Vertical integration and innovative performance: The effects of external knowledge sourcing modes

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ABSTRACT

We set out in this study to analyze the impact of vertical integration on the innovative performance of a firm and to explore the interaction between vertical integration and different modes of external knowledge sourcing. Our empirical results reveal an initial increase in the effect of vertical integration on innovative performance up to a certain level of integration, although this is subsequently followed by a decline; that is, the relationship is characterized by an inverted U-shape. The results further reveal that external knowledge sourcing is positively related to the innovative performance of a firm, albeit with a negative interaction with the level of vertical integration. In other words, firms with higher levels of vertical integration may be faced with barriers to the acquisition of external knowledge. Our findings suggest that firms should be cautious in their pursuit of a strategy of vertical integration, given the non-monotonic impact on innovative performance, whilst an increase in the level of vertical integration is also likely to diminish the effectiveness of the external knowledge sourcing.

1. Introduction

An area of particular interest in the field of strategic management is the analysis of the underlying reasons for the differences in the investment choices made by firms and their subsequent performance (Rumelt et al., 1994). In their pursuit of the answers to this extremely intriguing issue, many researchers have attempted to provide empirical evidence on whether the allocation of resources is affected by firm boundaries (Mullainathan and Scharfstein, 2001), or whether the firms’ investment decisions may be affected by its organizational form (Ciliberto, 2006). Despite the widespread consensus on the importance of the decision by a firm to pursue vertical integration, it remains unclear as to whether, or the way in which, these vertical boundary decisions affect the various dimensions of firm performance (Harrigan, 1985a; Martin, 1986; D’Aveni and Ravenscraft, 1994; Leiblein et al., 2002).

The empirical evidence in the prior studies is rather mixed, with some studies suggesting that a strategy of vertical integration does not induce performance differentials (Reed and Frommeller, 1990), some reporting that vertical mergers have a negative impact on profits due to the failure of such mergers to create differential advantages for the integrated firm (Bhuyan, 2002), and some noting that whilst vertical integration is associated with lower transaction and overhead costs, this is nevertheless accompanied by higher production costs (D’Aveni and Ravenscraft, 1994).

Peyrefitte et al. (2002) argue that a better understanding of the relationship between vertical integration and performance may be achieved by considering the role of managerial capabilities in directing such integration; they note that a lack of understanding of non-core businesses as well as a lack of the necessary managerial approach to the management of the activities being integrated both contribute to inferior performance. From an examination of the issue of costs after firms changed their vertical integration strategies, Mpoyi and Bullington (2004) found that such strategic changes significantly reduced production costs, although these changes did not affect inventory costs. Thus, the relationship between vertical integration and performance remains both inconclusive and unpredictable.

As a result of this rather ambiguous relationship between vertical integration and performance, the extant empirical literature has tended to focus mainly on issues relating to economic or financial performance. However, faced with such a rapidly changing environment and advancing technology, innovation has clearly become a prerequisite for any firm hoping to develop or maintain its competitive advantage. Thus, some of the more recent studies have begun to focus more on firm performance through the measurement of innovative capability.

Although the benefits and costs of vertical integration have been debated for several decades, few studies have gone on to link a firm’s vertical integration strategy with technological
innovation. Armour and Teece (1980) argue that vertical integration and R&D expenditure are positively correlated, suggesting that vertical integration can facilitate the transfer of technical information, and that when complex inter-stage interdependencies are involved, this can also facilitate the implementation of new processes or the introduction of new products.

Amongst the more recent studies, Jacobides and Winter (2005) argue that the scope of a firm is related to the process of capability development, whilst Macber (2006) undertakes a comparative analysis of the ways in which firms efficiently organize themselves to solve different types of problems relating to technological development. These studies highlight a very interesting and potential direction for further study aimed at clarifying the relationship between vertical integration and the innovative performance of a firm.

The need for flexibility in organizational capabilities has also emerged as a critical issue with regard to firm boundaries and the choices made by a firm between internal and external knowledge integration (Grant, 1996a), particularly in conditions of dynamically competitive markets. In such cases, the optimal growth of the firm involves a fine balance between the exploitation of existing resources and the development of new resources and capabilities (Penrose, 1959; Wernerfelt and Montgomery, 1988).

