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Does functional diversity in interfirm collaborations lead to innovation diversity? Firm-level evidence from the Australian food industry*

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Research on the collaboration–innovation nexus emphasises that collaborations and innovation are multidimensional. Despite this emphasis, there is limited evidence on how firms' collaborative diversity affects their innovation diversity. This paper addresses this gap by examining the relationships between (i) a firm's functional diversity of collaboration (FDC) and innovation diversity, and (ii) innovation diversity and firm growth. We used longitudinal data from 738 Australian food firms, and our findings suggest that the positive relationship between FDC and innovation diversity reaches a point of saturation, beyond which additional collaboration negatively influences firms' innovation diversity. Moreover, innovation diversity depends on the motives behind alliance formation and the firm's focus on innovation. Finally, the association between innovation diversity and growth performance is heterogeneous across firms' conditional growth rate distribution.

Key words: Australia, B2B collaborations, financial performance, innovation, panel data, poisson model.

1. Introduction

Australia is currently ranked 22nd on the Global Innovation Index (Dutta *et al*. 2019). Although Australia has high human capital and research capability, it is rated poorly for collaboration for innovation (Australian Government 2017; Dutta *et al*. 2018). To better capture the benefits of such collaboration, the Australian government has taken several initiatives to encourage it. One example of this is Cooperative Research Centres (CRCs)

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establishment by the Department of Industry Innovation and Science to develop a collaborative research partnership between industry and research organisations. Another is the establishment of Food Innovation Australia Ltd (FIAL), an industry-led not-for-profit organisation with the main goal of promoting firm-level innovation in the Food and Agribusiness (F&A) sector through business-to-business (B2B) and university–industry collaborations. The Australian F&A sector has little option but to serve the demand for high-quality, innovative products in the global food markets, given the country's increasing difficulty in competing on price (CSIRO Futures 2017).

Although the collaboration–innovation nexus has received some research attention in the Australian context (Soriano *et al*. 2019), understanding this relationship remains limited (Gronum *et al*. 2012). Soriano *et al*. (2019) highlight the lack of quantitative empirical research on this relationship in the Australian F&A sector. Extant Australian studies in the non-food sector focus either on the determinants of innovation and collaboration (Bhattacharya and Bloch 2004; Huang and Rice 2009; Vranic 2014) or the effects of innovation and collaboration on firms' financial performance (Palangkaraya *et al*. 2015; Palangkaraya and Webster 2015; Tuhin 2016).

The benefits of interfirm collaboration in achieving firm-level innovation are widely acknowledged by academics, governments and the press (Palmer *et al*. 2015; Australian Government 2017; Chapman *et al*. 2018). However, extant research on the subject has focused on the relationship between R&D collaboration and product or process innovation (Song and Di Benedetto 2008; Theyel 2013; Un and Asakawa 2015). Some recent studies have examined the influence of collaborative partners' diversity (suppliers, customers, universities and competitors) on innovation (van Beers and Zand 2014; Chapman *et al*. 2018). The limitation of these studies is that they measure collaborative partners' diversity rather than modes of collaboration. Consequently, each partner may provide similar information, or offer similar innovation-related functions, to the collaboration, thus reducing the scope for innovation in multiple domains (Jiang *et al*. 2010).

Interfirm collaboration and innovation are both multidimensional (Piening *et al*. 2016; Strohmeyer *et al*. 2017). The number of domains in which a firm innovates (e.g., product, process, marketing and organisational innovation) is counted as that firm's innovation diversity (Gronum *et al*. 2012; Strohmeyer *et al*. 2017). A firm may cooperate with partners in one or more innovation functions (e.g., joint research and development (R&D), joint manufacturing, joint marketing and distribution), which is referred to as Functional Diversity in Collaboration (FDC) (Jiang *et al*. 2010; van Beers and Zand 2014). FDC enables firms' access to a variety of knowledge, independent of the type of partner involved. This could, in turn, facilitate innovation diversity (Love *et al*. 2014). Despite the call for further research on the relationship between FDC and firms' innovation diversity (Pittaway *et al*. 2004), there has been limited research on how a firm's FDC affects its innovation diversity.

Innovation diversity represents firms' broader engagement with multiple forms of innovations and is considered an important component of increased firm performance, economic growth and development (Australian Government 2017). The performance benefits derived from a broader engagement with innovation could be higher than those of specific innovation types. This is because innovation types are interrelated, and a simultaneous engagement across different innovations may improve firms' innovation capabilities and adaptability to a competitive environment (Gronum *et al.* 2012; Verreynne *et al.* 2019). According to Gronum *et al.* (2012), pursuing a specific innovation may not necessarily lead to improved firm performance. Moreover, Verreynne *et al.* (2019) attribute the contradictory findings of extant studies on innovation and firm performance to their failure to consider firms' innovation diversity and instead focus on specific types of innovation.

This study aims to examine whether collaboration in multiple domains (i.e., FDC) leads to innovation diversity in the Australian F&A sector. The hypothesised mechanism is that FDC offers firms access to varied forms and types of knowledge, making them more productive in innovation, particularly in introducing multiple and diverse innovations. However, FDC can also be subject to decreasing returns because of the increased complexity and coordination costs (Piening *et al.* 2016; Laursen and Salter 2006), which may hinder a firm's innovation performance beyond a certain threshold of FDC. We explore this possibility of a curvilinear relationship between FDC and innovation diversity. As the contribution of inter-organisational collaboration to value creation may also depend on the motives behind alliance formation (van Beers and Zand 2014) and the firm's innovation focus (Østergaard *et al.* 2011), we also examine these influences. Finally, we test whether a firm's diversity of innovation enhances its growth performance.

Despite high-tech industries commonly being a small part of any economy, the bulk of the research on the collaboration–innovation nexus is based on firms operating in technologically advanced sectors (Dittrich and Duysters 2007; Baum *et al.* 2000; Jiang *et al.* 2010). Concerns have been raised over the generalisability of the findings to the case of low-tech industries, such as the food industry (Trott and Simms 2017; Acosta *et al.* 2015), especially in the context of Australia, where high-tech manufacturing contributes less than 1 per cent of the country's total output (O'Brien and Arundel 2015). Moreover, the antecedent and consequences of innovation have been well documented in the case of large firms (Verreynne *et al.* 2019). However, there is a lack of research in the context of small and medium-sized enterprises (SMEs). The firm's size can be a constraint on innovation because, unlike large firms, SMEs have fewer resources to explore new ideas and exploit them for commercial purposes. This study aims to fill these research gaps by focusing on small and medium-size business in the F&A sector in the context of Australia.

