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The innovation activities of small and medium-sized enterprises and their growth: quantile regression analysis and structural equation modeling

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Abstract Using an augmented version of Gibrat's law, we theorized the relationship between the innovation activities of small and medium-sized enterprises (SMEs) and their growth in sales, firm value, and research and development (R&D) investment in the following years. Based on 17 years of data from 598 SMEs in South Korea, this study examined the mediating role of sales growth and firm value growth in the relationship between innovation activities and R&D investment growth in a longitudinal setting. The study findings suggested that the innovation activities of SMEs at Time 1 influenced the sales growth of high-growth firms and high-tech sectors at Time 2 more positively than that of low-growth firms and low-tech sectors, and that SMEs consequently invested more in R&D at Time 3. However, the innovation activities of SMEs at Time 1 did not significantly affect their firm value growth at Time 2. Theoretical and managerial implications are discussed for scholars, managers, and policy makers.

Keywords Innovation activities · Firm growth · R&D · Quantile regression · Small and medium-sized enterprises

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1 Introduction

As knowledge-based economies highlight the importance of innovation and advanced knowledge and skills, many firms have been engaging in innovation activities to achieve high performance (Audretsch et al. 2014; Coad and Rao 2008; Coad et al. 2016; Colombelli et al. 2013; Del Monte and Papagni 2003; García-Manjón and Romero-Merino 2012). Innovation activities are the primary driving forces for sustainable growth because innovation helps firms achieve superior performance by developing new products or processes (Roper et al. 2008; Teece 1986; Wang and Thornhill 2010), and absorptive capacity, a byproduct of innovation activity, helps firms commercialize new information and knowledge (Bellucci and Pennacchio 2015; Cohen and Levinthal 1990; Wang and Thornhill 2010). One important effect of innovation is to deter the entry of new firms by creating entry barriers (Lukach et al. 2007; Phillips 1971), and this clearly reduces market competition (Del Monte and Papagni 2003; Phillips 1971). Therefore, firms aim to achieve a competitive advantage through innovation activities.

However, converting innovative activities into firm performance takes considerable time and resources, and many difficulties arise in overcoming uncertainty at every stage of the innovation process (Coad and Rao 2008). The effect of innovation activities on firm growth often depends on specific unobservable factors (Audretsch et al. 2014; García-Manjón and Romero-Merino 2012), and there is a lack of understanding of the relationship between innovation activities and the expected future performance of a firm. Specifically, scholars have yet to examine the underlying mechanism linking firms' innovation activities, firm growth, and research and development (R&D) investment growth based on a comprehensive perspective. Although previous literature has revealed the importance of innovation for firm growth (Coad and Rao 2008; Colombelli et al. 2013), it has not explored the mechanism connecting innovation activities with R&D investment through firm growth. It is unclear where firms should invest for their growth, although one potentially important channel for investment is R&D, a critical input to innovation and growth in knowledge-based economies (Brown et al. 2009). Moreover, although R&D investment is important for sustainable growth, it appears to be a double-edged sword (Coad et al. 2016): the uncertainty and long payback period of innovation activities might reduce firm growth, and this concern can eventually lead firms to discourage investment in R&D. While numerous government-level studies have been conducted on topics such as R&D subsidies and fiscal treatments, firm-level studies on investment in R&D are still lacking (Coad and Rao 2010). In addition, given that small and medium-sized enterprises (SMEs) have been gradually expanding their role in the national economy, the differences between SMEs and large companies in terms of innovation activities and growth outcomes have not received enough academic attention. Examining the complicated relationship between innovation activities and firm growth is important not only to scholars but also to managers and investors who have to allocate their limited resources to firms' R&D (Oriani and Sobrero 2008).

The purpose of this paper is, thus, to examine the relationship between the innovation activities of SMEs and their growth over time and to discuss the implications in terms of how SMEs can promote the effectiveness of R&D for sustainable growth. In so doing, this study seeks to contribute to the literature on innovation and firm growth in several ways. First, we analyze the dynamic association between innovation activities, firm growth, and R&D investment growth in the longitudinal setting of a dynamic co-evolving system (Coad 2010). We analyze the mediating role of firm growth in the relationship between innovation activities and R&D investment growth to examine the R&D financing channel for SMEs. Second, in addition to using sales growth, we use firm market value as another proxy for firm growth because previous studies have suggested that stock markets provide a useful channel to procure financial resources. For example, Brown et al. (2009) highlighted that stock markets can benefit the growth model of a firm that focuses on innovation by providing direct funding for innovation. Blass and Yosha (2003) also suggested that firms can finance R&D through inexpensive external equity markets. Thus, our empirical study considers two variables: sales growth and firm value growth to provide a more comprehensive view of our theorized model. Third, in addition to ordinary least squares (OLS) analysis, we apply quantile regression, structural equation modeling (SEM), and the Sobel test to further strengthen the robustness of the study results. Relying on these dynamic and evolutionary approaches that use multiple measures and methods, this study offers a comprehensive understanding of the firm growth process and thus addresses comments from Delmar et al. (2003).

In summary, this study addresses two main research questions: (1) Do SME innovation activities significantly contribute to SMEs' growth in sales and firm value in the following year? (2) Do SMEs that have grown significantly in terms of sales and firm value in the previous year increase their R&D investment in the following year? In exploring these research questions, this study follows two routes: (1) innovation activities at Time (T) 1, sales growth at T2, and R&D investment growth at T3; and (2) innovation activities at T1, firm value growth at T2, and R&D investment growth at T3. It then analyzes the mediating role of firm growth, sales growth, and firm value growth in the relationship between innovation activities and R&D investment growth of SMEs.

2 Theoretical framework and hypothesis development

2.1 Theoretical framework

The theory known as Gibrat's law or the law of proportionate effect has been tested in a number of empirical studies of the determinants of firm growth in many countries (Audretsch et al. 2014; García-Manjón and Romero-Merino 2012) and has provided a theoretical framework for a broad range of studies on industrial dynamics since Gibrat (1931) introduced the theory that firm growth is independent of firm size (Coad 2009).

The studies testing Gibrat's law can be divided into two main groups: (1) static studies focusing on 'optimal size' and (2) studies analyzing the persistence of growth. The study by Mansfield (1962) is a representative example of the static approach, while Chesher's study (1979) is a representative example of a temporal analysis—that is, a study analyzing the persistence of growth (Audretsch et al. 2004).

Early theoretical research on firm growth and size focused on a comparative statics framework dealing with optimal size and did not address the dynamic aspect of firm growth. According to the statics framework, firms are supposed to be at their 'optimal size,' and if they are not, they are supposed to grow instantaneously to reach it. Thus, firm growth was regarded as an appendage to the optimal size theory (Coad 2009). Given the growing dissatisfaction with the conventional static approach and emphasis on the uncertainty, change, and dynamics of the economy, studies on firm growth have since replaced studies on firm size and have become the main type of studies on 'firm growth and size' (Coad 2009; Marris 1999).

The main methodology for estimating Gibrat's law to analyze the persistence of firm growth developed by Chesher (1979) is as follows (Audretsch et al. 2004; Chesher 1979; Coad 2009):

$$\log(X_t) = \alpha + \beta_1 \log(X_{t-1}) + \varepsilon \quad (1)$$

where a firm's 'size' is represented by X_t, α is a constant term, and ε is the residual error. Research on Gibrat's law focuses on the coefficient β. If firm growth is independent of firm size, then β should be equal to unity. If β is smaller than 1, then smaller firms are expected to grow faster than their larger counterparts. In contrast, if β is larger than 1, then larger firms are expected to grow faster than their smaller counterparts (Audretsch et al. 2004; Coad 2009; Geroski 2005).

Path dependency is a very important theme in research on firm growth for several reasons (Coad 2009): a firm's history defines its future, the growth opportunities of a firm are constrained by its present production activities, and the competitiveness of a firm depends on accumulated firm-specific resources and production capabilities that have been developed over time. Gibrat's law (Eq. 1) adopts an evolutionary perspective reflecting path dependency: a firm's present size is regarded as the mere accumulation of all previous growth (Coad 2009). In line with this, Gibrat's law is useful for modeling firm growth (Coad 2009) and has been used to explain firm growth (Del Monte and Papagni 2003). A number of recent studies have examined the theoretical coherence and empirical relevance of Gibrat's law (Colombelli et al. 2013). Moreover, due to its usefulness, the equation for Gibrat's law has been developed to generate augmented versions of the equation (Coad 2010; García-Manjón and Romero-Merino 2012; Hölzl 2009). The law has been developed into two models: (1) a vector autoregression model for analyzing a serial growth rate correlation (e.g., Coad 2010; Coad and Rao 2010; Deschryvere 2014) and (2) a model for describing the effect of innovation activities or R&D on firm growth using control variables to control for any growth rate autocorrelation and possible dependence of growth on size (e.g., Coad and Rao 2008; Coad et al. 2016; Colombelli et al. 2013; García-Manjón and Romero-Merino 2012; Hölzl 2009). Therefore, the theoretical framework of this paper is an augmented version of the equation that was developed by Gibrat (1931), augmented by Chesher (1979), and has been used frequently in recent decades.

2.2 Hypothesis development

Researchers have discussed various indicators for measuring firm growth, including market capitalization, employment, sales and revenues, value of production, and added value (García-Manjón and Romero-Merino 2012). Ardishvili et al. (1998) pointed out that the most common indicators are market value, number of employees, sales, revenue, value of production, and added value. As firm growth is multidimensional, multiple measures and methods are important for understanding firm growth processes (Delmar et al. 2003). In this study, firm growth comprised both the output in terms of the result of innovation activities and the input in terms of the resources invested in R&D.

In line with this, we used two variables—sales growth and firm value growth—to measure firm growth. Sales growth is a financial indicator of the improvement in productivity through innovation activities in an individual firm, whereas firm value growth is a market evaluation indicator of the future value of a firm, taking into account innovation activities. Thus, we considered performance at both the individual firm level and the market level.

