Capital Markets Review Vol. 28, No. 1, pp. 25-47 (2020)

Do Heterogeneous Boards Promote Firm Innovation? Evidence from Malaysia

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Abstract: Research Question: What are the effects of board heterogeneity on a firm's innovation in Malaysia? **Motivation:** Prior literature has presented differing views on the role of the board of directors and based on the resource dependency theory, board of directors is seen as a boundary spanner in the environment, securing resources for the organization and providing strategic advice that aids in firm survival and performance (Hillman & Dalziel, 2003; Pfeffer & Salancik, 1978; Hillman *et al.*, 2000). This motivates us to explore the different dimensions of board characteristics and their influences on promoting innovation activities in the firms. **Idea:** In this study, we seek to understand the role of the board of directors in influencing innovation activities in firms by specifically investigating the effects of board heterogeneity on innovation in Malaysia. **Data:** Using a sample of 345 observations for the period 2010 to 2012, we examine eight different aspects of board heterogeneity. Financial data used as control variables are obtained from the Compustat database, while board heterogeneity data were hand collected from an individual company's annual report downloaded from the Bursa Malaysia's website. **Method/Tools:** Firm innovation is measured at two points in time. One is at the onset which entails R&D expenditure and the other at the end of the process which is the output of R&D, such as patents and patent citations. The final sample comprises 345 firm-year observations after excluding the missing data. **Findings:** Our results show that heterogeneous boards have both positive and negative effects on innovation. We find that gender, ethnic and tenure heterogeneity of directors encourage firms to innovate. In contrast, directors' heterogeneity on type of experience and external engagement is found to be detrimental to the firm's innovation. **Contributions:** Provides evidence that board heterogeneity can help to enhance firm innovation activities. The study also looks at innovation across a larger cross-section of firms across several industries and assist in formulating policies to promote appropriate board attributes that would promote innovation.

Keywords: Innovation, research and development, board heterogeneity, board diversity, emerging economies, Malaysia.
JEL classification: M41, N25, O16

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Acknowledgements: This project is funded by the Fundamental Research Grant Scheme (FRGS/1/2013/SS05/MUSM/03/3) provided by Malaysia's Ministry of Education.

Received 31 Jan 2020; Final revised 10 Feb 2020; Accepted 11 Feb 2020; Available online 31 Mar 2020.
To link to this article: https://www.mfa.com.my/cmr/v28_i1_a2/
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1. Introduction

Innovation is a critical component of a firm's strategy and is a crucial activity that leads to the formation of significant competitive advantage in any organization (Harden *et al.*, 2010; Teece *et al.*, 1997). Firms that do not adopt innovation strategies would become less competitive and, eventually, be rendered as irrelevant. A large and growing body of literature has shown that innovation leads to better productivity (Audretsch and Belitski 2020; Cassiman *et al.*, 2010) and firm performance (Chen *et al.*, 2020; Xu and Zhang, 2008; Rosenbusch *et al.*, 2011). Thus, for emerging economies, such as Malaysia, innovation is indeed pertinent to foster higher sustainable growth.

In this study, we seek to understand the role of the board of directors in influencing innovation activities in firms by specifically investigating the effects of board heterogeneity on innovation in Malaysia. Prior literature has presented differing views on the role of the board of directors. According to the resource dependency theory, the board of directors is seen as a boundary spanner in the environment, securing resources for the organization and providing strategic advice that aids in firm survival and performance (Hillman and Dalziel, 2003; Pfeffer and Salancik, 1978). This view emphasizes the merits of board (human and relational) capital, which enables the board to perform the provision of resources function. In support of this position, studies have found that board capital predicts who is invited to join the board (e.g. Hillman *et al.*, 2000) and the types of strategies, structures, and policies that the board recommends and supports (e.g. Mason and Westphal, 2001). This set of arguments motivates us to explore the different dimensions of board characteristics and their influences on promoting innovation activities in the firms.

The literature on the role of a board of directors underscores the importance of board heterogeneity as a factor that influences innovation within firms. Miller and Triana (2009) suggest that board demographic heterogeneity provides strategic human and social capital resources to firms. It could change resource allocation and enhance ideas on innovation. Phillips and Thomas-Hunt (2007) argue that heterogeneous boards are less likely to succumb to groupthink. Without the need to comply with a set of universal principles and beliefs, boards would tend to generate more creative ideas that are important for innovation. Knyazeva *et al.* (2009) found that directors with different skill sets amplify the overall expert knowledge of the board and decision-making flexibility, which are crucial in creating a conducive environment for innovation. Abebe and Myint (2018) posits that differentiation among board members' characteristics increases the propensity of a firm to adopt an innovative business model.

On the other hand, board heterogeneity could also hamper innovation activities when the backgrounds of the directors are too diverse (Anderson *et al.*, 2011). For example, board heterogeneity could result in communication and coordination problems. Directors with varied perspectives could cause conflicts during the board deliberations, hence protract the decision-making process. Similarly, Goodstein *et al.* (1994) find that board heterogeneity is less responsive to the required strategic changes, especially during periods of environmental turbulence. As a result, creativity and innovative activities in a firm would be stunted. In short, prior studies, which mainly use data from firms in developed countries, show that board heterogeneity could have both positive and negative effects on firm innovation. In other different settings, where the legal regimes, corporate ownership, capital market, and corporate governance are dissimilar from those in the developed countries, studies on the effect of board heterogeneity may not show the same results. Arnaboldi *et al.* (2018) documented very different results when they examined the relationship between board heterogeneity and bank performance among EU banks. The inconsistent outcomes of prior studies motivate us to re-examine the link in the context of Malaysia, an emerging economy.

In this study, we empirically analyze the effects of board heterogeneity on firm innovation using 345 observations of Malaysian public listed companies from 2010 to 2012. Further, based on existing theories and empirical results, we present five main hypotheses on the association between board heterogeneity and innovation. In summary, we find both positive and negative effects of board heterogeneity on firm innovation activities, which suggest that different facets of board heterogeneity have different implications towards firm innovation. It is shown that, except for age, demographic heterogeneity has a significant positive relationship on firms' innovation. Consistent with Miller and Triana (2009), we find gender diversity and ethnic diversity of directors enhance the innovation activities in firms. However, experience heterogeneity produces mixed implications on innovation, where directors' types of experience and external engagement impede innovation activities of the firms, but the tenure heterogeneity of directors encourages investments in R&D. Lastly, we find that education heterogeneity of directors has no significant impact on firm innovation.