2. Theoretical background and hypotheses development

2.1 Innovation diversity

Early innovation scholars defined innovation as the development of new products, production methods, new sources of supply, the exploitation of new markets and new ways to organise business (Schumpeter 1934). Similarly, it has been defined as the process of establishing new, improved capabilities or delivering increased utility (Drucker 1985). More recent definitions refer to implementing a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational aspect of business, the workplace organisation or external relations (OECD 2005). The Australian Innovation System Report 2017 describes *innovation active firms are those that have either introduced a new innovation, are currently developing a new innovation, or have abandoned an innovation within the last 12 months* (Australian Government 2017: 8). The report also highlights that about half of the Australian businesses (48.7 per cent) are innovation active. We utilise the 2018 Community Innovation Survey data to compare Australia's innovation performance with 30 European countries. International innovation data in Figure 1 suggest that Australian firms compare favourably against Spain and Poland, which have 31 and 23 per cent innovative active firms, respectively. However, Estonia outperforms Australia with more than 70 per cent innovation active firms.

Although innovation is a multidimensional construct, the innovation literature features widespread use of binary variables for innovation that may not adequately reflect its diverse nature (Love *et al.* 2011). A contribution of the current paper is its examination of 'innovation diversity', defined as the simultaneous and successful implementation of diverse types of innovation. Following Verreynne *et al.* (2019) and Strohmeyer *et al.* (2017), we define innovation diversity as the number of different domains (i.e., product, process, marketing and organisational) in which a firm has introduced something new in a given year.

2.2 Functional diversity of collaboration and innovation diversity

The literature on open and co-innovation (Mention 2011; Roldán-Bravo *et al.* 2016; Wynarczyk *et al.* 2013; Chesbrough 2006) recognises that innovation does not rely exclusively on the firm's internal efforts. Instead, it requires relationships with and contributions from entities outside the firm. More generally, alliances, strategic networks, joint ventures and other collaborations have been shown to increase firms' performance and innovativeness (Egbetokun 2015; Roldán-Bravo *et al.* 2016; Hottenrott and Lopes-Bento 2016; Roper *et al.* 2017). Baum *et al.* (2000) propose that the absolute number of external collaborations is not the main antecedent of innovative performance but rather the diversity of firms' collaborations. Accordingly, we

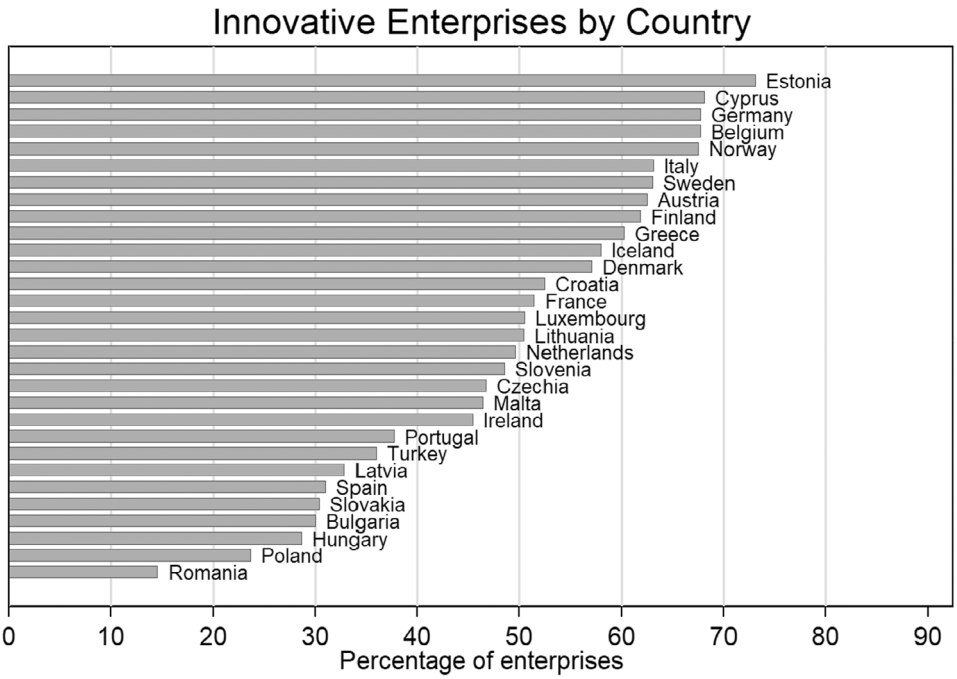

Figure 1 Innovative enterprises by country based on the Community Innovation Survey (CIS) 2018Note: Authors' elaboration using data from Eurostat Science, Technology and Innovation statistics available at https://ec.europa.eu/eurostat/web/science-technology-innovation/data/database

employ the FDC construct, defined as implementing different collaborative arrangements with external agents. Practically, FDC is the sum of different forms of B2B collaborations that a firm reports to be engaged in joint R&D, joint sourcing, joint manufacturing, integration of supply chains, joint marketing or distribution and others.

The benefits of external collaborations have been shown to arise from reduced costs of technological development or market entry, reduced risk of product or process development, scale economies, reduced time to market, division of labour and the development of complementary skills or assets (Delbufalo 2015; Egbetokun 2015; Hottenrott and Lopes-Bento 2016; Un and Asakawa 2015; Brown and Roper 2017). Nevertheless, studies also suggest that the relationship between external collaboration and innovation reaches a maximum, beyond which higher levels of external collaboration become unproductive or counterproductive. Consequently, this relationship may follow an inverted U-shaped or curvilinear relationship. To explain this saturation effect, the attention-based theory of the firm suggests that managerial attention is the most precious resource inside the organisation and allocating attention to particular activities is a key factor in explaining why some firms perform successfully in their innovative efforts (Laursen and Salter 2006; Ocasio 1997). Companies face many resource constraints such as

staffing, time and money. It becomes essential to choose correctly where and to what extent to dedicate this managerial attention and the associated resources. Thus, although external collaboration is associated with innovation performance, firms may 'over-search', negatively affecting their innovation performance.