In exploring the literature on the relationship between innovation activities and sales, we observed divergent results and opinions on the relationship between the two variables (García-Manjón and Romero-Merino 2012): while some authors reported that innovation activities affected firms' sales growth positively (Demirel and Mazzucato 2012; Freel 2000; Geroski and Toker 1996; Roper 1997), others reported no significant relationship between the two variables (Bottazzi et al. 2001). Moreover, the results of innovation activities tend to vary owing to the complicated innovation value chain, which comprises firms' characteristics, internal resources, and the market environment (Roper et al. 2008). In line with these arguments, in recent decades, many authors have examined the relationship between the two variables based on firms' growth level or technology level, and they have reported that while the innovation activities of high-growth or high-tech firms make an important contribution to their sales growth performance, this relationship turns out to be negative or nonsignificant for low-growth or low-tech firms (Coad and Rao 2008; Coad et al. 2016; Colombelli et al. 2013; García-Manjón and Romero-Merino 2012; Hölzl 2009; Segarra and Teruel 2014).

García-Manjón and Romero-Merino (2012) reported that the effect of innovation activities on sales growth is positive and that this relationship is more intense for high-growth firms. In addition, this effect is particularly significant for high-tech sectors, but negative or nonsignificant for low-tech sectors. Based on this result, García-Manjón and Romero-Merino highlighted that there is no one answer that is correct for every firm's growth, and that R&D is particularly necessary for the growth and survival of some kinds of business and some sectors. Coad and Rao (2008) noted that while the innovation of average-growth firms may not be so crucial for their sales growth, innovation is very important for high-growth firms, and this result implies that a successful innovative firm may rapidly gain market share, whereas a firm that invests in R&D but does not succeed may rapidly lose market share to its competitors.

Second, by examining the literature on the relationship between innovation activities and firm value, we found a positive effect of innovation activities on firm value (Blass and Yosha 2003; Bosworth and Rogers 2001; Chan et al. 1990; Chauvin and Hirschey 1993; Cho and Pucik 2005; Coad and Rao 2006; Doukas and Switzer 1992; Hall and Oriani 2006; Oriani and Sobrero 2008; Toivanen et al. 2002; Woolridge 1988; Zantout and Tsetsekos 1994). According to traditional valuation theory, the market value of a firm is equal to the sum of the net present value of the following two cash flows: (1) cash flows generated from assets in place and (2) expected cash flows from investment opportunities that are expected to be available to and undertaken by the firm in the future. In general, a firm's market value changes as the market acquires specific information about the firm, which can change the market's expectations. Therefore, common stock prices respond positively to news of a firm's strategic investment decisions, and the market seems to place much emphasis on potential long-term developments in valuing stocks (Woolridge 1988). Consequently, R&D-intensive firms have high market value (Blass and Yosha 2003), and the R&D capital of these firms receives a significant and positive evaluation from stock markets (Hall and Oriani 2006).

Toivanen et al. (2002) suggested that the market evaluates 'new news' about R&D activities of firms more highly, and this has a positive effect on firms' market value, which in this study refers to equity at the end of the year plus debt; however, patents have a negative effect on the market value of firms. Based on this result, Toivanen et al. (2002) suggested that patents are inappropriate as an indicator of the returns from innovation. Oriani and Sobrero (2008) suggested that R&D capital has a significantly positive impact on a firm's market value, which in this study refers to market capitalization plus loan capital and short-term borrowing. Based on this result, Oriani and Sobrero (2008) highlighted that investors recognize the value of the potential growth and opportunities created by R&D investments. Coad and Rao (2006) argued that the influence of innovation on market value varies dramatically across the distribution of a firm's market value: although the coefficients on innovativeness are very low for the lowest quantiles of the conditional Tobin's q distribution, the coefficient on innovativeness rises sharply as we move up the conditional distribution. Coad and Rao (2006) suggested that these results imply that stock markets are particularly sensitive to the innovative activity of firms with the highest market value, while they barely recognize the innovation attempts of firms with low market value.

Based on the literature on innovation activities and firm growth, we expect that the effect of innovation activities on firm growth varies across the distribution of firm growth rates. Therefore, the following can be hypothesized:

Hypothesis H1a The effect of innovation activities on firm growth varies across the sales growth rate distribution, and the effect is stronger when SMEs have achieved high growth in sales than when they have achieved low growth in sales.

Hypothesis H1b The effect of innovation activities on firm growth varies across the firm value growth rate distribution, and the effect is stronger when SMEs have achieved high growth in firm value than when they have achieved low growth in firm value.

R&D is characterized by some important features and difficulties in financing. First, R&D cannot be collateralized because of the intangible nature of R&D investment. Second, investors can face significant adverse selection due to asymmetric information, which creates difficulty in distinguishing good projects from bad ones. Third, moral hazard problems arising from imitation by rivals may be amplified by the inherent uncertainty of R&D, particularly in small and young firms. These features of R&D investment make it more susceptible to financing constraints than any other type of investment, and investment in R&D may be below the socially optimal rate (Brown et al. 2012; Coad and Rao 2010). Therefore, financing for R&D investment has become an important issue because if individual firms are reluctant to invest in R&D, it is impossible for them to reach optimal growth and development at the national or societal level.

Investment funds for firms' innovation activities are very diverse. Firms can finance internally by increasing sales and profit and can finance externally through stock markets and debt. However, calculating profitability for each year is not appropriate as an R&D investment indicator because R&D tends to entail further short-term costs before returning long-term benefits (Coad and Rao 2010). Furthermore, debt finance is not appropriate as an R&D investment indicator because financial institutions prefer to use tangible assets to secure loans and are reluctant to invest in R&D, and because firms are reluctant to finance debt for R&D investment, which may raise the cost of capital (Hall and Lerner 2010). For these reasons, profitability and debt are not appropriate as indicators of long-term and stable R&D investment. Therefore, we used sales and firm value as firm growth indicators to examine the virtuous circle between innovation activities and firm growth.

First, exploring the literature, we found that sales growth had a positive effect on R&D investment (Coad and Rao 2010; Deschryvere 2014). Coad and Rao (2010) suggested that past sales growth is strongly associated with subsequent growth in R&D expenditure. In particular, sales growth has a continuous effect on R&D growth that was present even at the third lag in the study by Coad and Rao (2010), but contrary to expectations, there was not a strong relationship between growth of profits and subsequent R&D investment. Furthermore, Coad and Rao (2010) highlighted the asymmetric effects of R&D growth by showing that firms are reluctant to reduce their R&D investment even after they experience negative sales growth. Deschryvere (2014) found a positive relationship between R&D growth and subsequent sales growth. In particular, the relationship between the two variables was stronger for continuous innovators than for occasional innovators.

Second, in the literature on the relationship between firm value and R&D investment, we found a positive relationship between the two variables (Blass and Yosha 2003; Brown et al. 2009, 2012; Hsu et al. 2014; Wang and Thornhill 2010). Financing R&D investment through stock markets is ideal, as it has a positive effect for both R&D-intensive firms and their investors (Wang and Thornhill 2010), as stockholders can expect to receive benefits from the residual value of firm value growth through innovation activities (Wang and Thornhill 2010; Williamson 1988). R&D investment also helps firms acquire specific resources and capabilities (Helfat 1994, 1997; Wang and Thornhill 2010). In addition, there are no collateral requirements for financing through equity (Brown et al. 2009), and the stock market's function of generating information can be particularly useful when it comes to financing innovation. Consequently, equity financing has a positive effect on innovation for industries dependent on external finance, as stock markets continuously facilitate the feedback of prospective information that can affect market stock prices (Hsu et al. 2014).

By studying the financing of R&D in Israel, Blass and Yosha (2003) demonstrated that R&D-intensive firms do not rely more on internal cash, and this may be because they are able to finance R&D through inexpensive external equity markets. Brown et al. (2009) reported that new stock issue has a significantly positive effect on R&D spending. Based on this result, they highlighted that stock markets can be a potentially important channel to connect financing, innovation, and economic growth. Thus, stock markets can be useful for the growth model of a firm that focuses on innovation and constrains financing by directly funding innovation. Brown et al. (2012) found that a firm's value has a significantly positive effect on R&D spending. Based on this result, they highlighted the importance of stock markets for innovation, as stock market development can promote economic growth by increasing firm-level innovative activity and by substantially increasing R&D investment.

These studies suggest that sales growth and firm value growth have a positive effect on R&D investment, and this discussion leads to our second set of hypotheses:

Hypothesis H2a The sales growth of SMEs has a positive effect on R&D investment growth in the following year.

Hypothesis H2b The firm value growth of SMEs has a positive effect on R&D investment growth in the following year.

Based on the above studies and our related discussion on the relationship between innovation activities and firm growth and between firm growth and R&D investment growth, we expect that firm growth plays a mediating role in the relationship between innovation activities and R&D investment growth. Overall, we expect that innovation activities affect firm growth and that firms that have achieved growth in sales and firm value will increase their R&D investment in the following year. In line with this, we postulate the following hypotheses:

Hypothesis H3a The innovation activities of SMEs have a positive and indirect effect on R&D investment growth via growth in sales.

Hypothesis H3b The innovation activities of SMEs have a positive and indirect effect on R&D investment growth via growth in firm value.

3 Data and econometric model

3.1 Data set

We analyzed the relationship between the innovation activities of 598 SMEs in South Korea and their growth over 17 years (1998–2014) by examining the 3-year relationship between innovation activities at T1, firm growth at T2, and R&D investment growth at T3. Therefore, we used 3-year (T1–T3) unit data[1] for one period, for a total of 15 data sets (see Table 1).

In South Korea, the definition of SMEs is stipulated by *The Framework Act on Small and Medium Enterprises* and *Enforcement Decree of The Framework Act on Small and Medium Enterprises* as follows: A business entity that meets all the standards set forth in the following items—(1) The main type of business in which the business entity is engaged and its average sales shall meet the standards set forth; (2) A corporation whose total assets are less than 500 billion won. We classified SMEs according to the Korean Standard Industrial Classification (KSIC; available at https://kssc.kostat.go.kr) to take into account industrial sector, and we then reclassified SMEs using the Eurostat indicator (available at http://ec.europa.eu/eurostat/statistics-explained) to analyze their technological level and knowledge-intensity dimensions (e.g., Bellucci and Pennacchio 2015; García-Manjón and Romero-Merino 2012). Finally, we grouped SMEs into six groups: high technology, medium–high technology, medium–low technology, and low technology for manufacturing (3-digit level) and knowledge-intensive services and less knowledge-intensive services for knowledge-based services (2-digit level). We obtained data for this study—firm size classification (e.g., SMEs and large firms), firms' sales, firm value, and R&D expenditure—from KISVALUE (https://www.kisvalue.com/web/index.jsp) and TS2000 (http://www.kocoinfo.com), which provide financial data for Korean companies.