This study makes several contributions to the literature on board heterogeneity and provides useful insights for policy formulation. The results of this study highlight that some aspects of board heterogeneity are more likely to contribute to innovation, but others could hinder or have an insignificant effect on firm innovation. These findings are in parallel with the results from studies on board heterogeneity and firm innovation in developed countries, suggesting that different operating environments may have an insignificant impact on the association between board heterogeneity and innovation activities. Secondly, the study provides evidence that board heterogeneity can help to enhance firm innovation activities, but concomitantly, some dimensions of board heterogeneity could curtail firm innovation. As a result, board composition may need to be configured if the innovation activities in firms are to be intensified. Board representation can be designed to improve firm efficiency (Dalziel *et al.*, 2011), which could have to favor implications on the level of firm innovation. Thirdly, the study looks at innovation across a broader cross-section of firms across several industries compared to prior research that looks at only one sector (Iren and Tee, 2018). Lastly, based on the findings, policymakers could have better insights when formulating policies to promote appropriate board attributes that would encourage innovation; for example, gender and racial diversity on boards should be encouraged.

This paper proceeds as follows. In section 2, we describe the role of board heterogeneity and firm innovation. Based on several dimensions of heterogeneity, we posit the possible associations between each aspect of board heterogeneity and innovation. In Section 3, the sample, variables, and methodology used in this study are discussed. The empirical analyses are presented in Section 4. We conclude this paper in Section 5.

2. Literature Review and Hypotheses Development

2.1 Board of Directors and Innovation

One of the primary roles of the board of directors is to provide resources to firms (Pfeffer and Salancik, 1978), which includes formulating ideas and advice that are important for firm survival and performance (Hillman and Dalziel, 2003). These resources are valuable when the board is involved in the initiation and implementation phases of strategic processes (Huse, 2005, 2007; Zahra and Pearce, 1989), such as the deliberation process on innovation activities. At this stage, board characteristics, especially board heterogeneity, are seen to contribute to an excellent knowledge base and creativity (Erhardt *et al.*, 2003) and provide strategic human and social capital resources (Miller and Triana, 2009) to influence the level of innovation in the firm. Nevertheless, board heterogeneity could also result in curtailing innovation effort due to the inability to reach a consensus because diversity in perspectives could result in discord, hence impede much needed strategic changes (Goodstein *et al.*, 1994).

In the following sections, we present our arguments and develop hypotheses on the association between different dimensions of board heterogeneity and innovation.

2.1.1 Demographic Heterogeneity

2.1.1(a) Gender Heterogeneity and Innovation

Strategic decisions by the board of directors are influenced by the demographic characteristics of the directors (Hillman *et al.*, 2000), where the composition of different races and genders provides diverse types of human and social capital. Female directors bring unique perspectives, experiences, and working styles that are different from their male counterparts (Daily and Dalton, 2003; Huse and Solberg, 2006). Women are different from men on how they perform a task, analyze, and process information. Moreover, with female directors on boards, a pleasant atmosphere in the boardroom are created that represent different values, such as corporate social responsibility (Harjoto and Rossi, 2019) and women's issues (Bilimoria and Huse, 1997). For example, female directors contribute ideas on marketing to women, women's preference for using a particular technology, and even on women's perceptions of a specific phenomenon.

Further, the addition of female directors to boards would contribute to increased board development or decreased level of conflict, hence, leading to increased board effectiveness (Nielsen and Huse, 2010). Women are generally considered to have more wisdom and diligence (Huse and Solberg, 2006) as well as more risk-averse (Croson and Gneezy, 2009; Niederle and Vesterlund, 2007) than many male board members. Therefore, the existence of the various ideas and perspectives from both male and female directors encourage creativity in improving the existing processes or inventing new solutions. Prior studies show that the more diverse the boards in terms of gender, the higher the innovation in the firms (Torchia *et al.*, 2011). The increase of female representation in the boardrooms provides firms with not only economic benefits but also stronger ethical commitments, social visibility, and the attraction of human talent (Reguera-Alvarado *et al.*, 2017). Similarly, board gender diversity encourages innovation, which then results in better firm performance (Miller and Triana, 2009; Conyon and He, 2017; Katmon *et al.*, 2019). We, therefore, posit that firm innovation will be higher with boards that have more significant gender heterogeneity.

Hypothesis 1. *Gender heterogeneity of directors is positively related to firm innovation.*

2.1.1(b) Ethnic Heterogeneity and Innovation

Firms with ethnically diverse boards of directors provide more resources because the different ethnic backgrounds of the directors allow them to provide the firms with more extensive networks and more comprehensive non-redundant resources (Singh, 2007). This advantage leads to a widened group of scanning abilities and consideration for alternatives relative to homogenous teams (Eisenhardt and Schoonhoven, 1990). Therefore, the diversity of information and resources provided by the networks of directors with different ethnic backgrounds is expected to lead to innovation. Miller and Triana (2009) find board ethnic diversity is positively related to firm innovation. However, the widely varying perspectives and opinions among team members from diverse ethnic groups could be counter-productive. Ethnic diversity has been found to increase the risk of emotional conflicts, such as interpersonal clashes, characterized by anger, frustration, and other negative feelings that may adversely affect performance (Katmon *et al.*, 2019; Salloum *et al.* 2019; Tsui *et al.*, 1992). Although there are challenges at the onset of the formation of a multicultural team due to differing work and communication styles, if this is proactively managed, the team can exhibit good cohesion and stimulate creativity and innovation (Bouncken *et al.*, 2016). Due to the

inconclusive views on the influence of ethnic heterogeneity on innovation, we, therefore, posit a non-directional association between these two variables.