Firms are thus forced to search for external sources of knowledge in order to diversify their research portfolios and to broaden their knowledge base. Any increase in the technological diversification of a firm can promote the cross-fertilization between different areas of technological expertise whilst simultaneously reducing the lock-in effect in those technologies with low profitability (Garcia-Vega, 2006). This thereby highlights the importance of external knowledge sourcing with regard to the development of the innovative capability of a firm.

However, we still know relatively little about whether, or the ways in which, organizational structure interacts with the external knowledge sourcing modes with regard to determining the innovative performance of a firm. As noted earlier, vertical integration is likely to influence the potential returns to R&D investment, which determines the firm's absorptive capacity, and which in turn influences the effectiveness of external knowledge sourcing. We therefore set out in this study to explore the ways in which the innovative performance of a firm interacts with its vertically-integrated structure and its external knowledge sourcing modes.

Using the ‘quality of innovation output’ and the ‘technological scope’ of a firm as the intermediate measures of innovative performance, the main contribution made by the present study is its clarification of the relationship between the level of vertical integration and the innovative performance of a firm. We also provide some contribution to the literature on organizational learning. Vertical integration and external knowledge sourcing modes are beneficial for firms with regard to enhancing their level of innovativeness; however, it should be noted that for firms with higher levels of vertical integration, a negative correlation is found in the interplay between vertical integration, external knowledge sourcing modes and innovative performance.

The remainder of this paper is organized as follows. Section 2 provides a brief review of the extant literature on vertical integration and technological innovation and discusses the relationship between vertical integration and innovative performance; the role of external knowledge sourcing and its impact on the relationship between vertical integration and innovative performance is also discussed in this section. Section 3 provides information on the data and methodology used to test our hypotheses, as well as our data analysis, with the results subsequently being presented in Section 4. Section 5 provides a discussion of our results, as well as a review of the limitations and recommendations for future research. Section 6 provides the conclusions drawn from this study.

2. Theoretical background and hypotheses

From a resource-based perspective, both vertical integration and diversification can be viewed as ways of capturing rents on scarce, firm-specific assets (that is, services which are difficult to sell in intermediate markets) (Penrose, 1959; Wernerfelt, 1984; Teece, 1986; Williamson, 1991) and of developing new capabilities (Wernerfelt, 1984). Although firm performance is measured in many of the prior studies by observing the innovative capability of a firm, the relationship between a strategy of vertical integration and innovative performance has still to be broadly discussed; thus, as noted above, the findings remain inconclusive. The present study sets out to clarify the relationship between vertical integration and a firm's innovative performance in order to fill this gap. We also examine the ways in which vertical integration interacts with external knowledge sourcing modes in determining a firm's innovative performance.

2.1. Vertical integration and innovative performance

From a knowledge-based perspective, the development of new knowledge by firms, a process that is clearly vital to their sustainable competitive advantage, arises from unique combinations of existing knowledge (Nelson and Winter, 1982; Fleming, 2001). It is argued in some studies that when complex interdependencies are involved, vertical integration can enhance technological innovation through the sharing of technological information common to the separate stages of the development of an industry: this can be achieved by facilitating the implementation of new technologies and through the formulation of more astute research objectives (Armour and Teece, 1980; Monteverde, 1995). Vertically-integrated firms with many of relevant complementary assets under control (Teece, 1986) would have better opportunities for internal application of knowledge generated by R&D and then facilitate appropriability of R&D (Kumar and Saqib, 1996).

Chesbrough and Teece (1996) offer a case for retaining new technologies in-house, since vertically-integrated firms have established processes for settling conflicts and coordinating their innovation activities; in other words, vertical integration facilitates systemic innovations by facilitating information flows and the coordination of investment plans (Teece, 1996). Afuah (2001) also suggests that in the early days of a new technology, a 'make' decision is better than a 'buy' decision, essentially because the firm's communication channels are the key to the success of the innovation.

In more specific terms, due to the lock-in effect on downstream firms arising from vertical integration, and since such vertical integration increases the expected value of the firm's R&D activities because of better appropriability (Kumar and Saqib, 1996), upstream firms will tend to be more innovative, thereby raising the likelihood of attracting other downstream firms (Brocas, 2003). As such, vertical integration, which serves as an internal mechanism for knowledge transfer and integration, is positively related to innovation. In contrast, however, in one particular earlier study, it was demonstrated that a high degree of vertical integration raises the height of a firm's exit barriers and also gives rise to greater inflexibility (Harrigan, 1980).

