef. | S.E. | Coef. | S.E. | Coef. | S.E. | Coef. | S.E. | Coef. | S.E. | Coef. | S.E. |
| Firm age | 0.906*** | (0.059) | 0.905*** | (0.059) | 0.903*** | (0.059) | 0.873*** | (0.061) | 0.868*** | (0.061) | 0.921*** | (0.059) | 0.924*** | (0.059) | 0.889*** | (0.060) |
| Firm size | 1.773*** | (0.246) | 1.769*** | (0.246) | 1.749*** | (0.246) | 1.742*** | (0.245) | 1.739*** | (0.245) | 1.531*** | (0.244) | 1.542*** | (0.244) | 1.529*** | (0.243) |
| Debt ratio | -0.217*** | (0.020) | -0.220*** | (0.020) | -0.219*** | (0.020) | -0.217*** | (0.020) | -0.214*** | (0.020) | -0.239*** | (0.020) | -0.235*** | (0.020) | -0.230*** | (0.020) |
| Quick ratio | -0.011* | (0.005) | -0.011* | (0.005) | -0.011* | (0.005) | -0.011* | (0.005) | -0.011* | (0.005) | -0.012* | (0.005) | -0.012* | (0.005) | -0.012* | (0.005) |
| Current ratio | 0.007† | (0.005) | 0.008† | (0.005) | 0.007† | (0.005) | 0.007† | (0.005) | 0.007† | (0.005) | 0.008† | (0.005) | 0.008† | (0.005) | 0.008† | (0.005) |
| R&D intensity | -0.259*** | (0.025) | -0.260*** | (0.025) | -0.262*** | (0.025) | -0.262*** | (0.025) | -0.263*** | (0.025) | -0.241*** | (0.025) | -0.241*** | (0.025) | -0.242*** | (0.025) |
| Patent stock | 0.947*** | (0.220) | 0.922*** | (0.235) | 1.059*** | (0.240) | 1.037*** | (0.240) | 1.062*** | (0.239) | 1.169*** | (0.237) | 1.166*** | (0.237) | 1.171*** | (0.236) |
| Board size | 0.646*** | (0.170) | 0.645*** | (0.170) | 0.637*** | (0.170) | 0.584** | (0.171) | 0.606*** | (0.171) | 0.664*** | (0.167) | 0.660*** | (0.167) | 0.635*** | (0.169) |
| TD | | | 0.313 | (1.010) | 6.445** | (2.401) | 6.220** | (2.402) | -1.985 | (3.460) | 6.307** | (2.368) | 5.534* | (2.430) | -3.051 | (3.419) |
| TD² | | | | | -7.527** | (2.675) | -7.145** | (2.679) | 0.567 | (3.826) | -7.322** | (2.638) | -6.509* | (2.687) | 1.470 | (3.777) |
| BI | | | | | | | 3.375* | (1.637) | -3.338 | (3.005) | | | | | -4.353 | (2.989) |
| GO | | | | | | | | | | | 0.041*** | (0.006) | 0.031* | (0.014) | 0.036** | (0.014) |
| TD × BI | | | | | | | | | 36.272** | (11.004) | | | | | 38.032** | (10.950) |
| TD² × BI | | | | | | | | | -34.054** | (11.942) | | | | | -34.618** | (11.853) |
| TD × GO | | | | | | | | | | | | | 0.113† | (0.068) | 0.087 | (0.068) |
| TD² × GO | | | | | | | | | | | | | -0.136† | (0.078) | -0.110 | (0.078) |
| Constant | -40.571*** | (4.021) | -40.623*** | (4.026) | -40.946*** | (4.019) | -40.628*** | (4.019) | -39.314*** | (4.046) | -38.040*** | (3.985) | -38.174*** | (3.992) | -36.362 | (4.018) |
| F | 75.66*** | | 67.23*** | | 61.54*** | | 56.44*** | | 48.87*** | | 62.07*** | | 52.79*** | | 44.28*** | |
| $R^2$ | 0.260 | | 0.260 | | 0.263 | | 0.265 | | 0.270 | | 0.284 | | 0.285 | | 0.292 | |