South Korea has continuously invested in R&D and is now ranked first in the world in terms of the ratio of R&D investment to gross domestic product (2013–2014), and the percentage of gross domestic expenditure on R&D by the business enterprise sector is relatively high (see main science and technology indicators[2] 2015). This implies that firms should finance R&D as a way to reduce their financial obligations because if the R&D investment does not lead to commercial success, increasing the investment is dangerous to firm survival. Moreover, according to SME status indicators in 2016,[3] South Korea's SMEs have been gradually expanding their role in the national economy, given that they accounted for 99.9% of the total number of businesses and 87.9% of total employment at the end of 2014. However, the share of SME R&D expenditure relative to the national total R&D expenditure has decreased continuously since 2009. These asymmetries between large firms and SMEs in R&D investment growth can negatively affect the growth of SMEs by reducing their market concentration and competitiveness.

[1] We excluded data when they were not continuously available for 3 years, as we analyzed data for 3-year periods.

[2] Main Science and Technology Indicators by OECD (http://stats.oecd.org).

[3] SME Status Indicators 2016 by Korean Federation of SMEs (http://www.kbiz.or.kr).

Table 1 The 15 three-year data sets

Three-year unit	T1 (Year)	T2 (Year)	T3 (Year)
1	1998	1999	2000
2	1999	2000	2001
3	2000	2001	2002
4	2001	2002	2003
5	2002	2003	2004
6	2003	2004	2005
7	2004	2005	2006
8	2005	2006	2007
9	2006	2007	2008
10	2007	2008	2009
11	2008	2009	2010
12	2009	2010	2011
13	2010	2011	2012
14	2011	2012	2013
15	2012	2013	2014

3.2 Model

As shown in Fig. 1, our study consists of three parts: examining the effect of innovation activities on firm growth (Step 1); examining the effect of firm growth on R&D investment growth (Step 2); and examining the mediation effect of firm growth (i.e., SMEs' sales growth and firm value growth) in the relationship between innovation activities and R&D investment growth in SMEs (Step 3).

We used the variables R&D intensity, sales growth, firm value growth, and R&D investment growth to analyze the relationship between innovation activities, firm growth, and R&D investment growth. Definitions and calculations of all the variables used in this study are summarized in Table 2.

Our dependent variables (growth rates) were calculated by taking the differences of the logs of their size (Coad and Rao 2008; Coad et al. 2016; Colombelli et al. 2013; García-Manjón and Romero-Merino 2012). This is defined as follows:

$$GROWTH_{i,t} = \ln\left(X_{i,t}\right) - \ln\left(X_{i,t-1}\right) \tag{2}$$

where $X_{i,t}$ is measured in terms of sales, EV, or R&D expenditure for firm i at time t. We then used an augmented Gibrat's law equation to examine innovation activities, firm growth, and R&D investment growth. Equations 3 and 4 were used for Step 1, and Eq. 5 was used for Step 2:

$$SALESG_{i,T2} = \alpha + \beta_1 INN_{i,T1} + \beta_2 SALESG_{i,T1} + \beta_3 SIZE_{i,T1} + \beta_4 IND_{i,T2} + \delta_{T2} + \varepsilon_{i,T2} \tag{3}$$

$$EVG_{i,T2} = \alpha + \beta_1 INN_{i,T1} + \beta_2 EVG_{i,T1} + \beta_3 SIZE_{i,T1} + \beta_4 IND_{i,T2} + \delta_{T2} + \varepsilon_{i,T2} \tag{4}$$

$$RDG_{i,T3} = \alpha + \beta_1 SALESG_{i,T2} + \beta_2 EVG_{i,T2} + \beta_3 RDG_{i,T2} + \beta_4 SIZE_{i,T2} + \beta_5 IND_{i,T3} + \delta_{T3} + \varepsilon_{i,T3} \tag{5}$$

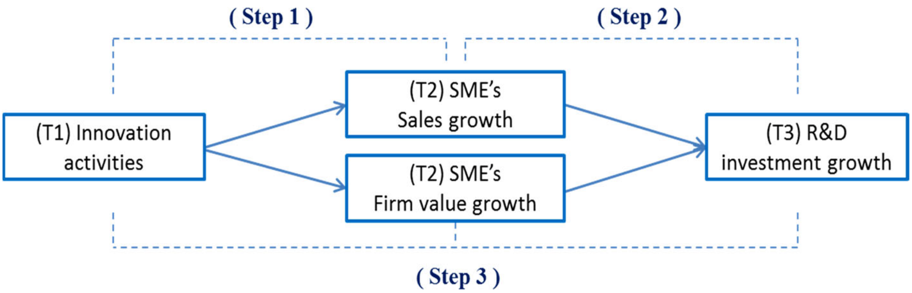

Fig. 1 Model

Table 2 Definitions and calculations of the variables

Variable	Definition and calculation
INN at T1 (innovation activities)	R&D intensity of the firm (R&D expenditure divided by total sales)
Growth rate	
SALES at T2	Log value of total amount of sales by the firm in 1 year
EV at T2 (enterprise value)	Log value of firm value, stock market value, and the amount that must be paid when buying companies (market capitalization at the end of year + the value of its debt)
RD at T3 (R&D expenditures)	Log value of growth of R&D expenditure (sum of assets and costs)
SIZE	Nominal value of total amount of sales by the firm

In Eqs. 3 and 4, $INN_{i,T1}$, calculated as R&D expenditure divided by the total amount of sales, was used to measure the innovation activities of the SMEs (Demirel and Mazzucato 2012; Falk 2012; García-Manjón and Romero-Merino 2012). We included lagged growth to control for any growth rate autocorrelation, given that previous studies have shown that a firm's growth is typically related to its growth in the previous year (Coad 2007; Lockett et al. 2011; Schimke and Brenner 2011). Moreover, we included lagged size (SIZE) and industry dummies (IND) to control for any possible dependence of growth on size or industry. We also used year dummies (δ) to control for any macroeconomic shocks. These regression equations were from previous studies that have analyzed the effect of innovation activities on firm growth (e.g., Coad and Rao 2008; Coad et al. 2016; Colombelli et al. 2013; García-Manjón and Romero-Merino 2012).

In addition to OLS[4] analysis, we applied quantile regression[5] to further strengthen the robustness of the study results. Although OLS analysis provides the average effect by calculating the effect of the independent variables for the 'average firm' by focusing on the mean and assuming a normal distribution (Gaussian residuals), the quantile regression method can analyze the effect of the independent variables across the various distributions of the dependent variables. Therefore, quantile regression is not influenced by outliers (Yu

[4] We applied an OLS analysis with a robust option to take into account heteroscedasticity.

[5] The quantile regression model was first introduced by Koenker and Bassett (1978).

et al. 2010), and it provides a more complete story and more robust results by calculating coefficient estimates across the various quantiles of the conditional distribution (Coad and Rao 2008; García-Manjón and Romero-Merino 2012). As the firm growth rates—the dependent variables of this study—generally displayed a characteristic heavy-tailed distribution (Coad and Rao 2008; Bottazzi and Secchi 2003), quantile regression has been considered a better approach than OLS analysis for examining firm growth. As a result, researchers have applied quantile regression to analyze the relationship between innovation activities and firm growth (e.g., Bianchini et al. 2014; Capasso et al. 2015; Coad et al. 2016; Falk 2012; García-Manjón and Romero-Merino 2012; Goedhuys and Sleuwaegen 2010; Hölzl 2009; Mata and Woerter 2013; Mazzucato and Parris 2015; Segarra and Teruel 2014). We applied the 'bootstrap' method to estimate the standard errors and levels of significance obtained by computationally resampling from the observed data that represented specific individual characteristics. This method has also been used in a number of previous studies (e.g., Coad and Rao 2006; Coad et al. 2016; Bartelsman et al. 2014; Capasso et al. 2015; Falk 2012; Segarra and Teruel 2014).

Figure 2 shows the probability density plot of growth rates—sales growth, firm value growth, and R&D investment growth—indicating the characteristics of a heavy-tailed distribution compared to a normal distribution.

Finally, we used SEM (path analysis) to examine the mediating role of firm growth, sales growth, and firm value growth, linking innovation activities and R&D investment growth, and also applied the Sobel test[6] to ensure the robustness of the study results.

4 Findings

4.1 Descriptive statistics

Table 3 shows the descriptive statistics, correlations, and multicollinearity diagnostics of the independent and control variables used in this study. We examined the variance inflation factor (VIF) values of the independent and control variables to check for possible multicollinearity. A VIF value that exceeds 10 is often considered to indicate multicollinearity. The VIF values in this study were 1.01–1.03, significantly lower than the threshold points, which suggests the absence of multicollinearity.

4.2 Empirical results

As shown in Table 4, the innovation activities (measured by R&D intensity) of SMEs had a significantly positive effect on their sales growth according to the OLS analysis focusing on the average condition. Based on these results, we found that innovation activities positively influence sales growth. When we focused on the quantile regression estimations, we found that the coefficient on innovation activities was only significantly positive for the higher quantiles (50–90%), and it was also much larger for the higher quantiles, whereas it was nonsignificant for the lower quantiles (10–25%).

We examined the relationship between the two variables according to technological level to determine the differences among the industrial sectors defined by the Eurostat indicator, i.e., the six groups classified by technological level and knowledge intensity.

[6] Based on Sobel's study (1982), we used this test to determine the mediating effect of the independent variable.