According to Abernathy and Wayne (1974), the "relentless pursuit of learning curve economies", with the attendant vertical integration implications, has a negative effect on technological innovation. The areas covered by a firm's core competences are
reflected in its path-dependent accumulation of knowledge leading to further technological development (Leonard-Barton, 1992). With regard to learning, however, this does lead to potential increased rigidity and myopia, which will ultimately make further change increasingly difficult.

Higher incidences of internal technology or knowledge transfer are also likely to provide the firm with the illusion of a lack of competition, essentially as a result of the stability of the firm’s customer base; however, this is then likely to have a negative influence on future technological innovation (Harrigan, 1980; Mascarenhas, 1985). We therefore argue that vertical integration is likely to encourage firms to innovate more due to the facilitation of appropriation, but that this relationship may be found to be negative at higher levels of vertical integration.

Hypothesis 1a. The relationship between vertical integration and the quality of a firm’s innovation output will be an inverted U-shape.

The decision on whether to outsource or vertically integrate a value-chain activity, which represents a complex choice to be faced by the managers of a firm, has long been a topic of primary interest in strategic management. Choices on how much to invest in different possible areas are also central to the firm’s strategy (Dierickx and Cool, 1989).

As mentioned earlier, the development of new knowledge, which is of considerable importance to a firm’s competitive advantage, arises from unique combinations of its existing knowledge (Nelson and Winter, 1982; Fleming, 2001), numerous studies examine the ways in which the choice of organizational structure influences not only knowledge exchange and protection (Kogut and Zander, 1992; Monteverde, 1993; Conner and Prahalad, 1996; Grant, 1996b) but also the coordination of complementary assets (Teece, 1986; Stieglitz and Heine, 2007). Integration requires firms to commit significant resources and to accumulate the necessary resources to generate or maintain their competitive advantage (Dierickx and Cool, 1989); this represents a large difficult-to-reverse investment, which directly affects the technological scope of the firm.

From an investigation into the ways in which firms efficiently organize themselves to develop and transfer knowledge relating to technological development, Macher (2006) notes that whilst specialized manufacturers realize performance advantages for problems that are simple and well structured, integrated manufacturers achieve performance advantages for problems that are both complex and ill structured. Additionally, firms using a strategy of vertical integration are mostly to gain access to the potential value of complementary assets. However, at higher levels of vertical integration, firms will be increasingly influenced by the trajectory of their prior technological development, and as a result, are likely to lose much of their former flexibility. We therefore propose a non-monotonic relationship between vertical integration and technological scope.

Hypothesis 1b. The relationship between vertical integration and technological scope will be an inverted U-shape.

2.2. The effects of external knowledge sourcing modes and vertical integration on innovative performance

Firms competing in global markets are faced with challenges and opportunities from the convergence of consumer preferences and the pace and scope of technological change, engaging in extensive and risky sunk R&D costs and relying extensively on external linkages (Veugelers, 1997) as the means of gaining access to external knowledge sources (Hill and Rotheram, 2003; Nicholls-Nixon and Woo, 2003). In addition to the importance of internal coordination, strategic advantage requires the integration of such external activities and technologies (Teece et al., 1997). In other words, within the context of dynamic technological and competitive conditions, dynamic capabilities are a prerequisite to “the firm’s ability to integrate, build and reconfigure internal and external competencies to address rapidly changing environments” (Teece et al., 1997).

Such capabilities must also be developed through learning (Zollo and Winter, 2002). Within the extant literature on innovation, organizational learning is usually seen as promoting comparative innovative efficiency (Perez-Lopez et al., 2005). Firms with the availability of a larger pool of external knowledge should have greater incentives to innovate (Caloghirou et al., 2004; Garcia-Vega, 2006); more importantly, however, the vertical scope of a firm affects the nature of its knowledge accumulation and capability development (Jacobides and Winter, 2005; Malerba et al., 2008), which in turn affects the capacity of the firm to absorb new external knowledge (Cohen and Levinthal, 1990).

Nevertheless, we still know relatively little about the interaction between organizational structure and external knowledge sourcing modes in determining a firm’s innovative performance. Although it is likely that vertical integration will facilitate the transfer of knowledge between the separate stages of a firm’s
Piscitello (2004) suggests that the innovative performance of a firm is dependent not only upon the firm's capacity to diversify, but also on its ability to exploit and extend its coherence over time. The ability to acquire and utilize knowledge effectively is critical to a firm's innovative activities and performance (Cohen and Levinthal, 1990), with a certain level of absorptive capacity being necessary for the combination of internal and external knowledge. This has to be developed through independent R&D to be able to take advantage of external sources of innovative activities (Cohen and Levinthal, 1989).