Hypothesis 2**.** *There is an association between ethnic heterogeneity and firm innovation.*

2.1.1(c) Age Heterogeneity and Innovation

Prior literature suggests that different age group has varying impact on innovation (Guo *et al.*, 2017; Ng and Feldman, 2013; Fernández-Temprano and Tejerina-Gaite, 2020). Old directors would have accumulated more job skills, knowledge and experience over their careers, thus enable them to have wisdom (Baltes *et al.*, 1995; Cornelius and Caspi, 1987), economic resources (Houle, 1990) and tend to deliberate and mature in their decision-making process (Fairchild and Li, 2005; Kang *et al.*, 2007) and have positive effect on firm performance (Fernández-Temprano and Tejerina-Gaite, 2020). This view suggests an old director's human capital worth more than the younger ones (Becker, 1964).

However, the other streams of studies have argued that older workers are perceived as less persistent in learning new technology, implementing technology change, and adapting to new technology and software (Avolio *et al.*, 1990; Morris and Venkatesh, 2000; Mostafa and El-Masry, 2008). Old workers also are associated with less ambitious or conscientious over time (Rabl, 2010; Wong *et al.*, 2008) and tend to devote their energy to preventing losses of resources compared to young workers that display strong orientation towards growth (Freund, 2006). Further, younger directors have the advantage of having the latest technical knowledge on the various facets of the firm's operations, which would enable them to remain competitive and willing to change (Taylor, 1975). They also bring more considerable energy and exhibit less risk-averse tendencies (Anderson *et al.*, 2011). Also, the younger generation is generally better educated and better acquainted with new technological developments (Bantel and Jackson 1989). They are well-versed in offering insights into new product developments, modern manufacturing, and service processes.

The above arguments, in general, support the need to have age heterogeneity among board members. However, some evidence shows a homogeneous team encourages smoother, less formal, and frequent communication, leading to a high level of behavioral integration (O'Reilly *et al.*, 1989; Wagner *et al.*, 1984). A similar age group shares common interests, experience, and values, enabling them to develop quantity, quality, and richness in their discussion that leads to innovation. Therefore, more significant age heterogeneity could produce innovative ideas that lead to innovation. We posit a positive association between age heterogeneity and innovation.

Hypothesis 3**.** There is a positive association between age heterogeneity of directors and firm innovation.

2.1.2 Occupational Heterogeneity

2.1.2(a) Education Heterogeneity and Innovation

The board of directors deals with the myriad of issues, which include financial, human resources, taxation, and legal. Therefore, the boards need excellent support in each area to appreciate the matters in hand and respond to them in a meaningful and effective manner. Mahadeo *et al.* (2012) argue that board education heterogeneity could provide a wide array of knowledge for boards to grapple with the multiple dimensions of a business decision. Further, different educational backgrounds are associated with various social statuses, networking and professional development paths and hence varied educational backgrounds arguably provide directors with different perspectives and cognitive paradigms that affect career development, social contacts (Useem and Karabel, 1986) and performance (Katmon *et*

al., 2019). With a diverse educational background and ideas from the broad spectrum of experience and knowledge base, a board of directors is more likely to promote innovation activities. Additionally, as the firm's operating environment becomes increasingly more complex, the demand for the varying talents and capabilities of a heterogeneous board increases (Anderson *et al.*, 2011).

Nevertheless, there are other factors such as experience, managerial skills, networks, and skills obtained outside of formal school education that influence the type of resources directors brought to the firms (Darmadi, 2013). Therefore, there is room for so-called "street smart" directors to play a role in the boardroom. The "street smart" directors may be less educated, but due to their long association with the firms they work for, their knowledge of the intricacies of the firms' business is also highly valued. Besides, there are also instances where directors engage in occupations and activities that have little in common with their original professional or academic studies, or they may have studied different subject areas (Mahadeo *et al.*, 2012). The directors' contributions to the firms are not related to the education backgrounds which they formally enrolled, which is supported by a recent study by (Assenga *et al.*, 2018).

In sum, the role of education heterogeneity in influencing innovation is inconclusive. We, therefore, posit a non-directional hypothesis as follows:

Hypothesis 4a. *There is an association between degree type heterogeneity of directors and firm innovation.*

Hypothesis 4b. *There is an association between education level heterogeneity of directors and firm innovation.*

2.1.2(b) Experience Heterogeneity and Innovation

Directors' prior working experience is valuable to firms (Gray and Nowland, 2013). The board meeting would be more pragmatic when directors with distinct working backgrounds share ideas. Discussions based on rich information are likely to result in creative and innovative ideas that lead to innovation in firms. Bantel and Jackson (1989) suggest that functional experience diversity of the executive team increases the team's creativity and innovation due to the variety in human capital. Prior literature has documented a positive association between directors' industry experience and strategic R&D decisions undertaken by firms (Chen, 2014; Dalziel *et al.*, 2011). Directors without the appropriate expertise could only make a limited contribution to the decision-making process, which involves R&D investment (Kroll *et al*., 2008). They are more likely to engage in their customary monitoring role and place greater emphasis on the financials of the R&D investment compared to the strategic implications of R&D investments (Kassinis and Vafeas, 2002; Kor and Misangyi, 2008). Nevertheless, boards with a high level of experience diversity would make slower changes than those with considerable homogeneity, particularly in an environment full of uncertainties (Goodstein *et al.*, 1994). During this situation, the directors bring to the board information about practices that may be foreign or unfamiliar to the firm and specific to the industry (Hillman and Dalziel, 2003).

Apart from functional and technical experience, the phenomenon of director interlocks can also contribute to increased R&D activities by firms. Directors who have multiple directorships in other firms are valued by the market (Gray and Nowland, 2013) because they are exposed to making strategic decisions that may involve significant R&D investment on a more frequent basis compared to directors who are singular board members. The frequency of exposure to the strategic decision-making process could help the directors to make timely decisions. Speed in decision making can be important for highly competitive industries.

Simultaneously, directorships can also have a cascading effect when directors' high-tech experience (from sitting on boards of firms dealing with high-tech R&D) can increase the level of firm innovation for low-tech firms (Reguera-Alvarado and Bravo, 2018). Multiple external engagements also provide an avenue for directors to increase their connectivity with outside parties, and they can help facilitate access to financing, which is essential for R&D investments (Hillman and Dalziel, 2003). In the context of family firms, highly experienced business founders tend to hinder product innovation as they tend to preserve the status quo and minimize changes in the firm (Querbach *et al.*, 2020).