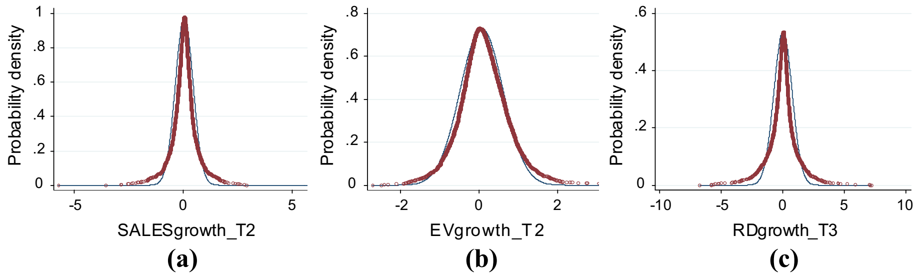

Fig. 2 The probability density plot of each growth rate—**(a)** sales, **(b)** firm value, and **(c)** R&D investment—compared to a normal distribution

Based on this analysis, we found that the innovation activities of the high-tech (high technology and medium–high technology) and knowledge-intensive service sectors positively influenced sales growth for the higher quantiles, whereas there was no positive relationship between the two variables for the low-tech (medium–low technology and low technology) and less knowledge-intensive service sectors.

These findings support *Hypothesis H1a* and are in line with data reported by Coad and Rao (2008) from a U.S. sample of firms for the 1963–1997 period and by García-Manjón and Romero-Merino (2012) for 18 European countries for the 2003–2007 period.

All these results imply that innovation or R&D activities make a greater contribution to the sales growth of SMEs for high-growth firms and high-tech sectors than for low-growth and low-tech sectors. Therefore, as García-Manjón and Romero-Merino (2012) noted, we can assume that innovation or R&D is particularly necessary for the growth and survival of some kinds of business and some sectors, and there is no answer that is correct for the growth of every firm. Table 4 displays the results from the OLS analysis and quantile regression estimations for Eq. 3.

Table 5 shows the results of our investigation of the relationship between the innovation activities of SMEs and their firm value growth. Using Eq. 4, we found no significantly positive association between the two variables, with only a significantly negative association for the lower quantiles (10%). Similar results were obtained for the different industrial sectors classified by technological level and knowledge intensity, and there were no significant relationships between the innovation activities and firm value growth of SMEs. These findings did not support *Hypothesis H1b*. Furthermore, they were not in line with the study by Coad and Rao (2006), which reported that stock markets were particularly sensitive to the innovative activity of firms with the highest market value, while they barely recognized the innovation attempts of firms with low market value. Thus, we can assume that we obtained these results because the market did not recognize the value of the potential growth and opportunities created by innovation activities of SMEs. Table 5 displays the results for the OLS analysis and quantile regression estimations for Eq. 4.

Quantile regression estimates for the whole sample are presented in Fig. 3. The OLS estimates are presented as horizontal lines, together with their 95% confidence intervals. As shown in Fig. 3a, the quantile regression curves show that the estimated coefficient on innovation activities varies across the conditional distribution for the sales growth rate. Thus, quantile regression estimates tell the whole story by showing the small influence on firm growth for the median quantile and the larger influence on firm growth for the upper quantile; thus, the coefficient on innovation activities rises sharply as the quantile increases.

Table 3 Descriptive statistics, correlations, and multicollinearity diagnostics

	Mean	St. dev.	Min	Max	1	2	3	4	5	6	7
Sales G_T2	0.043	0.409	−5.744	5.813	1.000						
EV G_T2	0.065	0.547	−2.710	4.270	0.166***	1.000					
RD G_T3	0.014	0.746	−6.752	7.172	0.031	0.045***	1.000				
INN_T1	0.072	0.269	0.000	10.684	0.130***	0.007	−0.036**	1.000			
Sales G_T1	0.053	0.410	−5.744	5.813	−0.150***	0.027	0.053***	−0.114***	1.000		
EV G_T1	0.058	0.582	−2.853	4.270	0.105***	−0.25***	0.003	−0.004	0.164***	1.000	
RD G_T2	0.042	0.728	−6.752	7.071	0.118***	0.084***	−0.207***	−0.119***	0.059***	0.046***	1.000
VIF (E. 3)	1.03	–	–	–	–	–	–	1.03	1.02	–	–
VIF (E. 4)	1.01	–	–	–	–	–	–	1.02	–	1.00	–
VIF (E. 5)	1.03	–	–	–	1.06	1.03	–	–	–	–	1.02

G indicates growth; EV, enterprise value; RD, research & development, INN, innovation activities; T1, Time 1; T2, Time 2; T3, Time 3; VIF, variance inflation factor, E.3 Eq. 3, E.4 Eq. 4, E.5 Eq. 5

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

Table 4 OLS analysis and quantile regression estimations for Eq. 3: Step 1

Industries (observations)	Variable	OLS (robust)	Quantile regression				
			10	25	50	75	90
Whole sample (4454)	INN_T1	0.144***	−0.184	−0.009	0.118**	0.327***	1.137***
	(S. E)	(0.046)	(0.123)	(0.037)	(0.058)	(0.120)	(0.299)
	(Pseudo)R^2	0.058	0.009	0.012	0.016	0.036	0.090
High technology (1432)	INN_T1	0.419	−0.348	0.031	0.073	0.842*	2.002***
	(S. E)	(0.314)	(0.354)	(0.083)	(0.172)	(0.455)	(0.402)
	(Pseudo)R^2	0.088	0.021	0.031	0.024	0.051	0.122
Medium–high technology (1214)	INN_T1	0.074	−0.656	−0.008	−0.029	1.308**	2.539***
	(S. E)	(0.099)	(0.509)	(0.184)	(0.415)	(0.516)	(0.590)
	(Pseudo)R^2	0.090	0.027	0.022	0.024	0.073	0.172
Medium–low technology (396)	INN_T1	0.818	−4.734***	−1.369	−0.468	0.695	4.912
	(S. E)	(1.433)	(1.519)	(1.141)	(0.676)	(1.493)	(3.106)
	(Pseudo)R^2	0.061	0.063	0.026	0.029	0.015	0.061
Low technology (342)	INN_T1	1.454	0.878	0.538	0.577	0.640	4.029
	(S. E)	(1.015)	(0.773)	(0.764)	(0.453)	(1.860)	(3.333)
	(Pseudo)R^2	0.108	0.050	0.033	0.026	0.026	0.067
Knowledge-intensive services (629)	INN_T1	0.124***	0.033	0.052	0.145**	0.132***	0.183
	(S. E)	(0.021)	(0.098)	(0.060)	(0.061)	(0.050)	(0.113)
	(Pseudo)R^2	0.049	0.004	0.004	0.015	0.041	0.086
Less knowledge-intensive services (309)	INN_T1	0.320	−0.921	0.205	0.425	0.549	0.563
	(S. E)	(0.311)	(1.080)	(0.503)	(0.311)	(0.416)	(0.822)
	(Pseudo)R^2	0.060	0.032	0.007	0.015	0.030	0.076

Standard errors (S.E.) for the quantile regression coefficients were obtained by using 1000 bootstrap replications

INN indicates innovation activities; T1, Time 1; OLS, ordinary least squares

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

However, as shown in Fig. 3b, we did not find a change in the estimated coefficient on innovation activities across the conditional distribution for the firm value growth rate; furthermore, as shown in Table 5, we did not find a significantly positive relationship between the two variables. The coefficients on innovation activities were within the OLS confidence intervals in almost all quantiles (except in the below-20% quantile; see Fig. 3b).

We used Eq. 5 to examine the relationship between firm growth and R&D investment growth. As shown in Table 6, the growth of SMEs in both sales and firm value had a significantly positive effect on R&D investment growth according to both the OLS analysis and the quantile regression estimations. These findings support *Hypotheses H2a* and *H2b*. Furthermore, they are in line with the studies by Coad and Rao (2010) and Deschryvere (2014), which found that past growth in sales is strongly associated with subsequent growth in R&D expenditure, and with the study by Brown et al. (2012), which showed that firm value has a significantly positive effect on R&D spending. In particular, the result that the

Table 5 OLS analysis and quantile regression estimations for Eq. 4: Step 1

Industries (observations)	Variable	OLS (robust)	Quantile regression				
			10	25	50	75	90
Whole sample (4454)	INN_T1	−0.007	−0.286*	−0.035	0.023	0.006	0.031
	(S.E.)	(0.021)	(0.170)	(0.077)	(0.025)	(0.041)	(0.175)
	(Pseudo)R^2	0.068	0.031	0.027	0.027	0.036	0.037
High technology (1432)	INN_T1	−0.050	−0.341	−0.229	−0.106	0.046	0.306
	(S.E.)	(0.073)	(0.269)	(0.205)	(0.143)	(0.273)	(0.326)
	(Pseudo)R^2	0.056	0.034	0.023	0.019	0.026	0.029
Medium–high technology (1214)	INN_T1	0.052	0.050	0.056	0.028	0.092	0.566
	(S.E.)	(0.035)	(0.327)	(0.182)	(0.256)	(0.385)	(0.374)
	(Pseudo)R^2	0.058	0.026	0.027	0.028	0.037	0.040
Medium–low technology (396)	INN_T1	1.357	−0.395	1.985	1.382	1.960	3.608
	(S.E.)	(1.958)	(2.146)	(1.593)	(2.009)	(3.166)	(3.099)
	(Pseudo)R^2	0.110	0.056	0.051	0.039	0.042	0.062
Low technology (342)	INN_T1	0.326	−2.899	−1.230	−0.707	2.449	2.364
	(S.E.)	(1.369)	(1.928)	(1.213)	(1.964)	(2.288)	(2.002)
	(Pseudo)R^2	0.075	0.038	0.021	0.021	0.034	0.080
Knowledge-intensive services (629)	INN_T1	−0.009	−0.098	0.046	0.012	−0.026	−0.065
	(S.E.)	(0.027)	(0.179)	(0.075)	(0.050)	(0.037)	(0.076)
	(Pseudo)R^2	0.099	0.034	0.036	0.051	0.070	0.065
Less knowledge-intensive services (309)	INN_T1	−0.228	−0.822	0.041	−0.268	−0.013	1.201
	(S.E.)	(0.365)	(1.274)	(0.707)	(0.348)	(0.755)	(1.159)
	(Pseudo)R^2	0.079	0.043	0.033	0.026	0.055	0.050

Standard errors (S.E.) for the quantile regression coefficients were obtained using 1000 bootstrap replications