As noted earlier, vertical integration provides better opportunities for internal application of knowledge generated by R&D and increases the expected value of R&D activities, stimulating R&D investment in both basic and applied research (Armour and Teece, 1980; Kumar and Saqib, 1996). We therefore argue that vertical integration may increase the absorptive capacity of a firm, which then enables it to benefit from the research activities of other firms with similar technological bases; however, a higher level of vertical integration may increase the risk of lock-in, which is likely to turn core competencies into core rigidities (Leonard-Barton, 1992). Firms that have succeeded in developing strong internal routines are less likely to be open to new knowledge brought in by external activities (Kim and Song, 2007).

Although firms require an external knowledge sourcing mode to broaden their knowledge base and enhance their innovative capability in order to avoid the risk of a competency trap, the effects of external knowledge sourcing modes may be quite diverse, depending on the level of vertical integration. In the present study, we propose that by going beyond the capabilities of most individual companies, and through the use of external sources of technology (Hagedoorn and Duysters, 2002), external knowledge sourcing modes have a positive effect on the innovative performance of a firm; however, this relationship is negatively moderated by the level of vertical integration. In other words, vertically-integrated firms with low to moderate levels of integration may have advantages in terms of their coordination of external knowledge, helping them to build new technological capabilities whilst also strengthening their existing capabilities, but not at higher levels of vertical integration.

**Hypothesis 2a.** At higher levels of vertical integration, the effects on the quality of a firm's innovation output arising from such integration and from the external knowledge sourcing mode will be negative.

**Hypothesis 2b.** At higher levels of vertical integration, the effects on a firm's technological scope arising from such integration and from the external knowledge sourcing mode will be negative.

### 3. Methodology

#### 3.1. Data and sample

The development of new capabilities is a key strategic priority for firms (Colombo, 2003). In this study we investigate the relationship between vertical integration and a firm's innovative performance, selecting the information technology (IT) industry to test our hypotheses, essentially because this industry exhibits a variety of strategies involving vertical integration, and because it has a multitude of segments which will often include both integrated firms and specialized firms. The IT industry is also characterized by rapid technological advancement, as well as short product life cycles and steep price declines; this is largely because, despite the fact that patents have become increasingly important within the 'information and communications technology' (ICT) industries (Hall, 2005), the strength of patent protection in these industries has remained relatively low (Cohen et al., 2000).

Given that the technological and market leaders in the IT industry are US firms (Malerba et al., 2008), we conduct our empirical investigation of the IT industry in America using a panel dataset (cross-sectional time-series) covering the period from 1998 to 2004, using multiple sources of data collection. Data on the sample of firms and segments are obtained from the Compustat database, whilst patent data are drawn from the USPTO database, and details on alliance activities are obtained from the SDC database. The classification of the sample firms corresponds to SIC code 357 (computer and office equipment), with screening of the data being undertaken on all firms to ensure complete data coverage for the entire 7-year period; this process yielded a total of 71 unique firms with balanced panel data across the whole of the period under examination.

#### 3.2. Variables and measures

##### 3.2.1. Dependent variables

**3.2.1.1. Patent citations (the quality of innovation output).** Within the extant literature on innovation, we find a long history of struggling with the measurement of firm's innovative performance. The available measures, such as R&D inputs, patent counts, patent citations, or counts of new product announcements have often been used, along with more specific survey-based measurements, in attempts to capture the innovative performance of a firm (Hagedoorn and Cloodt, 2003). Several authors suggest that patents are reasonably reliable indicators of innovative performance, and indeed, that they are generally better measures of R&D output than actual R&D spending (Griliches, 1990; Sampson, 2004). However, simple patent counts cannot accurately capture the value of a firm's innovation; thus, in this paper we focus on the quality of the firm's innovation output, assigning a weight to each patent using citations made by later patents.

**3.2.1.2. Technological scope.** In this study, the Technological Scope variable is constructed based on the Herfindahl index of concentration, with the technological portfolio for each firm being calculated as

\[
1 - \frac{1}{\left(\sum_{j} \frac{N_{ij}}{N_{i}}\right)^2} \cdot \frac{N_{i}}{N_{i} - 1}
\]

Let \(N_{ij}\) denote the number of patents held by the \(i\)th firm in category \(j\); let \(N_{i}\) denote that the \(i\)th firm has \(N_{i}\) patents in the analyzed period, and that each patent can be assigned to a technological field. Here we use a non-biased diversity estimator, as proposed by Hall (2002), to correct for the possible bias of the index. Higher values indicate broader technological scope, whilst smaller values indicate narrower technological scope.