Empirical findings, however, have indicated that increased external engagement has a curvilinear relationship with R&D investment (Reguera-Alvarado and Bravo, 2018). In other words, external commitments are advantageous up to a certain extent. However, beyond a certain threshold, it may be disadvantageous as too many external engagements leave directors with little time to engross themselves in deep contemplative decision making when the decisions involve charting the future direction of the company through R&D investments (Cashman *et al.*, 2012). Given the contradicting views on the association between experience heterogeneity and innovation, we posit the following non-directional associations.

Hypothesis 5a. *There is an association between experience heterogeneity of directors and firm innovation.*

Hypothesis 5b. *There is an association between the number of external engagements and firm innovation.*

2.1.2(c) Tenure Heterogeneity and Innovation

Tenure heterogeneity is a proxy for different experiences, perspectives, attributes, and values (Sperber and Linder, 2018). In general, empirical studies support the idea that long-tenured workers are associated with more knowledge because they develop great political savvy about various business issues, such as what changes are most feasible given the organization's culture (Gavin and Greenhaus, 1976; Ng and Feldman, 2010). Consistent with human capital theory (Becker, 1964), long-tenured workers also tend to be paid higher as they have accumulated knowledge, skills, and experience. As a result, studies found a positive relationship between tenure and firm performance (for example, Katmon *et al.*, 2019). In contrast, short-tenured workers are less talented workers; thus, they are pushed out of the organization earlier in their careers (Slaughter *et al.*, 2007).

There is a different conclusion on the link between tenure and creativity. Long-tenured workers tend to be more skilled, knowledgeable, and experienced about the firm, which could enhance creativity and innovation (Liu, 2016). However, their creativity could also be thwarted due to habitual behaviors and a preference for solving problems in a familiar conventional way, hence limiting their opportunities to develop different perspectives (Binnewies *et al.*, 2008) and ultimately affect performance negatively (Ahmadi *et al.*, 2018). This limitation can be overcome by short-tenured workers because they are less likely bounded by prior work experience and be more flexible towards environmental changes. Boards with a few latecomers may benefit from the different views on subject matters or constructive arguments in understanding business issues. This bunch of personalities could also facilitate the identification of entrepreneurial opportunities in different markets. Therefore, the mixture in a tenure would foster diversity in opinions, perspectives, and information, promoting creativity in problem-solving and developing openness to changes while minimizing groupthink (Cho and Hambrick, 2006). Variations in board members' tenure also increase the scope of external information and the access to networks from various industry sectors, because each director has previously served in different organizations in

different industries (Kim and Rasheed, 2014). In a firm that highly values innovations, the combination of long and short-tenured directors is required to enable the board to be work effectively and improve the efficiency of the firm (Christensen and Knudsen 2008).

Based on the above arguments, we predict that director tenure heterogeneity affects the firm's propensity to innovate positively. We state the hypothesis below.

Hypothesis 6. *Director's tenure heterogeneity is positively associated with firm innovation.*

3. Research Design and Methodology

3.1 Sample Selection

Table 1 presents the sample selection for this study for the years 2010-2012. Although the data extracted is only for three years and not very recent, yet however, the data obtained provide a rich source of information in terms of innovation and board heterogeneity. The rationale being is that in the Malaysian context, the average board tenure is at the approximate medium of 3 years. We select companies that reported research and development expenditure (R&D) in the Compustat database. Data on R&D is essential because it serves as the main proxy for innovation. R&D spending is a necessary prelude for firms as it leads to entrepreneurial exploration (Zahra, 1996) and innovation (Thornhill, 2006). Financial data used as control variables are also obtained from the Compustat database, while board heterogeneity data were hand collected from an individual company's annual report downloaded from the Bursa Malaysia's website. The final sample comprises 345 firm-year observations after excluding the missing data.

Table 1: Sample selection criteria

Firm data	No. of firm-year observations
Firms with data on R&D costs (the year 2010 to 2012)	585
Exclude firms without director heterogeneity data	(97)
Exclude firms without control variable data	(143)
Final sample	345

3.2 Dependent Variable – Firm Innovation

Firm innovation is measured at two points in time. One is at the onset, which entails R&D expenditure and the other at the end of the process, which is the output of R&D, such as patents and patent citations. Research on innovation has focused on patent data as patents are an excellent measure of innovation capital and the technological capabilities of the firm (Griliches, 1981). Furthermore, the diffusion of the patents, as measured by citation data, provides strong evidence of firm innovation success (Trajtenberg, 1990). Patents can further enhance the measuring of innovation capacity when they are categorized either by their originality and generality (Koh and Reeb, 2015).

In this study, R&D expenditure is used as the dependent variable. We argue the appropriateness of its use based on the following perspectives. First, the patent filing process in most emerging countries is cumbersome, and even though the number of filings has increased from a low base (for example, China's 12,698 patent applications in 2010 that marked a 54% increase over 2009 and a doubling from 2008). The lack of patent enforcement to protect patents also plagues the usefulness of using the patent data to gauge the innovativeness of a firm. Further, Dutz (2007) argues that innovation in emerging countries is less of breaking global technological boundaries but instead focused on improving practices across the entire economy and includes innovations in processes and organizational models. Second, R&D expenditure reflects decisions made by directors to allocate resources for innovation (Hoskisson *et al.*, 2002; Miller and Triana, 2009), whereas a firm's top

management team usually decides to file a patent with little input from the board. Thus, it is more appropriate to link the R&D expenditure with the board heterogeneity when examining the influence of boards on firm innovation.

3.3 Independent Variables

Based on prior literature, we use eight dimensions of board heterogeneity measures, i.e., age heterogeneity, gender heterogeneity, ethnic heterogeneity, degree type heterogeneity, education level heterogeneity, director experience (type of experience), external board seat heterogeneity (number of external engagements), and director tenure heterogeneity (tenure) (Adams and Ferreira, 2009; Carter *et al.*, 2010; Hillman *et al.*, 2000; Kim and Rasheed, 2014; Le *et al.*, 2013; Wahid, 2012; Rosenbusch *et al.*, 2011). In this study, we adopted those measures of director heterogeneity from Anderson *et al.* (2011) to ensure consistency in our predictions. Appendix A provides the mechanics of how each measure is derived. Except for gender and ethnic heterogeneity, which use the continuous measures, the other dimensions of heterogeneity are represented by categorical measures in the analysis.