INN indicates innovation activities; T1, Time 1; OLS, ordinary least squares

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

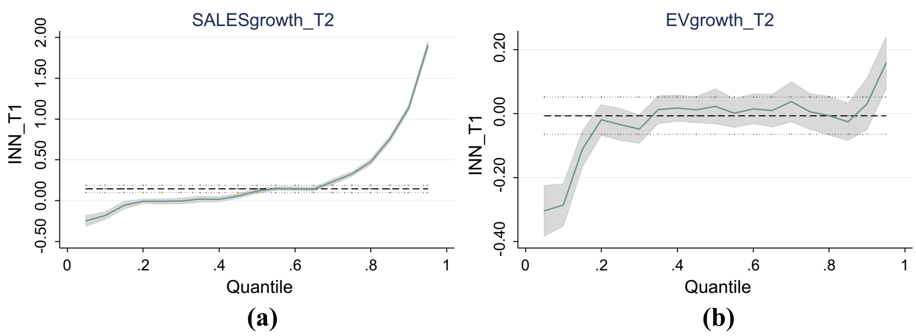

Fig. 3 Quantile regression plots of Eqs. 3 and 4 for the whole sample: Step 1. Effects of innovation activities on the small and medium-sized enterprise growth across the conditional quantiles for **(a)** sales growth and **(b)** firm market growth. The *horizontal lines* represent ordinary least squares estimates with 95% confidence intervals. Graphs were made using STATA module (Azevedo 2011)

Table 6 OLS analysis and quantile regression estimations for Eq. 5: Step 2

Industries (observations)	Variable	OLS (robust)	Quantile regression				
			10	25	50	75	90
Whole sample (4454)	Sales G_T2	0.078*	0.105*	0.103***	0.078***	0.083**	0.124***
	(S.E.)	(0.040)	(0.057)	(0.030)	(0.018)	(0.033)	(0.047)
	EV G_T2	0.077***	0.073*	0.064***	0.058***	0.058***	0.062*
	(S.E.)	(0.022)	(0.041)	(0.021)	(0.012)	(0.014)	(0.035)
	(Pseudo)R^2	0.050	0.011	0.010	0.010	0.017	0.033
High technology (1432)	Sales G_T2	0.079	0.152	0.101**	0.093**	0.099	0.139
	(S.E.)	(0.065)	(0.094)	(0.043)	(0.042)	(0.061)	(0.103)
	EV G_T2	0.091***	0.095	0.078**	0.041	0.037	0.079
	(S.E.)	(0.034)	(0.087)	(0.036)	(0.027)	(0.026)	(0.058)
	(Pseudo)R^2	0.049	0.014	0.011	0.010	0.014	0.031
Medium–high technology (1214)	Sales G_T2	0.128**	0.068	0.112**	0.103***	0.106**	0.103
	(S.E.)	(0.054)	(0.064)	(0.048)	(0.030)	(0.046)	(0.065)
	EV G_T2	0.109***	0.076*	0.061	0.083***	0.108**	0.082
	(S.E.)	(0.040)	(0.044)	(0.038)	(0.022)	(0.046)	(0.056)
	(Pseudo)R^2	0.067	0.015	0.013	0.018	0.019	0.031
Medium–low technology (396)	Sales G_T2	0.010	−0.281	0.051	−0.025	−0.068	0.037
	(S.E.)	(0.117)	(0.308)	(0.104)	(0.089)	(0.138)	(0.216)
	EV G_T2	0.053	0.017	−0.042	0.052	0.110*	0.082
	(S.E.)	(0.091)	(0.143)	(0.063)	(0.055)	(0.056)	(0.159)
	(Pseudo)R^2	0.039	0.006	0.012	0.011	0.027	0.049

Table 6 continued

Industries (observations)	Variable	OLS (robust)	Quantile regression				
			10	25	50	75	90
Low technology (342)	Sales G_T2	0.046	0.021	−0.007	−0.038	0.060	0.111
	(S.E.)	(0.143)	(0.270)	(0.206)	(0.097)	(0.157)	(0.304)
	EV G_T2	0.057	0.201	0.060	0.081**	0.096*	0.060
	(S.E.)	(0.068)	(0.225)	(0.079)	(0.041)	(0.049)	(0.115)
	(Pseudo)R^2	0.013	0.015	0.005	0.008	0.016	0.018
Knowledge-intensive service (629)	Sales G_T2	0.104	0.116	0.109	0.113	0.068	0.061
	(S.E.)	(0.086)	(0.146)	(0.096)	(0.071)	(0.085)	(0.184)
	EV G_T2	0.069	0.119	0.044	0.040	0.055	0.091
	(S.E.)	(0.046)	(0.121)	(0.045)	(0.029)	(0.036)	(0.096)
	(Pseudo)R^2	0.092	0.020	0.015	0.013	0.038	0.086
Less knowledge-intensive services (309)	Sales G_T2	−0.172	−0.339	−0.046	0.044	−0.008	0.136
	(S.E.)	(0.179)	(0.248)	(0.133)	(0.113)	(0.133)	(0.240)
	EV G_T2	0.083	0.378**	0.110	0.156**	0.064	−0.010
	(S.E.)	(0.091)	(0.168)	(0.070)	(0.070)	(0.085)	(0.174)
	(Pseudo)R^2	0.075	0.056	0.039	0.017	0.021	0.027

Standard errors (S.E.) for the quantile regression coefficients were obtained using 1000 bootstrap replications

G indicates growth; EV, enterprise value; T2, Time 2; OLS, ordinary least squares

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

firm value growth of SMEs had a significantly positive effect on R&D investment growth implies that when the market expects high future performance for the innovation activities of SMEs, stock markets can be a potentially important channel to connect SME innovation activity and growth.

However, we did not find the asymmetric effects for R&D investment between growing firms and declining firms, as noted by Coad and Rao (2010). As shown in Table 6 and Fig. 4, both fast-growing firms and declining firms showed higher coefficients on firm growth in terms of sales and firm value than did average-growing firms. This implies that declining firms decrease their R&D at almost the same rate as fast-growing firms increase their R&D (Deschryvere 2014).

Based on the technological level analysis, the growth of SMEs in high-tech sectors (high technology and medium–high technology) had a significantly positive influence on R&D investment growth, according to both the OLS analysis and the quantile regression estimations, while the positive relationship between two variables was observed only for some quantiles in other sectors.

The quantile regression estimation curve, in which the coefficients on firm growth were within the OLS confidence intervals, showed the relatively symmetric R&D growth between growing firms and declining firms. Figure 4 displays the quantile regression estimation curve of firm growth across the conditional distribution for the R&D investment growth rate.

We analyzed the indirect-effect path (X → M → Y) with SEM (path analysis) to examine the mediation effect of firm growth in the relationship between innovation activities and R&D investment growth. As shown in Table 7, we found a positive and significant mediating role of sales growth in the relationship between the two variables. However, we did not find a significant mediating role of firm value growth in the relationship between the two variables. These findings supported *Hypothesis H3a* but not *Hypothesis H3b*.

Recent studies have applied the Sobel test as a supplementary method to analyze mediation effects to further strengthen the robustness of their results (e.g., Boxall et al. 2011; Holcomb et al. 2009; Miron-Spektor et al. 2011; Ndofor et al. 2011; Reiche et al. 2011; Rodríguez and Nieto 2015). In line with these studies, we used the Sobel test and

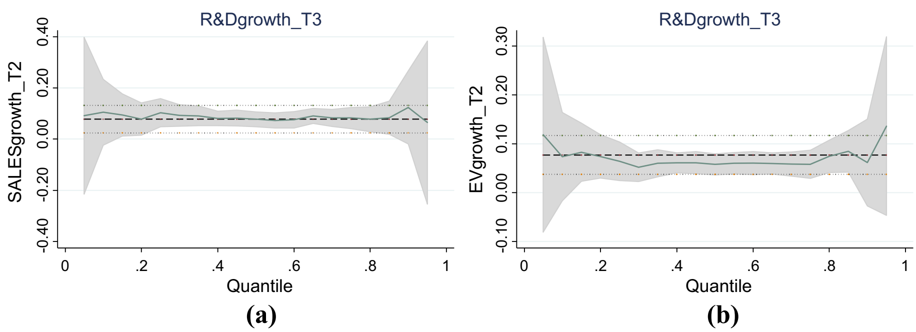

Fig. 4 Quantile regression plots of Eq. 5 for the whole sample: Step 2. Effects of small and medium-sized enterprise growth on R&D investment growth across the conditional quantiles for **(a)** sales growth and **(b)** firm market growth. The *horizontal lines* represent ordinary least squares estimates with 95% confidence intervals. Graphs were made using STATA module (Azevedo 2011)

Table 7 Mediation effect (SEM): Step 3

	Path	Direct effect		Indirect effect	
		ß	(S.E.)	ß	(S.E.)
Sales growth$_{i,T2}$	INN$_{i,T1}$ → Sales G$_{i,T2}$	0.198***	0.023		
	Sales G$_{i,T2}$ → RD G$_{i,T3}$	0.057**	0.027		
	INN$_{i,T1}$ → Sales G$_{i,T2}$ → RD G$_{i,T3}$			0.011**	0.006
	Goodness of fit	RMSEA = 0.037, CFI = 0.927, SRMR = 0.016			
EV growth$_{i,T2}$	INN$_{i,T1}$ → EV G$_{i,T2}$	0.014	0.031		
	EV G$_{i,T2}$ → RD G$_{,T3}$	0.062***	0.020		
	INN$_{i,T1}$ → EV G$_{i,T2}$ → RD G$_{i,T3}$			0.001	0.002
	Goodness of fit	RMSEA = 0.033, CFI = 0.606, SRMR = 0.015			

Root-mean-square error of approximation (RMSEA) and standardized root-mean-square residual (SRMR) values of less than 0.05 are considered to indicate a close fit; comparative fit index (CFI) scores above 0.9 are considered acceptable

INN indicates innovation activities; G, growth; RD, research & development; EV, enterprise value; T1, Time 1; T2, Time 2; T3, Time 3

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$; number of observations: 4454

Table 8 Mediation effect (Sobel test): Step 3

Path	ß	(S.E.)	Sobel test Z	p value
INN$_{i,T1}$ → Sales growth$_{i,T2}$ → RD growth$_{i,T3}$	0.013	0.006	2.32**	0.020
INN$_{i,T1}$ → EV growth$_{i,T2}$ → RD growth$_{i,T3}$	0.001	0.002	0.44	0.658

INN indicates innovation activities; RD, research & development; EV, enterprise value; T1, Time 1; T2, Time 2; T3, Time 3

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$; number of observations: 4454

obtained similar results to those from the SEM (path analysis). Table 8 shows the results relating to the mediation effect of firm growth according to the Sobel test.