##### 3.2.2. Independent variables

**3.2.2.1. VAS (level of vertical integration).** As noted by Harrigan (1985b), a strategy of vertical integration is a multi-dimensional concept; thus, different measures of vertical integration, each of which assesses a specific dimension, can yield complementary insights into an extremely complex phenomenon (Mpoyi and Bullington, 2004). In the present study, we use the ratio of value added to sales, VAS, adjusted for profitability and taxation (Tucker and Wilder, 1977) to measure the level of vertical integration within a firm. The ratio is operationalized through the use of the
following formula (Lindstrom and Rozell, 1993).

\[
\text{Value-added ratio} = \frac{\text{Interest Exp} + \text{Depreciation Exp} + \text{Rental Exp}}{\text{Sales} - \text{Net income} - \text{Total income taxes}}
\]

In order to capture the importance of a firm’s external knowledge sourcing, we use Alliance Activity and FSTS (foreign sales to total sales: a proxy for the level of internationalization) as two additional proxy measures for the external knowledge sourcing mode. These measures are described below.

3.2.2.2. Alliance activity. The incentives for a firm to form alliances are related to its need for resources (Eisenhardt and Schoonhoven, 1996). Technological change and expanding global competition have forced firms to search for external sources of knowledge through a wide diversity of alliances (Hagedoorn and Osborn, 2002) in order to improve their resource endowment and to master strategic uncertainty more effectively than their competitors (Eisenhardt and Schoonhoven, 1996; Hoffmann, 2007).

Openness to the use of external sources of information and ideas on the firm’s innovation processes, as well as interactions between different partners, are of significant importance when creating value through innovative activities (Chesbrough, 2003), since collaborations and partnerships can be a vehicle for new organizational learning (Mody, 1993). In this study, we use a dummy variable, Alliance Activity, to capture this aspect, based upon the alliance activity synopses provided by the SDC database. This dummy variable takes a value of 1 where the firm has R&D-related alliance activities, otherwise 0.

3.2.2.3. FSTS (level of internationalization). The firms that are able to effectively learn about their customers, competitors and regulators stand a far better chance of sensing and acting upon events and trends within the marketplace (Tippins and Sohi, 2003). Much evidence has been provided within the extant literature to show that foreign subsidiaries play the very important role of creating and acquiring valuable local knowledge, which in turn contributes to the knowledge base of the entire MNC (Almeida and Phene, 2004; Mu, Gnyawali and Hatfield, 2007). Sher and Yang (2005) argue that a firm will strengthen its innovative capabilities through internal development supplemented by external network linkages, then, as valuable knowledge is globally dispersed, the ability to learn from diverse international environments becomes a critical source of competitive advantage (Doz et al., 2001). Although the proxies for the degree of internationalization in the prior studies include foreign sales as a percentage of total sales (FSTS), foreign assets as a percentage of total assets (FATA) and the number of foreign subsidiaries, FSTS is used in much of the literature as the estimator of the degree of internationalization (Sullivan, 1994). Given that the IT industry is both mature and highly globalized, we also use the firm’s foreign sales to total sales, FSTS, as the proxy for its level of internationalization.

3.2.3. Control variables

3.2.3.1. Firm size. The size of a firm is often viewed as an indicator of scale economies and market power; however, significant empirical disparity is often observed with regard to this variable, with arguments for both large and small firm size being pursued within the extant literature on innovation (Arundel and Kabla, 1998; MacPherson, 1998; Love and Ashcroft, 1999). Firm Size is measured in the present study using the logarithm of the total number of employees.

3.2.3.2. Firm age. The effects of the age of the firm on innovation must also be taken into account; however, opinions on this particular aspect are again quite mixed. Some argue that firm age represents the experience and knowledge accumulated throughout its history and is closely related to better management of communication, the necessary creativity to innovate, and to a more effective capacity for absorption (Sorensen and Stuart, 2000). On the other hand, others argue that older firms develop established procedures and routines that create resistance to the integration of major external advances and thus represent barriers to innovation (Freel, 2003). Firm Age is measured in the present study as the logarithm of the number of years which have passed since the firm was first established.