The 'over-search' can lead to negative consequences such as too much information that the company has to manage, leading to higher coordination and managerial costs (Jiang *et al.* 2010; Delbufalo 2015; Laursen and Salter 2006); information that can appear at the wrong time and in the wrong place to be exploited (Laursen and Salter 2006); the difficulty of paying appropriate attention to information generated by a variety of processes (Delbufalo 2015; Laursen and Salter 2006); or constrained access to complementary assets and new knowledge (Oerlemans *et al.* 2013). This saturation effect has been tested for a number of different types of external collaborators (Oerlemans *et al.* 2013; Laursen and Salter 2006; Jiang *et al.* 2010), and the depth and amount of information exchanged in these collaborations (Laursen and Salter 2006). However, to the authors' knowledge, FDC's role has not been studied from the perspective of a firm's innovation diversity. In this study, we test the following hypotheses: FDC has an inverted U-shaped relationship with innovation diversity (Hypothesis 1).

2.3 Firm's focus on innovation and innovation diversity

Focus on innovation reflects the extent to which firms explore new technologies, customers needs and future markets in pursuit of competitive advantage (Dibrell *et al.* 2014). A focus on innovation is seen as a culture that motivates enthusiasm and creativity among different employees and managers (Calantone and Rubera 2012). Research into strategy features a firm's focus on innovation as a competitive orientation for the firm, demonstrated by the extent to which the firm's top managers are more inclined to take business initiatives (Covin and Slevin 1990). A multidimensional management view (Hauser 2006) of a firm's focus on innovation reflects its proactiveness and readiness to engage in and benefit from innovation (Damanpour 1991). Within a firm with an aggressive innovation posture, those managers involved in R&D projects are often encouraged and rewarded for experimenting with novel and unexplored things. At the same time, they encounter and acquire updated market and technical knowledge from external sources that advance their understanding of different scientific and technology-related domains. In such a climate, it is likely that more, and a greater variety of, novel ideas would be generated and implemented in a more diverse set of innovation domains. Based on this discussion, we present our second hypothesis: a firm's focus on innovation is associated positively with innovation diversity (Hypothesis 2).

2.4 Collaboration for innovation and innovation diversity

FDC exists when firms collaborate for a number of reasons, such as the promotion of their brands, market development, joint manufacturing and innovation. However, collaboration for innovation exists when firms solely collaborate for innovation or, in other words, the primary purpose of their collaboration is to innovate. As discussed earlier, in the context of open innovation, inter-organisational collaboration is productive in supporting firms' internal innovation activities (Deeds and Rothaermel 2003). This occurs through access to complementary assets (Teece 1986), the transfer of codified and tacit knowledge (Davis and Eisenhardt 2011) and risk allocation and the spreading of costs (Faems *et al.* 2005). Troy *et al.* (2008) argue that collaboration between firms increases firms' innovation performance; others have an alternative view based on cross-industrial information flows or the complexity of communications (Troy *et al.* 2008; Lo and Li 2018). To summarise these views, Boudreau *et al.* (2017) maintain that collaboration for innovation will remain beneficial for participating firms in terms of innovation diversity as long as financial, physical and time costs are not greater than participating firms' anticipated benefits.

While evidence (Lucena Pimentel and Stephen 2018; Walsh *et al.* 2016) suggests a strong association between collaboration and innovation, no study has been undertaken to show the positive impact of collaboration for innovation on innovation diversity. We argue that firms are more likely to pool distinct resources to promote innovation diversity if the purpose of the collaboration is innovation. Based on the discussion above, we propose our third hypothesis: business collaboration for innovation is positively related to a firm's internal innovation diversity (Hypothesis 3).

2.5 Innovation diversity and the firm's growth

The available empirical evidence on innovation and a firm's growth provides mixed findings. While some studies (e.g., Gronum *et al.* 2016; Salunke *et al.* 2013; Xayavong *et al.* 2016; Khan *et al.* 2017) show a positive relationship between innovation and growth performance, other studies show a negative relationship between the two constructs (e.g., Vermeulen *et al.* 2005). Given that innovation-related activities are costly and fraught with the risk of failure, low-growth firms often fail to manage innovation due to resource constraints and a lack of risk management strategies (Australian Government 2017). Moreover, in the absence of market transformation activities, simply devoting more resources to the firm's innovation activities may result in project failures (Liao and Rice 2010). Given the likely heterogeneity in returns to innovation, we argue that the significance of the relationship between innovation and firm performance may depend on contextual factors, such as the level of firms' growth (i.e., high- versus low-growth firms).

Standard regression techniques (OLS, fixed versus random effects) estimate firms' mean or average growth scores. One of the significant shortcomings of the average estimates of firms' growth is that they do not consider the skewness of firms' growth rate distribution (Coad and Rao 2008). Based on our theoretical argument presented above, we argue that the estimated coefficient values and statistical significance of innovation diversity vary over the conditional growth rate distribution. More specifically, we test the following hypothesis: innovation diversity is associated positively to the fastest-growing firms' growth rather than that of the average firm (Hypothesis 4).

3. Methods

3.1 Data

This research uses the Business Longitudinal Data (BLD) dataset, released by the Australian Bureau of Statistics (ABS), as a Confidentialised Unit Record File (CURF).[1] The BLD covers five reference periods from 2006–07 to 2010–11. The BLD contains data from three sources: (i) Business Characteristics Survey, collected directly by the ABS from businesses that remit Goods and Services Tax; (ii) business sales data recorded on Business Activity Statements (BAS) supplied by the Australian Taxation Office to ABS; and (iii) basic merchandise trade data from the Australian Customs and Border Protection Service.

The BLD includes both employing and non-employing businesses reporting $50,000 or more for sales of goods and services in their BAS return annually. The scope of the BLD is restricted to small and medium-sized businesses (i.e., <200 employees). Businesses included in the BLD are classified as per the Standard Institutional Sector Classification of Australia (SISCA) and in accordance with the Australian and New Zealand Standard Industrial Classification (ANZSIC 2006).