3.4 Control Variables

This study controls for variables that could affect firms' innovation. We control for board size (measured by the number of directors on the board) to capture the extent that larger boards are more effective in monitoring management (Adams and Mehran, 2012; Yermack, 1996) and thus can influence the investment level of R&D. We also control for firm-level variables such as firm's growth, debt, profitability, and cash flow. These variables affect a firm's ability to acquire or invest in R&D activities (Hoskisson *et al.*, 2002).

Growth is calculated based on the average increase in sales for over five years. Yearly growth is the ratio of the difference between current and previous year sales divided by the previous year sales (Anderson *et al.*, 2011). Firms' debt and firms' profitability are measured by total debts and return on assets, respectively. Cash flow from operations measures the amount of cash available from a firm's operation. We also control for the effect of a firm's complexity - structural complexity and firm size – on firm innovation (Damanpour, 1996). Structural complexity is measured by the number of firm's subsidiaries and firm size by the log of total assets. The firm's age is also controlled for as it may affect the R&D spending. A firm's age is measured by the log of the number of years since the firm was incorporated. Finally, we control for industry effect by including a dummy variable for technology companies. Technology companies tend to be more innovative compared to other industries (Ayyagari *et al.*, 2012). We summarise the expected sign of the control variable on R&D spending in Table 2.

3.5 Model Specification

The pooled ordinary least squares (OLS) method is used to test the above hypotheses. The error term is adjusted using White's test to obtain robust estimators. Table 2 summarises the definition of the variables. The regression model is as below.

$$\begin{aligned} R\&D_{i,t} = {} & \beta_0 + \beta_1 Age\ Het_{i,t} + \beta_2 Gender\ Het_{i,t} + \beta_3 Ethnic\ Het_{i,t} + \beta_4 Degree\ Type_{i,t} \\ & + \beta_5 Educ\ Level_{i,t} + \beta_6\ Experience_{i,t} + \beta_7 Ext\ Engage_{i,t} + \beta_8 Tenure\ Het_{i,t} \\ & + \beta_9 Board\ Size_{i,t} + \beta_{10} Growth_{i,t} + \beta_{11} Debt_{i,t} + \beta_{12} ROA_{i,t} + \beta_{13} CFO_{i,t} \\ & + \beta_{14}\ Subs_{i,t} + \beta_{15} Firm\ Size_{i,t} + \beta_{16} Firm\ Age_{i,t} + \beta_{17} Tech\ Co_{i,t} + \varepsilon_{i,t} \end{aligned} \quad (1)$$

Table 2: Definition of sample variables

	Expected sign	Measurements
Dependent variable		
R&D		Natural logarithm of R&D costs
Independent variables		
Age het		Appendix A provides the mechanics of how each measure is derived
Gender het		
Ethnic het		
Degree type		
Educ level		
Experience		
Ext engage		
Tenure het		
Control variables		
Board size	+	Number of directors on board
Growth	+	Average sales growth over five years = $\sum_{l}^{n} [\frac{\frac{Sales_l - Sales_{l-1}}{Sales_{l-1}}}{n}]$ where n-5
Debt	-	Book value of long-term debt and short-term debt divided by book value of total asset
ROA	+	Operating income divided by book value of an asset (in percentage)
CFO	+	Net cash flow from operating activities/ total assets
Subs	+	Number of subsidiaries owned by the firm
Firm size	+	Log of total assets
Firm age	+	Log of firm age
Tech co	+	Dummy variable, 1 = Yes, 0 = Otherwise

4. Results and Discussion

4.1 Descriptive Statistics

Table 3 presents the descriptive statistics of the sample firms. The average R&D expenditure per year for anyone firm is RM 490,000, while the median expenditure is RM 473,000. Most of the sample firms are young firms with an average age of 2.541 years, indicating that most start-up firms are heavily invested in R&D.

In terms of age heterogeneity, the mean score of 2.528 indicates that the dispersion of director age is moderate. For gender heterogeneity, the average Blau Index score is 0.131, which suggests that most firms in the sample are male-dominated. Ethnic heterogeneity has a Blau Index score on average of 0.409, suggesting that there is a moderately good mixture of directors from different ethnic backgrounds. As for the degree type, on average, the Blau Index score was 2.551, and the average Blau Index score for education level is 2.513. The director experience heterogeneity average was 2.977, which means that directors of the sample firms maintain between moderate and high levels of experience heterogeneity in different types of industries. Lastly, most sample firms score on average 2.473 for directors' tenure heterogeneity, which indicates moderate turnover among directors. Table 4 presents the correlation coefficients between variables in the model. The table shows that R&D is positively correlated with ethnic heterogeneity but not correlated to other variables.

4.2 Multivariate Regression Results

Table 5 presents the regression results on the association between innovation and board heterogeneity. The results show that gender and ethnic heterogeneity have positive effects on firm innovation. However, age heterogeneity of the directors does not affect firm innovation. These findings suggest that firms benefit from gender-diverse boards, for example, through their exemplary attendance at board meetings (Adams and Ferreira, 2009), which display their

Table 3: Descriptive statistics

Variable	Mean	Median	Std. Deviation	Min.	Max.
R&D	0.49	0.473	0.281	0.000	0.998
Age het	2.528	3.000	1.115	1.000	4.000
Gender het	0.131	0.000	0.157	0.000	0.500
Ethnic het	0.409	0.444	0.173	0.000	0.744
Degree type	2.551	3.000	1.104	1.000	4.000
Educ level	2.513	2.000	1.129	1.000	4.000
Experience	2.977	3.000	0.976	1.000	4.000
Ext engage	2.548	3.000	1.115	1.000	4.000
Tenure het	2.473	3.000	1.1	1.000	4.000
Board size	7.017	7.000	1.849	4.000	15.000
Growth	0.139	0.074	0.441	-0.329	3.456
Debt	0.369	0.340	0.217	0.012	1.456
ROA	1.496	3.060	13.646	-81.84	45.910
CFO	55.575	56.250	107.998	-439.07	515.48
Subs	15.42	5.000	44.455	0.000	429.000
Firm size	5.287	4.997	1.968	1.074	11.390
Firm age	2.541	2.485	0.767	0.000	4.575
Tech co	0.333	0.000	0.472	0.000	1.000

commitment to exchange ideas actively and effectively evaluate the issues at hand. The finding on the positive association between gender heterogeneity on board is also evidence that female directors are not hired as a measure of tokenism to appease regulatory authorities (Torchia *et al.*, 2011). Similarly, boards with high ethnic heterogeneity are the recipients of valuable resources produced by different directors' ethnic backgrounds (Carter *et al.*, 2010), which could further contribute to the creation of new knowledge, which is a critical component of innovation (McLeod and Lobel, 1992).