3.2.3.3. Prior performance. Some studies suggest that prior performance has a positive effect on firm innovation (Zahra, 1993; Tsai, 2001); indeed, since the prior performance of a firm will possibly influence its strategic decision making, it must therefore be controlled for. In this study, Prior Performance is measured by the firm’s return on assets (ROA) with a 1-year lagged variable.

3.2.3.4. Product diversity. Some studies have suggested that diversification may be related to firm innovation (Hitt et al., 1996; Francois et al., 2002); thus, in the present study, we use total entropy to capture the level of diversification in the firm (Jacquemin and Berry, 1979; Palepu, 1985), using the lines of business database obtained from Compustat to calculate Product Diversity, as follows:

\[
\text{Total entropy} = \sum_{i=1}^{N} S_i \ln(1/S_i),
\]

where \(S_i\) refers to the share of a firm’s total sales in the four-digit SIC industry \(i\), and \(N\) is the number of four-digit SIC industries in which the firm is operating.

3.2.3.5. RDI (R&D intensity). According to Penrose (1959), both tangible and intangible assets are important aspects of corporate growth, and one available measure of a firm’s investment in intangible assets is R&D expenditure. The extant theory and evidence suggests that R&D investment is related to firm innovation (Cohen and Levinthal, 1990; Landry et al., 2002), and that it is also a major contributor to the internal learning of the firm. In the present study, RDI is measured as the logarithm of the ratio of the firm’s R&D expenditure to total sales.

3.2.3.6. CI (capital intensity). Another measure of a firm’s investment in tangible assets is capital expenditure, with capital intensity being measured by a firm’s net plant, property and equipment divided by its total sales. The higher the level of a firm’s capital intensity, the more difficult it will be for the firm to undertake any rapid and substantial changes to its strategy in response to environmental conditions; thus, this can reduce the firm’s overall flexibility (Bierly and Chakrabarti, 1996). In this study, we calculate CI using the logarithm of the ratio of net plant, property and equipment to total sales.

3.2.3.7. Available slack. When referring to ‘slack resources’ researchers have commonly distinguished between three types of slack (‘available’, ‘recoverable’ and ‘potential’ slack) (Bourgeois, 1981; Bourgeois and Singh, 1983; Singh, 1986); of these, Herold et al. (2006) suggest that ‘available slack’ is the most appropriate measure for investigating the relationship between patent-based innovation and slack, essentially because it represents untapped, internal resources which could potentially be used for innovative purposes, and indeed, this variable refers to assets that have not yet been committed to any particular allocation (Bourgeois and Singh, 1983; Moses, 1992). Hence, we include the Available Slack
variable in the present study, measuring this as the firm’s profit margin (the ratio of net income to sales).

3.2.3.8. Year dummies. Finally, we include year dummies for 1999–2003 in order to control for the effects of citation truncation.

3.3. Data analysis

The models used in this study to facilitate our investigation of the innovative performance of a firm are specified as follows. Firstly, we adopt the cross-sectional time-series approach in our analysis of the impact of a firm’s vertical integration strategy on its innovative performance. Secondly, since the quality of innovation output is measured in this study by means of citation-weighted patenting, the model has to account for the nature of these patent counts as positive, integer values. Furthermore, patents are naturally bounded at zero, with any non-patenting firms obviously being calculated as zero; thus, we apply a negative binomial model to predict the relationship between vertical integration and the quality of innovation output. We also include year dummy variables into the model to control for the effect of citation truncation since the number of patent citations would be influenced by the citation spans.

Thirdly, given that the Technological Scope variable is truncated at 0 and 1, we implement a Tobit regression model to analyze the relationship between vertical integration and the technological scope of the firm (Maddala, 1983). Time dummies are also included within the model in order to control for time effects. Finally, we use a 1-year lag between the independent variables and the dependent variables, which helps to deal with the assumption of independence by effectively avoiding any contemporaneous correlations. The final panel used for regression analysis covers 6 years.

4. Results

The descriptive statistics and correlations of all of the variables used in this study are presented in Table 1. It would appear from the correlation matrix that collinearity amongst the variables is low, with the exception of the interaction terms. Having checked the VIFs, we find that these values are also low (less than 10). Furthermore, most of the t-values are found to be large and significant; we therefore conclude that multicollinearity is not a major problem in the present study.