The BLD panel is stratified based on industry division and business size. The industry division is based on the ANZSIC 2006 division, and business size is based on the number of employees. The BLD sample allocates approximately 40 businesses per stratum to ensure that at least 30 businesses remain active at the end of 5 years. This is to ensure that the attrition of some panels does not affect the longitudinal analysis. The food industry sample includes food-related businesses for human consumption in the following industry divisions: Agriculture, Forestry and Fishing; Manufacturing; and Wholesale Trade. The entire BLD sample consists of 3,075 firms. Out of these 3,075 firms, 984 (32 per cent) firms make up the food industry sample, and the remaining 2,091 (68 per cent) firms are in the non-food industry sample. This study uses panel data of food firms. However, it is possible that firms do not respond to all survey questions in each round of the panel data. Despite ABS'

[1] The data were provided to the authors under an agreement with the ABS that prohibits them from releasing any non-approved information.

efforts to reduce reporting errors and achieve full response to key survey questions, missing data arises because of questions not completed, questions not required to be completed, questions not asked in a given year, businesses permanently cease operations or become dormant during the life of the panel or businesses may become out of scope (i.e., become a large business with complex business structure) during the life of the panel for which no data are made available to protect confidentiality (ABS 2013a). As mentioned earlier, the total food industry sample consists of 984 firms and 984 × 5 years = 4,920 observations. However, only about 44 per cent of the food industry sample has non-missing values on all the variables of interest to test the relationship between FDC and innovation diversity. After removing missing and inconsistent responses, the final sample size used in this research comprises 2,187 observations belonging to 738 food firms. Therefore, our estimation sample is an unbalanced panel data with an average of 3 observations (i.e., 3-year data) per firm with a minimum of 1 and a maximum of 5 observations. It is worth mentioning that the major consideration of the BLD sample design was to ensure that the effect of attrition is minimal and enough live sample remains in each stratum at the end of 5 years to facilitate longitudinal analysis (ABS 2013b).

3.2 Variables and measures

3.2.1 Dependent variables

Firms' innovation diversity *(invdivr)* is derived from 17 binary variables pertaining to various dimensions of firm innovativeness (Appendix S1). Respondents were asked to indicate, with a 'yes' or 'no' response format, whether they have introduced a new or significantly improved dimension(s) of innovation during the year. Our index of innovation diversity is, therefore, a count variable $\left(\sum_{n=0}^{17} \textit{innovation dimensions}\right)$ ranging from 0 to a potential maximum of 17. The innovation dimensions reported in Appendix S1 are in accordance with the Oslo manual on the guidelines for collecting and interpreting innovation data (OECD 2005). The construction of this index is consistent with prior empirical research (Verreynne *et al.* 2019; Strohmeyer *et al.* 2017; Damanpour *et al.* 2009; Gronum *et al.* 2016; Ayyagari *et al.* 2011; Galbreath 2019; Arun *et al.* 2020). As the constituent indicators of innovation diversity are not necessarily correlated, there is no requirement to calculate measures of scale internal consistency (Strohmeyer *et al.* 2017).

This paper also examines the impact of innovation diversity on firms' growth. We calculate the firm's growth rate as the difference in the log of total sales. We obtain Consumer Price Index (CPI) data for different years from the World Bank (World Bank 2019) and adjust sales values for inflation using 2010 as the base year. This measure of firm growth has been applied in many prior studies (e.g., Coad and Rao 2008; Vranic 2014; Liao and Rice 2010; Freel 2000).

3.2.2 Main independent variables

The FDC variable is derived by counting the number of B2B collaborative arrangements a particular firm engaged in during the year. Respondents were asked, with a 'yes' or 'no' response format, whether this firm is involved in each of the following six types of collaborative arrangements: joint R&D, joint buying, joint manufacturing, integrated supply chains, joint marketing or distribution and/or other collaborative arrangements (Appendix S1). A firm's FDC is calculated by $\sum_{n=0}^{6} B2B\ collaboration$. FDC's construction is consistent with prior empirical research (Piening *et al*. 2016; Laursen and Salter 2006; Zhou *et al*. 2019; Wu 2011; Faems *et al*. 2005).

The two variables capture a firm's orientation toward innovation: (i) collaboration for innovation (*innocoll*) – an indicator variable that takes a value of 1 if the firm indicates that the purpose of B2B collaboration was to enhance the firm's innovation performance, 0 = otherwise; and (ii) focus on innovation (*assinn*) – a categorical variable measured on a four-point Likert scale, which indicates the extent to which a particular business focuses on innovation performance when assessing overall business performance. The four categories of the variable *focus on innovation* consist of: (i) *invfoc_nil,* which reflects firms that have no focus on innovation; (ii) *invfoc_smal,* which denotes firms that focus on innovation to a small extent; (iii) *invfoc_modr,* which indicates firms that focus on innovation to a moderate extent; and (iv) *invfoc_majr* for firms that focus on innovation to a major extent. These variables' choice is consistent with the prior studies on innovation (Dibrell *et al*. 2014; Calantone and Rubera 2012; Soriano *et al*. 2019; Laursen and Salter 2006). Table 1 shows the definitions and measurements of the variables used in this study.

3.2.3 Econometric specifications

We first investigate the impact of firms' FDC on innovation diversity. Our dependent variable (*invdivr*) takes on non-negative integer values: [0, 1, 2, 3,. . ., 17]. The Poisson specification is the fundamental starting point for the analysis of count data as it explicitly accounts for the small number of non-negative values taken by the dependent variable, including large numbers of zeros in the observed data. As the expected value of the dependent variable in a Poisson regression is given as the exponential function of the explanatory variables, this ensures positive predicted values of the dependent variable for any value of the explanatory variables. Following is the general form of the Poisson model used in this study:

$$\begin{aligned} Invdivr_{it} = {} & \beta_0 + \beta_1 * FDC_{it} + \beta_2 * FDC_{it}^2 + \beta_3 * Invfoc_{smalit} \\ & + \beta_4 * Invfoc_{modrit} + \beta_5 * Invfoc_{majrit} + \beta_6 * Innocoll_{it} \\ & + \beta_7 * Age_{it} + \beta_8 * Micro_{it} + \beta_9 * Small_{it} + \beta_{10} * Medium_{it} \\ & + \beta_{11} * Location_{it} + \beta_{12} * Finance_{it} + \beta_{13} * Export_{it} \\ & + \beta_{14} * Industry_{it} + \epsilon_{it} \end{aligned} \quad (1)$$