4.3 Additional tests to check the robustness of the study results

We performed the same analyses for large firms, with different results (see "Appendix"). We found that the innovation activities of large firms had a significantly positive effect on firm growth in terms of both sales and firm value, and that their growth in both sales and firm value had a significantly positive effect on subsequent R&D investment growth. Moreover, the growth in both sales and firm value of large firms played a mediating role in the relationship between innovation activities and R&D investment growth. Consequently, we found a virtuous cycle between the innovation activities of large firms and their growth through two routes.

Unlike previous studies, we used two variables to measure firm growth, applying quantile regression in addition to OLS analysis to estimate the three augmented Gibrat's law equations, and using SEM (path analysis) and the Sobel test to analyze the mediation effect of firm growth.

Finally, we performed the analysis for venture firms, a kind of SME, and found results consistent with the main results of this study (data not shown).

5 Conclusions and discussion

In recent decades, numerous studies have considered the relationship between innovation activities and firm growth, with a focus on estimating the effect of innovation activities on firm sales growth. However, in contrast to most previous studies, this study focused on the role of the stable innovation activities of SMEs in sustainable growth. In line with this, we used firm value, in addition to sales, as a proxy for firm growth, as stock markets have been shown to be a useful channel to decrease firms' financial obligations (see Brown et al. 2009; Blass and Yosha 2003). Our empirical study simultaneously considered two routes: (1) innovation activities at T1, sales growth at T2, and R&D investment growth at T3; and (2) innovation activities at T1, firm value growth at T2, and R&D investment growth at T3. Moreover, we analyzed the mediation effect of firm growth in the relationship between innovation activities and R&D investment growth through the two routes to examine the R&D financing channel of SMEs. This study adopted a dynamic and evolutionary approach—augmented Gibrat's law equations—using multiple measures and methods to provide a comprehensive understanding of the firm growth process and to highlight the way in which stock markets can be a potentially important channel to connect SME innovation activities and growth.

In this longitudinal study, we first found a significant and positive relationship between the innovation activities of SMEs and their growth in sales the following year, and this relationship was stronger for high-growth firms and high-tech sectors than for low-growth firms and low-tech sectors. Moreover, SME sales growth had a significantly positive effect on subsequent R&D investment growth. In sum, among SMEs, innovation activities influenced the sales growth of high-growth firms and high-tech sectors more positively than low-growth firms and low-tech sectors, and high-growth firms and high-tech sectors subsequently invested more in R&D the following year. However, we also found that the innovation activities of SMEs did not significantly affect their firm value growth, whereas it did for large companies. One reason for this could be that the market does not recognize the value of the potential growth and opportunities created by SME innovation activities. In addition, we found a mediating role of sales growth in the relationship between the innovation activities of SMEs and their R&D investment growth, but we did not find such a mediating role of firm value growth. However, we did find a mediating role of large firms' growth in both sales and firm value in the relationship between the two variables.

The results of this study have a few important implications. First, SMEs should actively collaborate with external research institutions, i.e., universities, to improve their R&D capability for sustainable growth. As Arrow (1962) and Acs et al. (2013) suggested, knowledge is one of the primary drivers of firm growth due to its strong propensity to spill over from knowledge-creating firms to other firms, which can then access such knowledge at a low cost. Moreover, SMEs adopting a process innovation strategy depend considerably on the acquisition of external knowledge sources to improve their weak internal innovative capabilities (Hervas-Oliver et al. 2014), and a number of studies have found a positive association between the innovation performance of SMEs and their collaboration with external institutions (Audretsch et al. 2014; Gunasekaran et al. 2006; Rodríguez and Nieto 2015; Zeng et al. 2010). In particular, Lee (2000) suggested that university-industry collaboration is useful to both firms and universities, because firms can access new research and discoveries and university faculty members can conduct their own academic research by obtaining funds for their students and laboratory equipment. Therefore, these previous studies support the need for collaboration between SMEs and external institutions, especially universities.

Second, policymakers should be aware of the importance of stock markets for financing R&D and take action to improve the related system. Stock market development and liberalization could substantially increase R&D investment and foster innovative activity (Brown et al. 2012; Hsu et al. 2014). Indeed, financing from the equity market can reduce a firm's financial obligations and help to alleviate the financial effects of failed R&D projects (Wang and Thornhill 2010). Furthermore, reduced financial obligations from equity financing can increase discretionary slack (Bourgeois 1981). These previous studies suggest that financing R&D through the equity market is important for the sustainable R&D investment of SMEs. In particular, a study by Blass and Yosha (2003) on financing R&D in Israel, where the ratio of R&D to gross domestic product is the second highest in the world, demonstrated that R&D-intensive firms do not rely more on internal cash, and this might be because they are able to finance R&D through inexpensive external equity markets, which has important implications.

One of the limitations of this study is the time lag between innovation activities and their commercial success. However, we analyzed longitudinal data and multiple industry to overcome this limitation, as previously suggested and tested (e.g., Davidsson and Wiklund 2006; García-Manjón and Romero-Merino 2012; Liu et al. 1999; Weinzimmer et al. 1998; Yang and Huang 2005).

In conclusion, this empirical study suggests the following: (1) SMEs should actively collaborate with external research institutions, i.e., universities, to improve their R&D capability; and (2) when the market expects high future performance of SME innovation activities, stock markets could be a potentially important channel to connect their innovation activities and growth.

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Appendix: Empirical results for large firms

See Figs. 5, 6 and Tables 9, 10, 11.

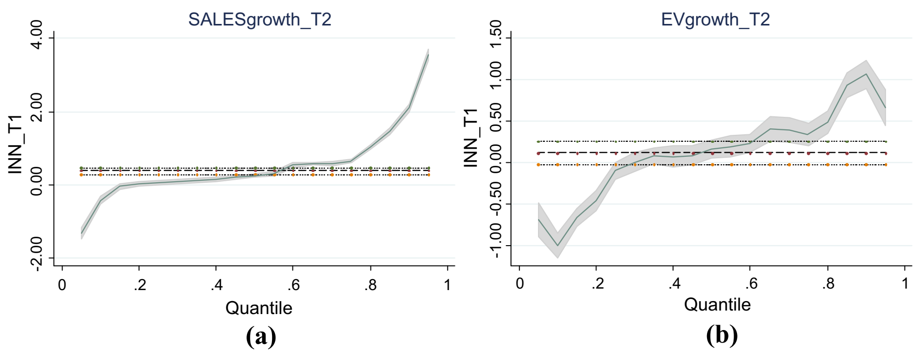

Fig. 5 Quantile regression plots of Eqs. 3 and 4: Step 1 for large firms. Effects of innovation activities on small and medium-sized enterprise growth across the conditional quantiles of **(a)** sales growth and **(b)** firm market growth. The *horizontal lines* represent ordinary least squares estimates with 95% confidence intervals. Graphs were made using STATA module (Azevedo 2011)

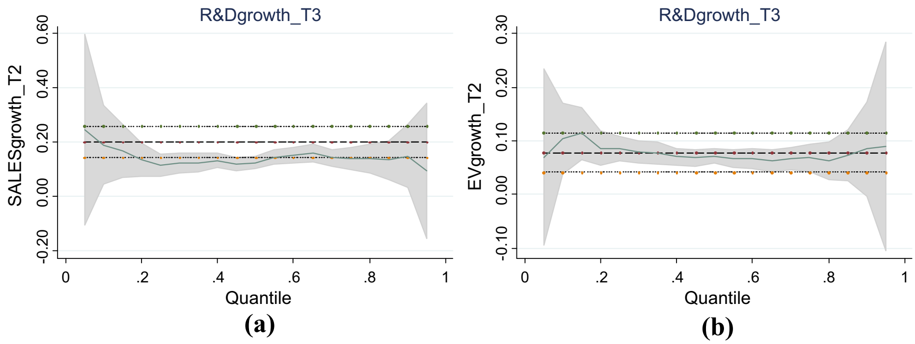

Fig. 6 Quantile regression plots of Eq. 5: Step 2 for large firms. Effects of small and medium-sized enterprise growth on R&D investment growth across the conditional quantiles of **(a)** sales growth and **(b)** firm market growth. The *horizontal lines* represent ordinary least squares estimates with 95% confidence intervals. Graphs were made using STATA module (Azevedo 2011)

Table 9 OLS analysis and quantile regression estimations for large firms

	Dependent variable	Independent variable	OLS (robust)	Quantile regression				
				10	25	50	75	90
Step 1 Eq. 3	Sales $G_{i,T2}$	INN_T1	0.385***	−0.418**	0.069	0.248**	0.656***	2.106***
		(S.E.)	(0.107)	(0.173)	(0.057)	(0.114)	(0.153)	(0.312)
	(Pseudo)R2		0.010	0.004	0.002	0.004	0.011	0.035
Step 1 Eq. 4	EV $G_{i,T2}$	INN_T1	0.121**	−0.999***	−0.093	0.166	0.339**	1.066***
		(S.E.)	(0.059)	(0.319)	(0.194)	(0.104)	(0.171)	(0.309)
	(Pseudo)R2		0.041	0.029	0.016	0.015	0.019	0.028
Step 2 Eq. 5	RD $G_{i,T3}$	Sales $G_{i,T2}$	0.203***	0.190***	0.117***	0.125***	0.141***	0.150***
		(S.E.)	(0.044)	(0.039)	(0.025)	(0.029)	(0.033)	(0.050)
	RD $G_{i,T3}$	EV $G_{i,T2}$	0.078***	0.104***	0.085***	0.072***	0.069***	0.086**
		(S.E.)	(0.022)	(0.033)	(0.013)	(0.011)	(0.016)	(0.040)
	(Pseudo)R2		0.092	0.014	0.013	0.013	0.018	0.042

Standard errors (S.E.) for the quantile regression coefficients were obtained using 1000 bootstrap replications

G indicates growth; INN, innovation activities; EV, enterprise value; RD, research & development; T1, Time 1; T2, Time 2; T3, Time 3; OLS, ordinary least squares

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$; number of observations: 6962