4.1. Effects of vertical integration and the external knowledge sourcing mode

4.1.1. The effects on the quality of innovation output

The models explaining the effects of the level of vertical integration and the external knowledge sourcing mode on the quality of innovation output of a firm are described in Table 2. Model 1 is a base-line model that includes control variables only. Model 2, which includes the main independent variables of interest, reveals that the level of vertical integration is positively significant \( (p < 0.1) \), and that the square of vertical integration is negatively significant \( (p < 0.05) \). These results provide support for Hypothesis 1a, which predicts that an inverted U-shape relationship will be found between the level of vertical integration and the quality of a firm’s innovation output. Furthermore, the external knowledge sourcing mode (alliance activity and internationalization) is also found to be positive and significant.

We introduce the respective interaction terms into Models 3 and 4 to assess the interactive effects on the quality of innovation output, concluding with Model 5, which includes all of the variables and the interaction terms. Model 5 is used here to interpret our results. The results from Model 5 reveal a significantly negative relationship between the level of vertical integration and alliance activity \( (p < 0.05) \); however, the relationship between vertical integration and internationalization (FSTS) has no significance; thus, Hypothesis 2a is supported only by the Alliance Activity variable. The coefficient of the level of vertical integration is positive and significant \( (p < 0.1) \), and the square term is negative and significant \( (p < 0.05) \); this also provides support for our prediction in Hypothesis 1a.

4.1.2. The effects on technological scope

The models explaining the effect of the level of vertical integration and the external knowledge sourcing mode on
technological scope are described in Table 3, with Model 1 including only the control variables. Model 2, which includes the main independent variables of interest, reveals that the level of vertical integration is positive and significant ($p < 0.05$), and that the square term is negative and significant ($p < 0.05$). These results provide support for Hypothesis 1b, which posits the existence of an inverted U-shaped relationship between the level of vertical integration and technological scope.

The respective interaction terms are introduced into Models 3 and 4 in order to assess the interactive effects on the firm's technological scope. All of the independent variables and interaction terms are included in Model 5, which is again used here to interpret our results. The results of Model 5 reveal that the coefficients on Alliance activity and FSTS are positive and significant; however, the interaction terms are both negative and significant ($p < 0.01$ and $p < 0.1$). These results provide
support for Hypothesis 2b. Similarly, the coefficient on the level of vertical integration is both positive and significant ($p < 0.01$) and the square term is negative and significant ($p < 0.01$); which provides further support for Hypothesis 1b.

As regards the control variables, we find that Firm Size has a positive correlation with both the quality of innovation output and technological scope. The relationship between firm size and innovation has long been an issue for debate within the innovation literature; our results support the argument that larger firms tend to be more innovative. With the Firm Age variable in this study being found to have a negative correlation with the Technological Scope variable in the full model; this result provides further support for the argument that older firms are more likely to create resistance to the integration of external technological advances which may thereby impede any potential broadening of the firm's technological base. The CI variable is found to negatively relate to the Patent Citations variable in the full model, providing support for the argument that at higher levels of capital intensity, firms are difficult to undertake the changes and reduce their flexibility in innovation. Finally, our results provide consistent support for the notion of the positive relationship between R&D and innovation.

5. Discussion

The issue of the relationship between vertical integration and performance has continued to be a topic of discussion for several decades. Our aim in the present study is to provide further insights into this issue by investigating the effects of vertical integration on the innovative performance of a firm, and by further investigating the role of the external knowledge sourcing mode, including the ways in which this sourcing mode interacts with a firm's vertical integration to influence the innovative performance of a firm.

Our empirical results provide evidence to show that the effects of vertical integration on firm's innovative performance are non-monotonic; that is, we find the existence of an inverted U-shaped relationship, with vertical integration initially having a positive effect on innovative performance, but this relationship subsequently turning negative at higher levels of vertical integration. On the one hand, this result indicates that vertical integration is more likely to strengthen a firm's knowledge base in related technological areas due to the advantage of knowledge transfer and facilitation of appropriation; on the other hand, it also provides support for the argument in many of the prior studies that a higher degree of vertical integration leads to inflexibility (Harrigan, 1980), which in turn tends to impede innovation, thereby creating the potential for the entry of new competitors to exploit the capabilities which they have developed in different contexts. This scenario, which is often used to explain the dynamic patterns of vertical integration in the computer industry, and to explain why vertically-integrated firms demonstrate heterogeneous performance, is the main contribution of the present study.