Table 1 Definitions and measurements of variables

Variables	Definition/measurement
Dependent variables	
Invdivr	Innovation diversity measured as the number of different forms of innovations implemented by the business (see Appendix S1)
Growth	Difference in the inflation-adjusted (log) total sale from the previous year
Independent variables	
FDC	Functional Diversity of Collaboration (FDC) is the sum of different forms of B2B collaborations that a firm reports to be engaged in (see Appendix S1)
FDC-Square	The square of the (FDC) variable
Invfoc	Invfoc is a categorical variable that indicates the extent to which a particular business focuses on innovation performance when assessing overall business performance invfoc_nil = no focus; invfoc_smal = small extent, invfoc_modr = a moderate extent; invfoc_majr = a major extent.
Innocoll	Business collaboration on innovation (1 = yes, 0 = no).
Controls	
Firm Age	Years of operation regardless of changes in ownership (number of years)
Firm Size	Firm size is a categorical variable based on number of full-time employees. 0 = Non-employer; 1 = Micro enterprise (up to 5 employees); 2 = Small firm (5 to 20 employees); 3 = Medium firm (20 to 200 employees)
Location	Number of locations operated by this business
Finance	Received any financial assistance from Australian Government organisation, including grants, subsidies and tax concessions (1 = yes, 0 = no)
Export	Dummy variable for exporter (1 = yes, 0 = no)
Industry	Industry divisions defined by ANZSIC 2006 classes (food industry component includes: Agriculture, Forestry and Fishing; Manufacturing; and Wholesale Trade)

We control the industry-specific effects in equation 1 because there are differences across industries in terms of pressure to innovate (Levin *et al.* 1987). We use bootstrapped standard errors with 1000 replications to provide consistent and efficient estimates of the Poisson regression model (Wooldridge 2015). Additionally, we estimate the Poisson model using negative binomial specification because it relaxes the assumption of the equidispersion and explicitly controls for overdispersion in the data (Cameron and Trivedi 2010). Using the random effect model, the empirical analysis of equation 1 controls for unobserved firm characteristics. Following Un *et al.* (2010), we do not use a fixed-effects model. It results in omitting some important time-invariant variables (e.g., industries) and firms that do not show variation in their innovation performance over time.

Next, we examine the impact of innovation diversity on firms' growth. Following Coad and Rao (2008), the general form of the linear panel model for firms' growth is given as:

$$Growth_{it} = \beta_0 + \beta_1 * invdivr_{i,t-1} + \beta_2 * Growth_{i,t-1} + \beta_3 * Sales_{i,t-1} + \beta_4 * Industry_{it} + \delta_t + \epsilon_{it} \quad (2)$$

We include lagged values of innovation diversity ($invdivr_{i,t-1}$), growth rate ($Growth_{i,t-1}$) and total sales ($Sales_{i,t-1}$) to deal with potential dynamics, endogeneity and autocorrelation (van Beers and Zand 2014; Coad and Rao 2008; Zhou *et al*. 2019). We also include industry and year dummies to control industry-specific effects and common macroeconomic shocks.
Equation 2 is estimated using different estimators such as OLS, fixed versus random effects and quantile regression. We use bootstrapped standard errors with 1000 replications in the quantile regression estimation. The advantage of using quantile regression is that it is robust to outliers and avoids the strong assumption of the identical distribution of the error term. Moreover, it allows the estimation of coefficients at different quantiles of the conditional sales growth distribution (Coad and Rao 2008).

4. Results

We find a relatively low level of innovation and FDC in Australian firms (see Appendix S2 for the summary statistics of the main variables), as indicated by the low mean values of *invdivr* (0.74) and *FDC* (0.30). However, the low mean value of innovation diversity could be due to the wide range of innovation activities considered in this study compared to prior research. For example, in the context of Australian tourism firms, Verreynne *et al*. (2019) measure innovation diversity as the sum of six groups of innovation types with an average value of 1.95. In German manufacturing firms, Strohmeyer *et al*. (2017) aggregate four types of innovation to construct an innovation diversity index with an average value of 1.08. The index of innovation diversity in this research ranges from 0 to a *potential maximum* of 17 innovation. The maximum number of innovation observed in our data is 11, with an average value of 0.74 (Appendix S2).

Regarding collaboration, only about 14 per cent of innovation active businesses in Australia are engaged in any collaboration, as per the Innovation System Report 2017 (Australian Government 2017). To make an international comparison, we retrieve business-to-business collaboration data of innovative enterprises in European countries from the Community Innovation Survey, 2018. The data presented in Figure 2 show that France takes the lead in terms of business-to-business collaboration as more than 50 per cent of innovative firms have co-created goods or services in the year 2018. Our results are consistent with prior Australian studies and government reports that highlight a low level of collaboration in small and medium-sized firms (Gronum 2015; Australian Government 2017; Innovation and Science Australia 2017).

A large proportion of firms (37 per cent) indicate that they do not focus on innovation as a measure of business performance, and 24 per cent report a major focus on measuring innovation performance. Concerning firms' motivation in establishing interfirm collaborations, only 7 per cent of firms collaborate for innovation. The variables included in this study exhibit relatively low pairwise correlation presented in Appendix S3.

Table 2 presents the results of the Poisson and negative binomial models. In the Poisson model results (numeric column 1), the expected increase in innovation diversity log count for a one-unit FDC increase is 0.376. We exponentiate regression coefficients to get the underlying Incident Rate Ratio (IRR) for ease of interpretation. Our result suggests that a unit increase in FDC is associated with an increase in the innovation diversity by a factor of exp(0.376) = 1.46. The coefficient of FDC is positive and significant at the 1 per cent level of significance across both models. The evidence suggests that FDC makes an important contribution to the innovation diversity in Australian food firms, possibly because greater FDC may enhance firms' knowledge breadth, which is essential for better innovation outcomes. Although it may be costly to engage in multiple collaborations because of the possible leakage of sensitive knowledge (van Beers and Zand 2014), our finding suggests substantial FDC benefits in terms of firms' innovativeness.