We also find that the heterogeneity in directors' education plays a minimal role in firm innovation - the association between innovation and the two dimensions of education heterogeneity; i.e., the level and type of education were insignificant. This finding is consistent with a prior study that found that educational specialization diversity plays no role in determining the top management team's innovativeness (Bantel and Jackson, 1989). Simons (1995) suggests that board diversity in educational levels provides impetus to innovative activities within the firm, only when the board uses a decision-making process that allows the board's education diversity to become prominent in open debate.

In terms of experience heterogeneity, the result shows that the myriad of experiences induces a negative effect on innovation. The finding suggests that a board of directors with extremely diverse experience can discourage innovation activities in firms because it leads to a slower decision-making process due to lengthy process losses (Milliken and Martins, 1996). Also, the diverse experience of directors may result in interaction difficulties coupled with low levels of behavioral integration (Hambrick and Mason, 1994) that impedes decisive action within groups of directors. Recently, a study indicates that commonality in director skill sets leads to better firm performance (Adams *et al.*, 2018). The findings on experience heterogeneity also provide suggestive evidence that boards should be structured based on the relevant skill sets and experience related to the industry. By narrowing the search for directors with the appropriate skill sets and expertise specifically related to the firm's industry would bring about marginal benefits on R&D expenditure.

Table 4: Correlation coefficients between variables in the test models

	R&D	Age het	Gender het	Ethnic het	Degree type	Educ level	Experience	Ext engage	Tenure het	Board size	Growth	Debt	ROA	CFO	Subs	Firm size	Firm age
Age het	-0.053																
Gen het	0.044	0.207**															
Ethnic het	0.135*	0.017	-0.103*														
Degree type	-0.006	-0.017	-0.035	-0.025													
Educ level	0.048	0.054	-0.004	-0.023	0.302**												
Experience	0.045	0.035	0.253**	0.071	0.053	0.176**											
Ext engage	-0.094	0.267**	0.161**	-0.025	0.030	-0.000	0.127										
Tenure het	-0.001	0.014	-0.060	0.182**	0.041	0.137*	0.072	-0.069									
Board size	0.058	-0.095*	0.087	0.076	0.149**	0.038	0.450**	-0.003	0.057								
Growth	0.051	0.039	-0.041	-0.036	-0.014	0.072	0.009	0.042	0.009	-0.021							
Debt	-0.045	-0.083	-0.132	0.021	0.077	0.124*	0.144**	-0.122*	0.085	0.283**	-0.051						
ROA	0.025	-0.017	0.043	0.002	0.091	-0.062	0.003	0.020	-0.118*	0.123*	0.058	-0.177**					
CFO	0.052	0.014	0.003	0.020	0.003	-0.081	-0.070	-0.065	-0.011	-0.021	-0.101	-0.126*	0.505**				
Subs	0.065	-0.181**	-0.047	0.057	-0.076	-0.036	0.138*	-0.230**	0.111*	0.436**	-0.015	0.121*	0.053	0.023			
Firm size	0.035	-0.234	-0.027	0.117*	0.035	-0.061	0.280**	-0.358**	0.132*	0.562**	-0.086	0.433**	0.209**	0.159**	0.494**		
Firm age	0.026	-0.195**	-0.124*	0.060	0.056	-0.021	0.049	-0.252**	0.392**	0.163**	-0.187**	0.283**	0.051	0.083	0.076	0.523**	
Tech co.	0.081	0.040	-0.058	0.029	-0.071	0.059	-0.222**	0.127*	0.060	-0.230**	0.112*	-0.287**	-0.246**	-0.155**	-0.170**	-0.503**	-0.280**

Notes: **and * indicate significance at the 1% and 5% levels, respectively (two-tailed).

Table 5: OLS regression results

	Model 1		Model 2	
Variable	B	t-stat	β	t-stat
Intercept	-2.204	-4.106***	-1.992	-2.767***
Demographic heterogeneity				
Age het.			0.129	1.462
Gender het.			1.495	2.176**
Ethnic het.			1.470	2.554***
Education heterogeneity				
Degree type			0.054	0.495
Educ level			-0.132	-1.346
Experience heterogeneity				
Experience			-0.496	-4.676***
Ext engage			-0.198	-2.034**
Tenure			0.212	1.983**
Control variables				
Board size	-0.122	-1.516	0.013	0.151
Growth	0.035	0.184	0.041	0.199
Debt	-1.306	-2.273**	-1.162	-2.044**
ROA	0.000	-0.030	0.002	0.275
CFO	0.001	1.021	0.001	0.543
Subs	0.006	3.387***	0.004	2.289**
Firm size	0.633	5.860***	0.598	6.075***
Firm age	-0.395	-2.385***	-0.538	-2.870***
Tech co	1.538	6.833***	1.283	5.571***
Observations		345		345
Adjusted R-squared		0.225		0.325
F-statistic		12.123***		9.264***

Notes: ***, **and * indicate significance at the 1% , 5% and 10% levels, respectively (two-tailed).

We also find a significant negative association between directors' numbers of external engagement and innovation, suggesting that busy directors could discourage innovation. With tight schedules, these directors cannot effectively contribute innovative ideas that encourage innovation in firms (Cashman *et al.*, 2012). This finding is in line with Ferris *et al.* (2018) which studied firms in the U.S. Further, the results of our study show the directors' tenure heterogeneity is positively associated with innovations, which suggests that directors with different length of service with the firm contribute diversity in knowledge and information-processing behaviors that could lead to more alternatives, better evaluation of strategic options and more accurate predictions of environmental changes (Finkelstein and Hambrick, 1996). Tenure diversity allows for different perspectives to be brought forth in director interactions. More extended tenured directors have a greater understanding of the firms' capabilities and strengths and have a deep-seated knowledge of a firm's culture. Whereas, directors who are recently added to the director's pool bring with them a more outwardly perspective of the environment faced by the firm. Interaction among different tenured directors leads to synergistic decision making on innovation activities because of the various aspects in understanding the capabilities of the firm and how it relates to its current competitive environment. Consequently, these boards of directors are more likely to promote new ideas that encourage innovations in firms.