Table 10 Mediation effect (SEM): Step 3 for large firms

	Path	Direct effect		Indirect effect	
		ß	(S.E.)	ß	(S.E.)
SALES growth$_{i,T2}$	INN$_{i,T1}$ → Sales G$_{i,T2}$	0.368***	0.046		
	Sales G$_{i,T2}$ → RD G$_{i,T3}$	0.146***	0.030		
	INN$_{i,T1}$ → SALES G$_{i,T2}$ → RD G$_{i,T3}$			0.054***	0.013
	Goodness of fit	RMSEA = 0.018, CFI = 0.975, SRMR = 0.009			
EV growth$_{i,T2}$	INN$_{i,T1}$ → EV G$_{i,T2}$	0.134*	0.072		
	EV G$_{i,T2}$ → RD G$_{,T3}$	0.087***	0.019		
	INN$_{i,T1}$ → EV G$_{i,T2}$ → RD G$_{i,T3}$			0.012*	0.007
	Goodness of fit	RMSEA = 0.023, CFI = 0.858, SRMR = 0.010			

Root-mean-square error of approximation (RMSEA) and standardized root-mean-square residual (SRMR) values less than 0.05 are considered to indicate a close fit; comparative fit index (CFI) values above 0.9 are considered acceptable

G indicates growth; INN, innovation activities; RD, research & development; EV, enterprise value; T1, Time 1; T2, Time 2; T3, Time 3

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$; number of observations: 6962

Table 11 Mediation effect (Sobel test): Step 3 for large firms

Path	ß	(S.E.)	Sobel test Z	*p*-value
INN$_{i,T1}$ → Sales growth$_{i,T2}$ → RD growth$_{i,T3}$	0.052	0.013	4.02***	0.000
INN$_{i,T1}$ → EV growth$_{i,T2}$ → RD growth$_{i,T3}$	0.012	0.007	1.71*	0.087

INN indicates innovation activities; RD, research & development; EV, enterprise value; T1, Time 1; T2, Time 2; T3, Time 3

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$; number of observations: 6962

References

Acs, Z. J., Audretsch, D. B., & Lehmann, E. E. (2013). The knowledge spillover theory of entrepreneurship. *Small Business Economics, 41*(4), 757–774. doi:10.1007/s11187-013-9505-9.

Ardishvili, A., Cardozo, S., Harmon, S., & Vadakath, S. (1998). *Towards a theory of new venture growth.* Paper presented at the Babson Entrepreneurship Research Conference, Ghent, Belgium.

Arrow, K. (1962). Economic welfare and the allocation of resources for invention. In National Bureau of Economic Research (Ed.), *The rate and direction of inventive activity: Economic and social factors* (pp. 609–626). Princeton, NJ: Princeton University Press. http://www.nber.org/chapters/c2144.

Audretsch, D. B., Coad, A., & Segarra, A. (2014). Firm growth and innovation. *Small Business Economics, 43*(4), 743–749. doi:10.1007/s11187-014-9560-x.

Audretsch, D. B., Klomp, L., Santarelli, E., & Thurik, A. R. (2004). Gibrat's law: Are the services different? *Review of Industrial Organization, 24*(3), 301–324. doi:10.1023/B:REIO.0000038273.50622.ec.

Azevedo, J. P. (2011). *grqreg: Stata module to graph the coefficients of a quantile regression*. Boston, MA: Boston College Department of Economics. http://fmwww.bc.edu/repec/bocode/g/grqreg.ado.

Bartelsman, E., Dobbelaere, S., & Peters, B. (2014). *Allocation of human capital and innovation at the frontier: Firm-level evidence on Germany and the Netherlands*. Amsterdam, the Netherlands: Tinbergen Institute. Retrieved from http://papers.tinbergen.nl/13095.pdf.

Bellucci, A., & Pennacchio, L. (2015). University knowledge and firm innovation: Evidence from European countries. *Journal of Technology Transfer, 41*(4), 730–752. doi:10.1007/s10961-015-9408-9.

Bianchini, S., Pellegrino, G., & Tamagni, F. (2014). *Innovation strategies and firm growth: New longitudinal evidence from Spanish firms* (Working paper). Retrieved from http://www.dipecodir.it/upload/file/Workshop%20Explaining%20Economic%20Change/Innovation%20Strategies%20and%20Firm%20Growth_%20New%20longitudinal%20evidence%20from%20spanish%20firms_pdf.pdf.

Blass, A., & Yosha, O. (2003). Financing R&D in mature companies: An empirical analysis. *Economics of Innovation and New Technology, 12*(5), 425–447. doi:10.1080/1043859022000029249.

Bosworth, D., & Rogers, M. (2001). Market value, R&D and intellectual property: An empirical analysis of large Australian firms. *The Economic Record, 77*(239), 323–337. doi:10.1111/1475-4932.t01-1-00026.

Bottazzi, G., Dosi, G., Lippi, M., Pammolli, F., & Riccaboni, M. (2001). Innovation and corporate growth in the evolution of the drug industry. *International Journal of Industrial Organization, 19*(7), 1161–1187. doi:10.1016/S0167-7187(01)00068-6.

Bottazzi, G., & Secchi, A. (2003). Common properties and sectoral specificities in the dynamics of US manufacturing companies. *Review of Industrial Organization, 23*(3–4), 217–232. doi:10.1023/B:REIO.0000031366.28559.c1.

Bourgeois, L. J. (1981). On the measurement of organizational slack. *Academy of Management Review, 6*(1), 29–39. doi:10.5465/AMR.1981.4287985.

Boxall, P., Ang, S. H., & Bartram, T. (2011). Analysing the 'black box' of HRM: Uncovering HR goals, mediators, and outcomes in a standardized service environment. *Journal of Management Studies, 48*(7), 1504–1532. doi:10.1111/j.1467-6486.2010.00973.x.

Brown, J. R., Fazzari, S. M., & Petersen, B. C. (2009). Financing innovation and growth: Cash flow, external equity, and the 1990s R&D boom. *The Journal of Finance, 64*(1), 151–185. doi:10.1111/j.1540-6261.2008.01431.x.

Brown, J. R., Martinsson, G., & Petersen, B. C. (2012). Do financing constraints matter for R&D? *European Economic Review, 56*(8), 1512–1529. doi:10.1016/j.euroecorev.2012.07.007.

Capasso, M., Treibich, T., & Verspagen, B. (2015). The medium-term effect of R&D on firm growth. *Small Business Economics, 45*(1), 39–62. doi:10.1007/s11187-015-9640-6.

Chan, S. H., Martin, J. D., & Kensinger, J. W. (1990). Corporate research and development expenditures and share value. *Journal of Financial Economics, 26*(2), 255–276. doi:10.1016/0304-405X(90)90005-K.

Chauvin, K. W., & Hirschey, M. (1993). Advertising, R&D expenditures and the market value of the firm. *Financial Management, 22*(4), 128–140. doi:10.2307/3665583.

Chesher, A. (1979). Testing the law of proportionate effect. *The Journal of Industrial Economics, 27*(4), 403–411. doi:10.2307/2097961.

Cho, H. J., & Pucik, V. (2005). Relationship between innovativeness, quality, growth, profitability, and market value. *Strategic Management Journal, 26*(6), 555–575. doi:10.1002/smj.461.

Coad, A. (2007). A closer look at serial growth rate correlation. *Review of Industrial Organization, 31*(1), 69–82. doi:10.1007/s11151-007-9135-y.

Coad, A. (2009). *The growth of firms: A survey of theories and empirical evidence*. Cheltenham, UK: Edward Elgar. http://www.elgaronline.com/view/9781848443273.xml.

Coad, A. (2010). Exploring the processes of firm growth: Evidence from a vector auto-regression. *Industrial and Corporate Change, 19*(6), 1677–1703. doi:10.1093/icc/dtq018.

Coad, A., & Rao, R. (2006). Innovation and market value: A quantile regression analysis. *Economic Bulletin, 15*(13), 1–10. Retrieved from http://www.accessecon.com/pubs/EB/2006/Volume15/EB-06O10012A.pdf.

Coad, A., & Rao, R. (2008). Innovation and firm growth in high-tech sectors: A quantile regression approach. *Research Policy, 37*(4), 633–648. doi:10.1016/j.respol.2008.01.003.

Coad, A., & Rao, R. (2010). Firm growth and R&D expenditure. *Economics of Innovation and New Technology, 19*(2), 127–145. doi:10.1080/10438590802472531.

Coad, A., Segarra, A., & Teruel, M. (2016). Innovation and firm growth: Does firm age play a role? *Research Policy, 45*(2), 387–400. doi:10.1016/j.respol.2015.10.015.

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly, 35*(1), 128–152. doi:10.2307/2393553.

Colombelli, A., Haned, N., & Le Bas, C. (2013). On firm growth and innovation: Some new empirical perspectives using French CIS (1992–2004). *Structural Change and Economic Dynamics, 26*, 14–26. doi:10.1016/j.strueco.2013.03.002.

Davidsson, P., & Wiklund, J. (2006). Conceptual and empirical challenges in the study of firm growth. In P. Davidsson, F. Delmar, & J. Wiklund (Eds.), *Entrepreneurship and the growth of firms* (pp. 39–61). Cheltenham, UK: Edward Elgar. https://www.elgaronline.com/view/1845425758.00010.xml.

Del Monte, A., & Papagni, E. (2003). R&D and the growth of firms: Empirical analysis of a panel of Italian firms. *Research Policy, 32*(6), 1003–1014. doi:10.1016/S0048-7333(02)00107-5.

Delmar, F., Davidsson, P., & Gartner, W. B. (2003). Arriving at the high-growth firm. *Journal of Business Venturing, 18*(2), 189–216. doi:10.1016/S0883-9026(02)00080-0.

Demirel, P., & Mazzucato, M. (2012). Innovation and firm growth: Is R&D worth it? *Industry and Innovation, 19*(1), 45–62. doi:10.1080/13662716.2012.649057.

Deschryvere, M. (2014). R&D, firm growth and the role of innovation persistence: An analysis of Finnish SMEs and large firms. *Small Business Economics, 43*(4), 767–785. doi:10.1007/s11187-014-9559-3.

Doukas, J., & Switzer, L. (1992). The stock market's valuation of R&D spending and market concentration. *Journal of Economics and Business, 44*(2), 95–114. doi:10.1016/0148-6195(92)90009-Y.