†p<0.1, *p<0.05, **p<0.01, ***p<0.001
TD: Technological diversification, BI: Board independence, GO: Growth opportunity


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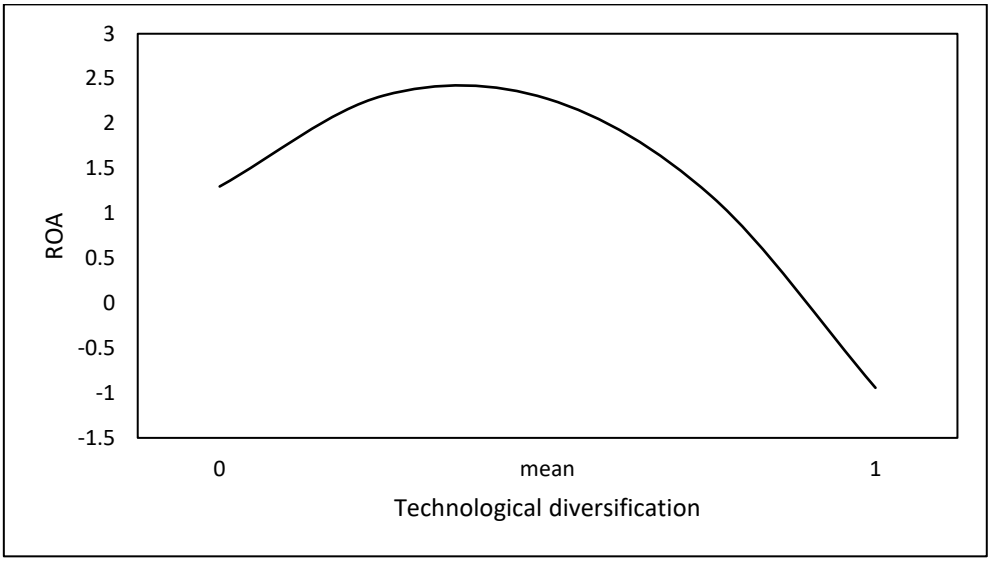


Figure 1. The relationship between technological diversification and firm performance