A further contribution of this study is our investigation of the ways in which the different modes of external knowledge sourcing interact with vertical integration to determine the innovative performance of a firm. Our findings mostly confirm that the mode of external knowledge sourcing contributes a firm's searching and gaining access to new resources (Eisenhardt and Schoonhoven, 1996; Grant and Baden-Fuller, 2004; Arranz and Fdez. de Arroyabe, 2008; Zeng et al., 2010) and improving its ability to innovate by having greater opportunities to learn (Kafouros et al., 2008). The results show that alliance activities and internationalization have positive impacts on the innovative performance of a firm, although the positive impact of internationalization on the quality of innovation output is statistically insignificant. The results also indicate that, compared to the level of internationalization, alliance activities have a greater likelihood of beneficial impacts on the innovative performance. Particularly, additional attention should be paid to this finding: the impact of the external knowledge sourcing modes is mixed. When the external knowledge sourcing is from alliances, the external knowledge sourcing mode plays an important role in accessing and acquiring external valuable knowledge and thereby contributes to a firm's innovative performance; however, when the external knowledge sourcing is from internationalization, such mode may be less influential in this regard. One of the plausible explanations is a firm-specific characteristic-internationalization, which might play a greater role in appropriating the fruits of innovation in lined with the argument of Kafouros et al. (2008). Nevertheless, the interaction between the level of vertical integration and the modes of external knowledge sourcing are found to have a negative relationship with the innovative performance of a firm.

In specific terms, vertical integration efficiently facilitate a firm to engage in related R&D activities, which deepens knowledge related to particular technological areas and in turn improves the absorptive capacity of a firm. When combined with the firm's external knowledge sourcing mode, vertical integration may provide opportunities for such firms to absorb additional external knowledge, which then contributes to the deepening and broadening of the firm's overall technological capabilities. However, it should be noted that firms with higher levels of vertical integration are more likely to search for the opportunities that will enable them to profit from their existing technologies, thereby creating resistance to the integration of other external technological advances. In other words, the effectiveness of the external knowledge sourcing is moderated by the level of vertical integration.

We further investigate the relationship between vertical integration and the innovative performance of a firm from two different aspects, the quality of a firm's innovation output and its technological scope. This relationship has invariably been examined in the prior literature by means of analyzing the relationship between vertical integration and R&D expenditure, or between vertical integration and patents. Using these two different aspects as proxies for the innovative performance of a firm, we can further untangle the relationship between vertical integration and the firm's innovative performance. Finally, as regards the argument of Garcia-Vega (2006), which points to the importance of technological diversification in promoting innovation, in the present study, we explore the determinants of technological diversification in an attempt to clarify the relationship between vertical integration, external knowledge sourcing modes and technological scope.

There are certain limitation and future research of the present study which must be taken into consideration. The focus of our investigation in this study of the effects of vertical integration on the innovative performance of a firm is on one industry in isolation. To achieve some level of generalization of the results, analysis of multiple industries will be necessary, particularly as the unanswered questions and confusing findings on vertical integration may be related to industry-specific differences. Another interesting avenue for future work relates to multidimensional concept of vertical integration, as noted by Harrigan (1985b). Here we use the value added to sales ratio, adjusted for taxation and profitability, to identify the level of a firm's vertical integration. Future research into this issue could attempt to use different measures, each of which assesses a specific dimension, and yield more complementary insights into the phenomenon.
6. Conclusions

The primary aim of this study is to provide a more refined understanding of vertical integration strategies and their impact on the innovative performance of a firm. Our main finding is that vertically-integrated firms are more likely to enhance their innovative performance; however, this finding becomes negative for those cases where firms have higher levels of vertical integration. In other words, the influence of a strategy of vertical integration on the innovative performance of a firm will tend to vary based upon the level of vertical integration; that is, the relationship is non-monotonic. The results of this study further highlight the importance of the modes of external knowledge sourcing with regard to the building and expansion of a firm's innovative capability; however, we also find that this negatively moderates the relationship between the level of vertical integration and a firm's innovative performance.

The results point to the importance of external knowledge sources, and suggest that firms need to have a sound mechanism in place for the coordination of their external resources, upon which they can build new capabilities, thereby strengthening their existing capabilities; however, the effects of the mode of external knowledge sourcing will diminish with increasing levels of vertical integration. Our findings indicate that by engaging in a strategy of vertical integration at a moderate level, firms may be able to strike an appropriate balance between internal and external learning.

References