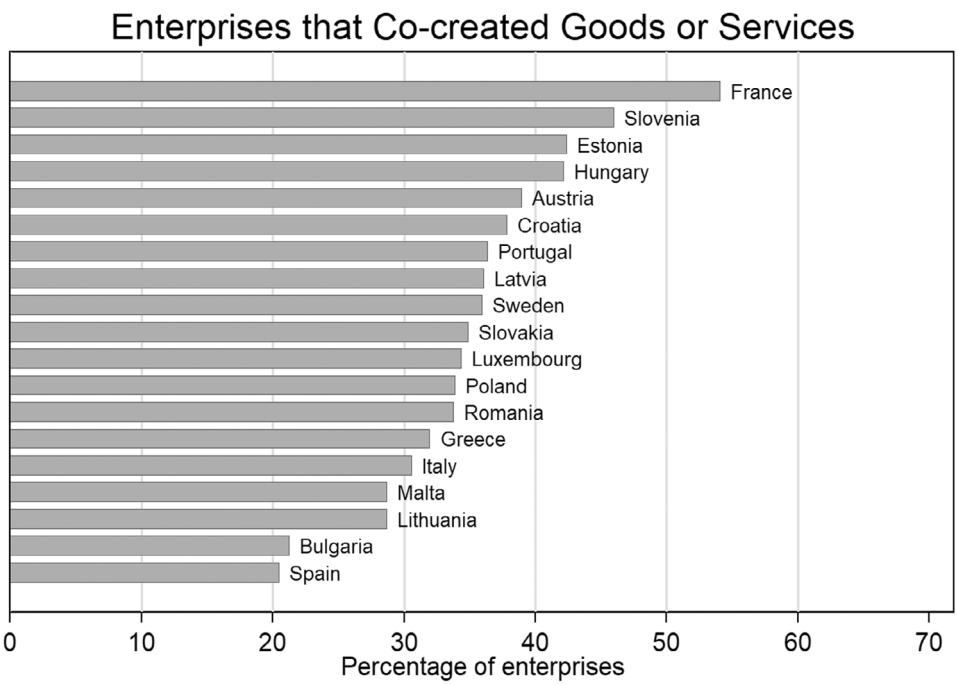

Figure 2 Percentage of innovative enterprises that co-created goods or services based on the Community Innovation Survey (CIS) 2018.Note: Authors' elaboration using data from Eurostat Science, Technology and Innovation statistics available at https://ec.europa.eu/eurostat/web/science-technology-innovation/data/database

Table 2 Panel Poisson and Negative Binomial Models Estimates

Variables	Panel Poisson (b/se)	Negative Binomial (b/se)
Functional Diversity of Collaboration (FDC)	0.376***	0.386***
	(0.078)	(0.094)
FDC-Square	−0.051**	−0.049*
	(0.02)	(0.025)
Invfoc_nil	Ref	Ref
Invfoc_smal	0.943***	1.075***
	(0.126)	(0.149)
Invfoc_modr	1.335***	1.516***
	(0.126)	(0.147)
Invfoc_majr	1.476***	1.699***
	(0.135)	(0.159)
Innocoll	0.578***	0.779***
	(0.084)	(0.102)
Firm Age	0.007	0.016*
	(0.01)	(0.01)
Location (Number of locations operated)	0.041	0.098**
	(0.044)	(0.047)
Finance	0.131*	0.202**
	(0.078)	(0.091)
Export	0.289**	0.268**
	(0.112)	(0.113)
Non-Employer	Reference	Reference
Micro-size	0.473**	0.355**
	(0.165)	(0.162)
Small-size	0.422**	0.215
	(0.176)	(0.17)
Medium-size	0.53**	0.363**
	(0.183)	(0.176)
Industry division		
Agriculture, Forestry and Fishing	Reference	Reference
Manufacturing	0.95***	0.941***
	(0.124)	(0.119)
Wholesale Trade	0.869***	0.83***
	(0.151)	(0.142)
Year		
2006/07	Reference	Reference
2007/08	0.235*	0.354**
	(0.097)	(0.122)
2008/09	−0.099	−0.212
	(0.109)	(0.145)
2009/10	0.362***	0.376***
	(0.092)	(0.114)
2010/11	0.369***	0.415***
	(0.096)	(0.117)
Constant	Supressed	Supressed
Log likelihood	−2003.0693	−1940.1002
Wald $\chi 2$	506.11***	605.66***
Number of observations	2187	2187
Number of groups	738	738

Source: Authors' calculations using ABS BLD 2006–07 to 2010–11.
Notes: Standard errors in parenthesis. ***significance at 1%, ** significance at 5% and *significance at 10%. The intercept terms are supressed to comply with ABS' output clearance requirements.

In confirming our hypothesis H1, our results show that the relationship between FDC and innovation diversity remains positive up to a saturation point, beyond which it is negative. This is evident by the FDC-Squared term's statistically significant and negative coefficient in both the Poisson and negative binomial. Data access rules prevent us from displaying ABS data geometrically (i.e., curvilinear) (Thompson *et al.* 2013). However, we can determine the quadratic function's peak by incorporating the linear and quadratic parameters estimates of FDC in the following formulae: -linear coefficient of FDC/(2*quadratic coefficient of FDC). Hence the value of FDC where the parabola reaches its peak is $\frac{-.376}{2(-.051)} \cong 4$ collaborations. This seems quite a high peak given that we consider six collaborations and represent a non-linear or curvilinear relationship rather than a full inverted U-shape.

Estimates in Table 2 support H2: a firm's focus on innovation is associated positively with innovation diversity. A focus on innovation increases innovation diversity by a factor of exp(0.943) = 2.57 compared to firms that do not focus on innovation (Table 2, numeric column 1). Likewise, compared to firms that do not focus on innovation, a moderate and major focus increases innovation diversity by a factor of exp(1.335) = 3.88 and exp (1.476) = 4.38, respectively. Consistent with H3, we find a significant positive coefficient of collaboration for innovation (*innocoll*). Firms that engage in collaboration for innovation are expected to have higher innovation diversity by a factor of exp(0.578) = 1.78 compared to firms that do not engage in collaboration for innovation. This implies that the motivation for establishing interfirm collaboration also matters in stimulating innovation.

Prior studies suggest that firms' internal characteristics, such as size and age, significantly influence innovation as size represents available resources and age characterises rigidity (Yu and Lee 2017). Small-sized firms are particularly vulnerable due to the low level of slack resources, making them less likely to innovate than large firms (Tian *et al.* 2019). Consistent with prior results, our results suggest that an increase in firm size promotes innovation diversity, as indicated by firm size categories' positive and statistically significant coefficient. However, contrary to Huergo and Jaumandreu (2004), we find that age (Table 2, numeric column 2) increases firms' innovation diversity (0.016, p-value <0.1), possibly because older firms have more established internal structures to manage innovation. Unlike prior studies that find a negative association between internationalisation and innovation (Bahl *et al.* 2021), our findings demonstrate that exporting firms have a higher innovation diversity (0.289, p-value <0.05). This could be due to Australia being a geographically isolated open western economy in comparison to the transition economies. Moreover, the positive effect of internalisation could be due to the ability of exporting firms to better acquire, integrate and accumulate new knowledge about customers, suppliers and other stakeholders.