Falk, M. (2012). Quantile estimates of the impact of R&D intensity on firm performance. *Small Business Economics, 39*(1), 19–37. doi:10.1007/s11187-010-9290-7.

Freel, M. S. (2000). Do small innovating firms outperform non-innovators? *Small Business Economics, 14*(3), 195–210. doi:10.1023/A:1008100206266.

García-Manjón, J. V., & Romero-Merino, M. E. (2012). Research, development, and firm growth. Empirical evidence from European top R&D spending firms. *Research Policy, 41*(6), 1084–1092. doi:10.1016/j.respol.2012.03.017.

Geroski, P. A. (2005). Understanding the implications of empirical work on corporate growth rates. *Managerial and Decision Economics, 26*(2), 129–138. doi:10.1002/mde.1207.

Geroski, P. A., & Toker, S. (1996). The turnover of market leaders in UK manufacturing industry, 1979–86. *International Journal of Industrial Organization, 14*(2), 141–158. doi:10.1016/0167-7187(95)00479-3.

Gibrat, R. (1931). *Les inégalités économiques*. Paris: Recueil Sirey.

Goedhuys, M., & Sleuwaegen, L. (2010). High-growth entrepreneurial firms in Africa: A quantile regression approach. *Small Business Economics, 34*(1), 31–51. doi:10.1007/s11187-009-9193-7.

Gunasekaran, A., Putnik, G. D., Peças, P., & Henriques, E. (2006). Best practices of collaboration between university and industrial SMEs. *Benchmarking: An International Journal, 13*(1/2), 54–67. doi:10.1108/14635770610644574.

Hall, B. H., & Lerner, J. (2010). The financing of R&D and innovation. In B. Hall & N. Rosenberg (Eds.), *Handbook of the economics of innovation* (Vol. 1, pp. 609–639). Amsterdam, the Netherlands: Elsevier. http://dx.doi.org/10.1016/S0169-7218(10)01014-2.

Hall, B. H., & Oriani, R. (2006). Does the market value R&D investment by European firms? Evidence from a panel of manufacturing firms in France, Germany, and Italy. *International Journal of Industrial Organization, 24*(5), 971–993. doi:10.1016/j.ijindorg.2005.12.001.

Helfat, C. E. (1994). Firm-specificity in corporate applied R&D. *Organization Science, 5*(2), 173–184. doi:10.1287/orsc.5.2.173.

Helfat, C. E. (1997). Know-how and asset complementarity and dynamic capability accumulation: The case of R&D. *Strategic Management Journal, 18*(5), 339–360. doi:10.1002/(SICI)1097-0266(199705)18:5<339:AID-SMJ883>3.0.CO;2-7.

Hervas-Oliver, J.-L., Sempere-Ripoll, F., & Boronat-Moll, C. (2014). Process innovation strategy in SMEs, organizational innovation and performance: A misleading debate? *Small Business Economics, 43*(4), 873–886. doi:10.1007/s11187-014-9567-3.

Holcomb, T. R., Holmes, R. M., Jr., & Connelly, B. L. (2009). Making the most of what you have: Managerial ability as a source of resource value creation. *Strategic Management Journal, 30*(5), 457–485. doi:10.1002/smj.747.

Hölzl, W. (2009). Is the R&D behaviour of fast-growing SMEs different? Evidence from CIS III data for 16 countries. *Small Business Economics, 33*(1), 59–75. doi:10.1007/s11187-009-9182-x.

Hsu, P.-H., Tian, X., & Xu, Y. (2014). Financial development and innovation: Cross-country evidence. *Journal of Financial Economics, 112*(1), 116–135. doi:10.1016/j.jfineco.2013.12.002.

Koenker, R., & Bassett, G., Jr. (1978). Regression quantiles. *Econometrica, 46*(1), 33–50. doi:10.2307/1913643.

Lee, Y. S. (2000). The sustainability of university-industry research collaboration: An empirical assessment. *The Journal of Technology Transfer, 25*(2), 111–133. doi:10.1023/A:1007895322042.

Liu, J.-T., Tsou, M.-W., & Hammitt, J. K. (1999). Do small plants grow faster? Evidence from the Taiwan electronics industry. *Economics Letters, 65*(1), 121–129. doi:10.1016/S0165-1765(99)00126-3.

Lockett, A., Wiklund, J., Davidsson, P., & Girma, S. (2011). Organic and acquisitive growth: Re-examining, testing and extending Penrose's growth theory. *Journal of Management Studies, 48*(1), 48–74. doi:10.1111/j.1467-6486.2009.00879.x.

Lukach, R., Kort, P. M., & Plasmans, J. (2007). Optimal R&D investment strategies under the threat of new technology entry. *International Journal of Industrial Organization, 25*(1), 103–119. doi:10.1016/j.ijindorg.2006.02.002.

Mansfield, E. (1962). Entry, Gibrat's law, innovation, and the growth of firms. *The American Economic Review, 52*(5), 1023–1051. http://www.jstor.org.oca.korea.ac.kr/stable/1812180.

Marris, R. (1999). Edith Penrose and economics. *Contributions to Political Economy, 18*(1), 47–65. doi:10.1093/cpe/18.1.47.

Mata, J., & Woerter, M. (2013). Risky innovation: The impact of internal and external R&D strategies upon the distribution of returns. *Research Policy, 42*(2), 495–501. doi:10.1016/j.respol.2012.08.004.

Mazzucato, M., & Parris, S. (2015). High-growth firms in changing competitive environments: The US pharmaceutical industry (1963 to 2002). *Small Business Economics, 44*(1), 145–170. doi:10.1007/s11187-014-9583-3.

Miron-Spektor, E., Erez, M., & Naveh, E. (2011). The effect of conformist and attentive-to-detail members on team innovation: Reconciling the innovation paradox. *Academy of Management Journal, 54*(4), 740–760. doi:10.5465/AMJ.2011.64870100.

Ndofor, H. A., Sirmon, D. G., & He, X. (2011). Firm resources, competitive actions and performance: Investigating a mediated model with evidence from the in vitro diagnostics industry. *Strategic Management Journal, 32*(6), 640–657. doi:10.1002/smj.901.

Oriani, R., & Sobrero, M. (2008). Uncertainty and the market valuation of R&D within a real options logic. *Strategic Management Journal, 29*(4), 343–361. doi:10.1002/smj.664.

Phillips, A. (1971). *Technology and market structure: A study of the aircraft industry*. Lexington, MA: Heath Lexington Books.

Reiche, B. S., Kraimer, M. L., & Harzing, A.-W. (2011). Why do international assignees stay? An organizational embeddedness perspective. *Journal of International Business Studies, 42*(4), 521–544. doi:10.1057/jibs.2011.5.

Rodríguez, A., & Nieto, M. J. (2015). Does R&D offshoring lead to SME growth? Different governance modes and the mediating role of innovation. *Strategic Management Journal, 37*(8), 1734–1753. doi:10.1002/smj.2413.

Roper, S. (1997). Product innovation and small business growth: A comparison of the strategies of German, UK and Irish companies. *Small Business Economics, 9*(6), 523–537. doi:10.1023/A:1007963604397.

Roper, S., Du, J., & Love, J. H. (2008). Modelling the innovation value chain. *Research Policy, 37*(6–7), 961–977. doi:10.1016/j.respol.2008.04.005.

Schimke, A., & Brenner, T. (2011). *Temporal structure of firm growth and the impact of R&D* (Working Paper No. 32). Karlsruhe, Germany: Karlsruher Institut für Technologie. Retrieved from http://econpapers.wiwi.kit.edu/downloads/KITe_WP_32.pdf.

Segarra, A., & Teruel, M. (2014). High-growth firms and innovation: An empirical analysis for Spanish firms. *Small Business Economics, 43*(4), 805–821. doi:10.1007/s11187-014-9563-7.

Sobel, M. E. (1982). Asymptotic confidence intervals for indirect effects in structural equation models. *Sociological Methodology, 13,* 290–312. doi:10.2307/270723.

Teece, D. J. (1986). Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. *Research Policy, 15*(6), 285–305. doi:10.1016/0048-7333(86)90027-2.

Toivanen, O., Stoneman, P., & Bosworth, D. (2002). Innovation and the market value of UK firms, 1989–1995. *Oxford Bulletin of Economics and Statistics, 64*(1), 39–61. doi:10.1111/1468-0084.00002.

Wang, T., & Thornhill, S. (2010). R&D investment and financing choices: A comprehensive perspective. *Research Policy, 39*(9), 1148–1159. doi:10.1016/j.respol.2010.07.004.

Weinzimmer, L. G., Nystrom, P. C., & Freeman, S. J. (1998). Measuring organizational growth: Issues, consequences and guidelines. *Journal of Management, 24*(2), 235–262. doi:10.1177/014920639802400205.

Williamson, O. E. (1988). Corporate finance and corporate governance. *The Journal of Finance, 43*(3), 567–591. doi:10.1111/j.1540-6261.1988.tb04592.x.

Woolridge, J. R. (1988). Competitive decline and corporate restructuring: Is a myopic stock market to blame? *Journal of Applied Corporate Finance, 1*(1), 26–36. doi:10.1111/j.1745-6622.1988.tb00155.x.

Yang, C.-H., & Huang, C.-H. (2005). R&D, size and firm growth in Taiwan's electronics industry. *Small Business Economics, 25*(5), 477–487. doi:10.1007/s11187-004-6487-7.

Yu, H.-C., Chen, C.-S., & Hsieh, D.-T. (2010). Keiretsu style main bank relationships, R&D investment, leverage, and firm value: Quantile regression approach. In C.-F. Lee, J. Lee, & A. C. Lee (Eds.), *Handbook of quantitative finance and risk management* (pp. 829–841). New York, NY: Springer. http://dx.doi.org/10.1007/978-0-387-77117-5_53.

Zantout, Z. Z., & Tsetsekos, G. P. (1994). The wealth effects of announcements of R&D expenditure increases. *Journal of Financial Research, 17*(2), 205–216. doi:10.1111/j.1475-6803.1994.tb00186.x.

Zeng, S. X., Xie, X., & Tam, C. M. (2010). Relationship between cooperation networks and innovation performance of SMEs. *Technovation, 30*(3), 181–194. doi:10.1016/j.technovation.2009.08.003.