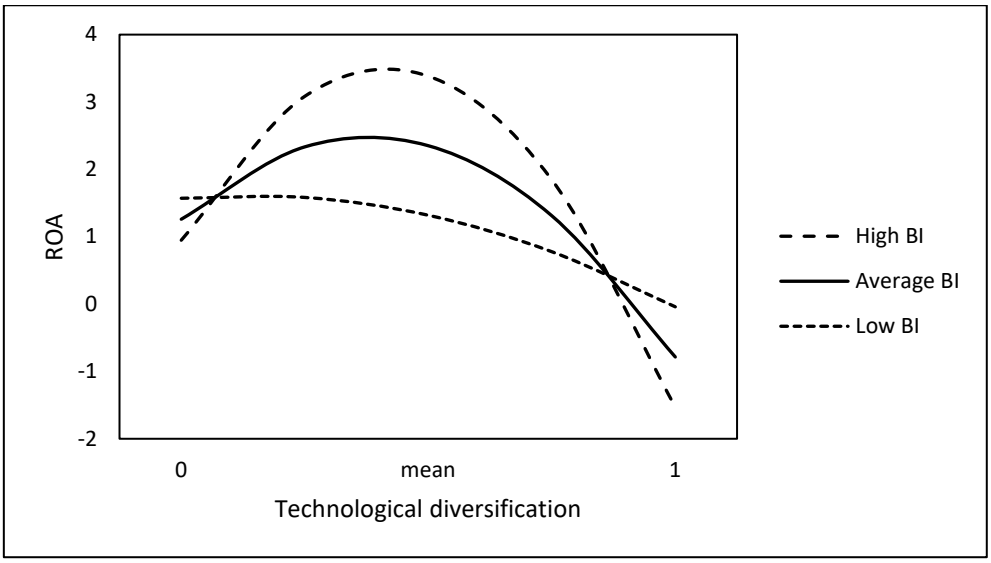


Figure 2. The moderating effect of board independence


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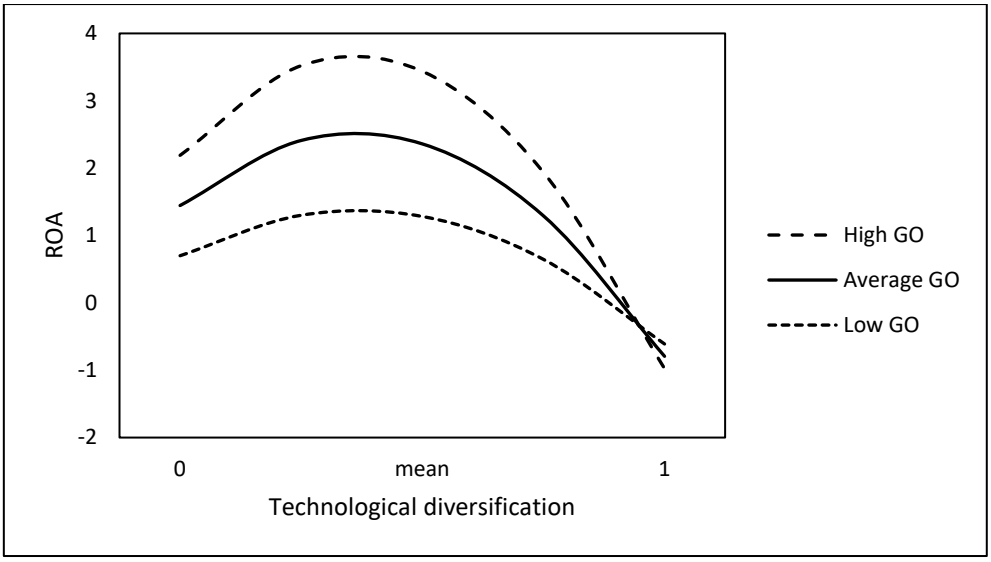


Figure 3. The moderating effect of growth opportunity

In addition to the above-mentioned theoretical contribution, some managerial implications also emerged from the findings of this study. First, the non-linear effect of technological diversification on firm performance informs corporate decision-makers that maintaining a moderate level of technological diversification is contributive to more flexibility and applicability of a firm in a broad range of domains. That is, firms need to establish criteria for evaluating and comparing their technological portfolios to avoid insufficient or excess technological diversification. Second, the moderating effect of independent directors suggests that corporate owners should assess the composition and independence of the board. In high-tech sectors, appointing independent directors not only enhances the efficacy of corporate boards but also aids corporate executives to envision unrealized technological possibilities. Finally, the moderating effect of growth opportunity reminds corporate executives that firms may benefit from pursuing a higher level of technological diversification, but firms may benefit more from focusing on a narrow set of technological capabilities in opportunity-constrained situations; namely, managers should incorporate growth opportunity to realize the value possessing a diversified technological portfolio.

Although we endeavored to fill in the knowledge gap regarding a firm's technological activities by pointing out the influence of technological diversification on firm performance together with the moderate roles of independent director and firm growth, this study also has some limitations that should be acknowledged. First, this study focused on high-tech industries so that we could utilize patents to proxy for a firm's technological diversification. Similarly, in this study, growth opportunity was reflected by a financial indicator. We could not perfectly extract information about growth opportunity from an accounting indicator. Future research can validate the findings of this study by employing non-patent and financial instruments such as a questionnaire survey to measure a firm's technological attempts and growth opportunities. Second, although we included several control variables, such as firm and corporate governance-level variables, other elements, like industry level, could be further controlled to eliminate the disturbance of other factors on the relationship that this study is interested in (Chiu *et al*., 2008; Del Monte and Papagni, 2003). Last but not the least, while this study looked at the contingency effects of board independence and growth opportunity on the technological diversification-performance association, other situational variables could be examined in future studies, for example, the competitive intensity and industrial characteristics that may have


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contingency effects on the performance effect of technological diversification.

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