The OLS and fixed versus random-effects estimates (Table 3) indicate the 'average' effect of innovation diversity on the 'average' firm's growth. As per

Table 3 Regression estimates of firm performance (Sales growth)

Variables	OLS	Fixed-Effects	Random-effects	Quantile Regression (%)			
				25	50	75	90
Invdivr (t-1)	0.010	0.008	0.012	0.004	0.003	**0.011***	**0.013***
	(0.008)	(0.010)	(0.009)	(0.005)	(0.003)	(0.005)	(0.006)
Growth (t-1)	−0.166***	−0.012	−0.295***	−0.071	−0.154***	−0.162**	−0.213***
	(0.045)	(0.044)	(0.045)	(0.038)	(0.034)	(0.049)	(0.041)
Sale (t-1)	−0.002	−0.929***	−0.019	0.029***	0.002	−0.029***	−0.083***
	(0.01)	(0.089)	(0.013)	(0.006)	(0.004)	(0.006)	(0.01)
Industry dummies	YES	NO	YES	YES	YES	YES	YES
Year dummies	YES	NO	YES	YES	YES	YES	YES
Constant	Supressed	Supressed	Supressed	Supressed	Supressed	Supressed	Supressed
[Pseudo-] R-Square	0.0310	0.3798	0.0507	0.0175	0.0160	0.0483	0.1357
Observations	1923	1923	1923	1923	1923	1923	1923
Number of groups	716	716	716	716	716	716	716

Source: Authors' calculations using ABS BLD 2006–07 to 2010–11.
Notes: The number of observations are reduced to 1923 consisting of 716 firms because of the dynamic panel model where independent variables are measured at time t-1. Standard errors in parenthesis. ***significance at 1%, ** significance at 5% and *significance at 10%. The intercept terms are supressed to comply with ABS' output clearance requirements.

these estimates, there is no significant relationship between innovation diversity and firm growth. However, these 'average effects' do not state the story given the heavy-tailed nature of the growth rate distribution (Coad and Rao 2008). It may not be a good strategy to examine the relationship between innovation and sales growth for the average firm that hardly grows. We, therefore, estimate the innovation–growth nexus at different quantiles of the conditional sales growth distribution. Our results (Table 3) show that the values and statistical significance of the estimated coefficient on innovation diversity vary over the conditional growth rate distribution. More specifically, the quantile regression solutions at the lower and median quantile appear to have no significant effect on firm growth. However, the coefficient on innovation rises and turns significant, albeit modestly, for the fast-growth firms at the upper (75th and 90th) quantiles. This evidence supports H4: innovation diversity is associated positively with the fastest-growing firms' growth rather than the average firm's.

5. Discussion

The main goal of this study is to analyse the relationships between FDC, diversity of innovation, focus on innovation, collaboration for innovation and growth performance in the Australian food industry. Accordingly, we examine the nature of the relationship between a firm's FDC (antecedent) and its innovation diversity. Also, we test the relationship between innovation diversity and two antecedents: focus on innovation and collaboration for innovation, and, finally, the influence of innovation diversity on its growth performance.

First, our results suggest a curvilinear relationship between FDC and innovation diversity. In other words, the benefits of multiple types of collaborations are subject to decreasing returns, indicating that there is a point where additional collaboration becomes unproductive (Laursen and Salter 2006). This result is consistent with previous literature that suggests a curvilinear relationship between collaboration for innovation and performance (Faems *et al.* 2005; Laursen and Salter 2006; Delbufalo 2015). Some explanations of the curvilinear relationship include the high transaction cost of managing many collaborations and the lower marginal value of each additional collaboration (Hottenrott and Lopes-Bento 2016). In particular, limitations on absorptive capacity when too many ideas cannot be managed or limitations on attention allocation when some ideas might not be taken seriously due to information overload (Laursen and Salter 2006). Prior research suggests that SMEs often lack the resources to invest in innovation (Danneels 2002; Eisenhardt and Martin 2000). Since the majority of Australian food firms are SMEs, the lack of absorptive capacity to manage and benefit from multiple collaborations, as well as an increasing overlap in scientific resources and expertise (duplication and repetition of projects) between Australian food firms, may result in undesirable knowledge

redundancy and less effectiveness of collaborative efforts (Jiang *et al.* 2010; Soh & Subramanian, 2014).

Second, this study finds that focusing on innovation and collaboration for innovation are two significant predictors of innovation diversity in Australian food industry firms. Our results are consistent with the literature that confirms the importance of an innovative-oriented culture, proactiveness or shared vision for innovation performance (Calantone and Rubera 2012; Damanpour 1991; Dibrell *et al.* 2014). We extend this literature confirming that focus on innovation benefits innovation diversity, possibly because it creates an environment conducive to generating a greater variety of ideas that result in a more diverse set of innovation domains. In addition, we extend the literature on collaboration for innovation (Faems *et al.* 2005; Troy *et al.* 2008; Lo and Li 2018), supporting its positive relationship with innovation diversity. Different types of innovations require a variety of knowledge present in external sources such as competitors, suppliers or customers. Collaborating among actors who are simultaneously competitors corresponds to the so-called 'co-opetition' (Bengtsson and Kock 2000; Brandenburger and Nalebuff 2021). The idea of collaboration with a competitor is based on the logic of horizontal integration as it helps firms to grow market share and intensity of firms' core competency (Yu and Lee 2017). Moreover, current competitive environments to innovate demand complex technological and market knowledge that is difficult to find in collaboration agents that are not one's competitors (Bouncken *et al.* 2018). Competitors have valuable resources, and sharing puts them ahead of their typical rivals (Brandenburger and Nalebuff 2021). Further, additional benefits such as joint exploitation of resources available or cost-sharing (Segrestin 2005) justify collaboration with competitors. However, firms may also establish vertical collaboration with customers and suppliers. Prior studies suggest that suppliers usually have more knowledge of product component, and customers have more knowledge of the market (Lagrosen 2005; Brockhoff 2003; Yu and Lee 2017). Hence, vertical collaboration with suppliers and customers may help firms to develop market-oriented products and reduce costs, respectively (Faems *et al.* 2005). For example, Danone and Nestlé Waters signed a collaborative arrangement to design plastic bottles made from 100 per cent bio-based materials (cellulose fibres) with the US company Origin Materials in 2017. This collaboration resulted in the NaturALL Bottle Alliance, which was joined by PepsiCo a year later. Another example is Australian companies' coalition of developing the first soft plastic food wrapper made with recycled content. Companies such as Nestlé, CurbCycle, iQ Renew, Licella, Viva Energy Australia, LyondellBasell, REDcycle, Taghleef Industries and Amcor have brought their diverse individual expertise together to collect and process waste soft plastic and create the first food-grade prototype wrapper (American Stock News, 2021).