5. Conclusion

Despite growing recognition of the potential importance of heterogeneous boards on firm innovation activities, there has been limited research on the effects of diverse boards on firm innovation, especially in emerging markets. We attempt to fill in this gap. In the context of firm innovation, we find that heterogeneous boards have both positive and negative effects on innovation. Further, the examination of the impact of demographic, education, and experience heterogeneity on firm innovation indicates that gender, ethnic, and tenure heterogeneity of directors encourages innovations in firms. On the other hand, directors' heterogeneity in the type of experience and external engagements are detrimental to firm innovations. We also find that age and education heterogeneity have insignificant influence in promoting innovation.

Overall, our findings provide insights on the importance of managing board heterogeneity in realizing its full potential. Consistent with this view, boards of directors must be configured to attain the benefits of heterogeneity in undertaking innovative activities. Initiatives have been taken by the Malaysian government to increase gender heterogeneity on boards by stipulating that all listed companies should have at least 30% women representation on the board of directors by 2020 (Brown, 2017). This target is currently underachieved, where women only represent 19% of board members in Malaysian public listed companies (Women make up only 19% of board members in public listed companies: Wan Azizah, 2019). Hence, policies need to be developed beyond gender diversity, as our findings indicate certain facets of board heterogeneity to be essential conduits in facilitating increased firm innovation.

As this study found associations between heterogeneous boards and innovation, future research can address several limitations encountered in this study. The first involved our proxy for innovation, which is R&D expenditure. Several studies have suggested that spending money on R&D does not necessarily result in innovation and thus may not be a suitable measure of innovation intensity (Nobel and Birkinshaw, 1998; Rothaermel and Hess, 2007). Future research should focus on improving the measures of innovative activity within a firm, and one such promising method is the approach employed by Ayyagari *et al.* (2012). Further, in the absence of time series data and information on innovation policies and reforms across our sample of companies, we are unable to address the endogeneity concerns and leave the identification issues in this area for future research.

We compiled the board heterogeneity measures separately rather than using an aggregated board heterogeneity measure employed by Anderson *et al.* (2011). We applied this approach to determine which facet of board heterogeneity enhances or inhibits innovation within the firm. Nevertheless, the method employed by Anderson *et al.* (2011) may be able to provide insights on the aggregate effect of overall board heterogeneity on innovation.

Finally, as this study was conducted through the lens of an emerging market, therefore, caution must be made not to generalize this finding to other countries, which probably might be at different stages of development.

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Appendices

Appendix A: An Illustration of Deriving Board Heterogeneity – Kotra Industries Berhad (KIB) in 2012

This appendix provides a detailed step-by-step process of the construction of the board heterogeneity measure. As an example, we use Kotra Industries Berhad's board of directors as specified in the 2012 annual report as an example. This appendix starts with the construction of the six individual inputs (age heterogeneity, gender heterogeneity, ethnic heterogeneity, educational heterogeneity, professional heterogeneity, and board experience heterogeneity). The process concludes with the aggregation of the six individual inputs to determine the board heterogeneity score for this firm.

Director	Age	Ethnic group	Gender	Degree type	Education level	Experience	No. of external board seats	Tenure
1	79	Malay	M	Masters and above	Technical Degree	5	7	12.33
2	54	Chinese	M	Degree	Technical Degree	10	0	12.33
3	60	Chinese	M	No Degree	N/A	10	0	12.33
4	45	Chinese	M	No Degree	N/A	15	0	12.33
5	55	Chinese	F	Degree	Technical Degree	17	0	12.33
6	75	Malay	M	No Degree	N/A	6	0	12.33
7	67	Chinese	M	No degree	N/A	2	0	5.17
8	59	Malay	M	Degree	Technical Degree	10	1	12.33

Age Heterogeneity = *coefficient of variation of directors' ages*: The measure of directors' age heterogeneity uses the coefficient of variation (CV) of director age across the full board. For Kotra Industries Berhad (see Column 2), the CV_{AGE} = (Standard deviation of age divided by Mean age) = 11.32/61.75 = 0.183. Based on the CV_{AGE} for the entire sample, Kotra Industries Berhad's CV_{AGE} falls into the third quartile. Thus, the firm earns a score of 3.0 on a relative scale of 1-4.

1st Quartile	**2nd Quartile**	**3rd Quartile**	**4th Quartile**	**KIB's Age Hetero. Score**
$CV_{AGE} < 0.127$	$0.127 \leq CV_{AGE} < 0.164$	$0.164 \leq CV_{AGE} < 0.206$	$CV_{AGE} \geq 0.206$	3.0

Ethnic Heterogeneity's *Blau Index* = $1 - \sum_{i=1}^{s} p_i^2$: where p is the proportion of directors in a category i and s is the number of categories. For Kotra Industries Berhad (see Column 3), there a 5 Chinese and 3 Malay directors. Therefore, Kotra Industries Berhad ethnic heterogeneity score is $1 - \left(\frac{5}{8}\right)^2 + \left(\frac{3}{8}\right)^2 = 0.469$. Based on the $BLAU_{ETHNIC}$ for the entire sample, Kotra Industries Berhad's $BLAU_{ETHNIC}$ falls into the third quartile. Thus, the firm earns a score of 3.0 on a relative scale of 1-4.