Finally, we do not see any significant effect on innovation diversity and firms' growth using OLS, fixed-effects and random-effects estimators. However, these estimators do not provide a complete and accurate picture

of the underlying relationship between innovation and firm performance because they are estimated at sample means and refer to the average firm (Coad and Rao 2008). Quantile regression estimates suggest that the relationship between innovation and growth varies throughout the conditional growth rate distribution. The magnitude and statistical significance of quantile regression estimates show that innovation diversity is only weakly related to a firm's growth at the upper quantile. It has no effect on growth for the low or average growth firms. Consequently, the relationship between innovation diversity and growth is highly contextual (Gronum 2015). The modest growth effect of innovation in this study can be explained on the grounds that the majority of the firms in our dataset are non-employing or microfirms (around 50 per cent as in Appendix S2), and such firms may lack the capacity to transform their innovation into commercial success.

These results support claims that particular cases, such as low-growth small firms that suffer resource constraints, cannot muster the minimum resources needed to develop innovation projects (Rosenbusch *et al.* 2011). In such cases, it is better to concentrate efforts on a few innovations than to dilute efforts into many (Gronum 2015; Roxas *et al.* 2014). A related explanation is that larger companies face the uncertainty and risks of innovation with high growth and more resources (Eisenhardt and Martin 2000) or previous experience with innovation projects more common in larger organisations (Majchrzak *et al.* 2004; Danneels 2002).

6. Conclusion

This study focuses on the drivers of innovation in the F&A sector of Australia (Soriano *et al.* 2019). This is the first study that examines the relationship between firms' FDC and innovation diversity in the context of Australia. The study also investigates the important role of firms' strategic orientation toward collaboration and innovation. Finally, this research explores how firms' innovation diversity translates into growth.

Our results partially agree with previous studies about complementarities between collaborations (Love *et al.* 2014; Love *et al.* 2011). FDC can be an example of how diverse collaborative arrangements, such as joint R&D, integrated supply chains, joint marketing or distribution, can complement each other, facilitating economies of scope and knowledge combinations that benefit innovation diversity. Our findings imply that instead of relying exclusively on internal R&D, Australian firms need to open up to collaborations. Moreover, the more diverse those collaborations are, the more diverse will be the resulting innovation. However, business managers must carefully consider the appropriate number of collaborations based on their unique contributions before expanding their collaboration portfolio. This can be achieved by critically evaluating resources and capabilities and choosing the right collaborations that accommodate firms' absorptive capacity. This is important because simply increasing firms' collaborative diversity could be

costly, given the non-linear relationship between FDC and firms' innovation diversity.

We find strong evidence to suggest that FDC's contribution to innovation diversity depends on the motives behind alliance formation and the firm's focus on innovation. Collaboration and networking for innovation enable firms to improve their outreach abilities to serve as many target groups, benefactors and beneficiaries as possible. A lack of collaboration for innovation may also result in duplication and repetition of projects that have already failed. Future research could analyse some of our reasoning, such as the lower absorptive capacity of SMEs for innovation diversity, their specific difficulties in transforming this diversity into commercial success or the particular benefits of collaborating with competitors to enhance that diversity.

We suggest that policymakers in Australia continue to encourage open innovation practices to facilitate collaboration and innovation. Although not examined in this study, one prior study provides empirical evidence that R&D subsidies have positive unintended effects on collaborative diversity (Chapman *et al*. 2018), meaning that a firm's collaboration with other organisations can be used as a precondition for receiving support. Other measures to promote innovation and collaboration could be in demand and supply-side policy instruments. The supply-side policy measures may include human capital development through Australia's Vocational, Education and Training (VET) packages. It could help firms better engage in diverse collaborations and exploit new knowledge (Australian Government 2017). The demand-side policy measures may include facilitating access to information and strengthening markets for innovation offerings (Verreynne *et al*. 2019).

Research on collaboration and organisational posture employs either the firm or a dyadic relationship (firm–customer or firm–supplier) as the unit of analysis. We deem collaborative, systematic networked or ecosystem-like approaches valuable for the diversity of innovation-based research. There is a need for comparative studies about networks, value chains and systems to offer insight into micro-level differences, which will otherwise remain veiled due to the specificity of the contextual differences. Further research efforts could also focus on some intervention scenarios (e.g., local regulations and power systems), the nature of collaborative arrangements (e.g., one-to-one vs one-to-many or many-to-many) and the relative importance of different collaborative partners to gain an in-depth understanding of the institutional structures that are in place under such circumstances.

Disclaimer

The results of these studies are based, in part, on Australian Business Registrar (ABR) data supplied by the Registrar to the ABS under A New Tax System (Australian Business Number) Act 1999 and tax data supplied by the

ATO to the ABS under the Taxation Administration Act 1953. These require that such data are only used for the purpose of carrying out functions of the ABS. No individual information collected under the Census and Statistics Act 1905 is provided back to the Registrar or ATO for administrative or regulatory purposes. Any discussion of data limitations or weaknesses is in the context of using the data for statistical purposes and is not related to the ability of the data to support the ABR or ATO's core operational requirements. Legislative requirements to ensure privacy and secrecy of these data have been followed. Source data are de-identified, and so data about specific individuals or firms have not been viewed in conducting this analysis. In accordance with the Census and Statistics Act 1905, results have been treated where necessary to ensure that they are not likely to enable the identification of a particular person or organisation.

Data Availability Statement

The data that support the findings of this study are available from the Australian Bureau of Statistics. Restrictions apply to the availability of these data, which were used under license for this study.

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