1st Quartile	**2nd Quartile**	**3rd Quartile**	**4th Quartile**	**KIB's Age Hetero. Score**
$BLAU_{ETHNIC} < 0.278$	$0.278 \leq BLAU_{ETHNIC} < 0.444$	$0.444 \leq BLAU_{ETHNIC} < 0.500$	$BLAU_{ETHNIC} \geq 0.500$	3.0

Gender Heterogeneity *Blau Index* = $1 - \sum_{i=1}^{s} p_i^2$: where p is the proportion of directors in a category i and s is the number of categories. For Kotra Industries Berhad (see Column 4), there are 1 Female and 7 Male directors. Therefore, Kotra Industries Berhad ethnic heterogeneity score is $1 - \left(\frac{1}{8}\right)^2 + \left(\frac{7}{8}\right)^2 = 0.219$. Based on the $BLAU_{ETHNIC}$ for the entire sample, Kotra Industries Berhad's $BLAU_{ETHNIC}$ falls into the first half. Thus, the firm earns a score of 1.0 on a relative scale of 1-2.

1st Half	**2nd Half**	**KIB's Gender Hetero. Score**
$BLAU_{ETHNIC}$ <0.245	$BLAU_{ETHNIC}$ ≥0.245	1.0

Degree Type Heterogeneity *Blau Index* = $1 - \sum_{i=1}^{s} p_i^2$: where p is the proportion of directors in a category i and s is the number of categories. For Kotra Industries Berhad (see Column 5), there are 1 Director with a Post-graduate degree, 3 directors with an undergraduate degree, and 4 directors with no degree whatsoever. Therefore, Kotra Industries Berhad education type heterogeneity score is $1 - \left(\frac{1}{8}\right)^2 + \left(\frac{3}{8}\right)^2 + \left(\frac{4}{8}\right)^2 = 0.594$. Based on the $BLAU_{DEGTYPE}$ for the entire sample, Kotra Industries Berhad's $BLAU_{EDUTYPE}$ falls into the third quartile. Thus, the firm earns a score of 3.0 on a relative scale of 1-4.

1st Quartile	**2nd Quartile**	**3rd Quartile**	**4th Quartile**	**KIB's Edu. Type Hetero. Score**
$BLAU_{DEGTYPE}$ <0.486	0.486≤$BLAU_{DEGTYPE}$< 0.571	0.571≤ $BLAU_{DEGTYPE}$ < 0.612	$BLAU_{DEGTYPE}$ ≥0.612	3.0

Education Level Heterogeneity *Blau Index* = $1 - \sum_{i=1}^{s} p_i^2$: where p is the proportion of directors in a category i and s is the number of categories. For Kotra Industries Berhad (see Column 6), there are 4 Directors with a technical degree and 4 directors with no degree whatsoever. Therefore, Kotra Industries Berhad's education level heterogeneity score is $1 - \left(\frac{4}{8}\right)^2 + \left(\frac{4}{8}\right)^2 = 0.500$. Based on the $BLAU_{EDULEVEL}$ for the entire sample, Kotra Industries Berhad's $BLAU_{EDULEVEL}$ falls into the third quartile. Thus, the firm earns a score of 3.0 on a relative scale of 1-4.

1st Quartile	**2nd Quartile**	**3rd Quartile**	**4th Quartile**	**KIB's Edu. Level Hetero. Score**
$BLAU_{EDULEVEL}$ <0.571	0.571≤$BLAU_{EDULEVEL}$ <0.656	0.656≤$BLAU_{EDULEVEL}$< 0.720	$BLAU_{EDULEVEL}$≥ 0.720	1.0

Experience: We measure director experience heterogeneity as the number of different experience areas represented on the board of directors. Experience is defined as having worked or is working in a particular field, as depicted in Appendix B. If multiple directors hold experience in a particular field (i.e., consulting), we count this as a value of one because the full board possesses this experience (rather than a particular director). For Kotra Industries Berhad, there is 1 director experience in the field of accounting and audit, 1 director in the field of Science, Engineering, Manufacturing & R&D, 3 directors with experience in Medical & Health, 1 director in Sales, Marketing & Customer Service, and 1 director in Technology yielding an experience heterogeneity for the firm of 6.0. Based on experience heterogeneity for the entire sample, Kotra Industries Berhad's experience heterogeneity falls in the highest quartile, and the company earns a score of 4.0.

First Quartile	Second Quartile	Third Quartile	Fourth Quartile	KIB's Func. Hetero. Score
Exp. $<$ 4.0	4.00 $\leq$ Exp. $<$ 5.00	5.00 $\leq$ Exp. $<$ 6.00	Exp. $\geq$ 6.00	4.0

External board seats: We measure external board seat heterogeneity as the coefficient of variation of the number of board seats held by directors beyond the seat in the target firm. For Kotra Industries Berhad, the average director holds 1 external board seat with a standard deviation of 2.45, yielding a coefficient of variation of 2.45 (2.45/1). Based on the coefficient of variation of external boards for the entire sample, Kotra Industries Berhad's CV of external board seats falls in the highest quartile, and the firm earns a score of 4.0.

First Quartile	Second Quartile	Third Quartile	Fourth Quartile	KIB's Seat Hetero. Score
Seat $<$ 1.1	1.1 $\leq$ Seat $<$ 1.5	1.5 $\leq$ Seat $<$ 1.98	Seat $\geq$ 1.98	4.0

Director tenure: We measure director tenure heterogeneity as the coefficient of variation of the years that the director has served on the firm's board. For Kotra Industries Berhad, the average director has served 10.51 years with a standard deviation of 3.37 years, yielding a coefficient of variation of 0.32 (10.51/3.37). Based on the coefficient of variation director tenure for the entire sample, Kotra Industries Berhad's CV of director tenure falls in the lowest quartile, and the firm earns a score of 1.0.

First Quartile	Second Quartile	Third Quartile	Fourth Quartile	KIB's Tenure Hetero. Score
Tenure $<$ 1.1	1.1 $\leq$ Tenure $<$ 1.5	1.5 $\leq$ Tenure $<$ 1.98	Tenure $\geq$ 1.98	4.0

Appendix B: Fields in which directors have experience

Fields of experience
Academic
Accounting & Audit
Consulting
Creative Arts
Science, Engineering, Manufacturing & R&D
General Management
Human Resources
Investing, Finance & Banking
Legal, Compliance & Ethics
Medical & Health
Politics, Government & Defense
Public/Investor Relations & Corporate Responsibility
Purchasing & Supply Chain Management
Risk Management, Quality Control & Regulation
Sales, Marketing & Customer Service
Strategy & Operations
Technology
Publishing & Media
Plantation & Agriculture
Other