“Do R&D expenditure, royalty and technology licensing expenses increase operational performance of the biotech industry in Taiwan?”

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Abstract

Over the last two decades R&D has played an integral role in the biotechnological medicine industry. Biotech breakthroughs have resulted in an R&D expenditure boom, encouraging further exploration of its potential therapeutic applications. It is, however, complex, costly, and full of uncertainty. Thus, R&D investment is an appropriate mechanism to encourage firms to innovate. This paper examines the associations between R&D expenditure (RDI), royalty and technology licensing expenses (ROY) and firm value in terms of return on equity (ROE), in the biotechnology medicine industry from the period of 1996 to 2007 in Taiwan. Utilizing OLS regression analysis the empirical results indicate: (1) Both RDI and ROY are strongly connected to financial performance within the same year implemented and subsequent years. RDI has a considerably negative effect that outweighs the positive effect of ROY on ROE. (2) In the short run, RDI and ROY bare no effect on market value. (3) In the long run, RDI enhances market value, and has a significantly more positive effect than ROY on market value.

Keywords: R&D expenditure, operational performance, biotechnology medicine industry.
JEL Classification: O16, O32, P17.

Introduction

Over the last two decades in Taiwan, the information and semiconductor industries have enjoyed considerable economic profits. Since the 21st century, in response to a more knowledge based economy and global competition, countries worldwide have actively increased investments in technology resources, accelerated R&D innovation, cultivated technology talents, and developed key technologies and industries in order to reinforce economic growth and improve the quality of life. In Taiwan's national development plan, the key industries targeted are the biotech and information ones. The Taiwanese government, in particular, has undertaken the development of the biotech industry in Taiwan and aims to make it as popular as its IT (Information Technology) industry. Taiwan's industrial technical innovations are a valuable resource that can ensure national competitiveness and sustain economic growth. These innovations also offer higher quality levels in the biotech industry, thus enabling Taiwan to enter the international market.

Biotech is a scientific technology that enables the production of biological systems that improve the quality of life through bio-processes, cells, or metabolites (Yearbook of Biotechnology Industry, 2008). In 2007, Taiwan defined Biotech as a science that is a combination of biochemistry, microbiology, genetics, and chemical engineering. Many of its applications include medicine, healthcare, mechanical and electrical information, material chemistry, recycling, food and agriculture, etc. Biotech used in R&D and manufacturing can reduce production costs and the adverse impact on the environment associated with manufacturing, thereby, leading to an upgradation to the quality of life.

It is an integrated science and also a knowledge-intensive economic industry. Although it has been under development in Taiwan for over 20 years, results are still lagging behind those of Europe and the United States. In 2003 Taiwan's Executive Yuan resubmitted an "Action Plan for Strengthening the Biotech Industry" and had several goals: an average growth of 25% in the biotech business industry over the next five years; USD $ 440 million investment; the construction of over 500 biotech firms within ten years, and the reinforcement of 18 successful investments in Biotech by 2010.

Moreover, in order to renovate the biotech and new medicine industries into key industries for Taiwan's economic transformation with a view to create another "billion dollar industry", the Executive Yuan and Legislative Yuan passed the "Regulations on the Development of Biotechnology and New Medicine Industry" on June 15, 2007. The bill included several incentives beginning with a tax preference for the biotech industry that is valid until 2021 and relaxed R&D regulations. The preference also includes tax credits for shareholders' investments and technical shareholders, which boosts the development of the Biotech and new medicine industries in Taiwan. In order to raise Taiwan's competitiveness in the biotech industry to a level equal to those of Europe and the United States, the government modified its policy and began offering the biotech and new medicine industries exclusive tax credits as stated at the end of the "Production Reinforcement Articles". Moreover, in an effort to simulate the clustering effect the science parks created in Taiwan, the government established biotech parks, encouraging and supporting construction of new and expanding biotech companies.

Schumpeter (1942) suggested that innovation was the key factor for economic growth and indicated that innovation could result in creative destruction and renew industry techniques. Balkin et al. (2000) indicated that companies must possess the ability to continue innovation of their products in order to survive in the competitive market. Thus, a company's investment in innovation has become one of the indexes for evaluating and maintaining corporate competitiveness. According to Lin et al. (2006), continuous innovation was the main source of acquiring a competitive advantage for firms. In order to maintain a competitive advantage, firms must treat research and investment as the keys to strengthen their competitive advantage (Hsieh et al., 2003; Tsai and Wang, 2004). This study focuses on the biotech industry of medicine. In the past, pharmaceutical factories tended to adopt costly chemical synthesis techniques which allowed for the easy manipulation expiration dates and the toxicity of medicine. However, with the application of new techniques (such as nanotechnology), a simple change in physical structure significantly increases the absorption effect, transmission efficiency, and extends the expiry without affecting the original effect. These new techniques will even enable the extension of the patent period of new medicines. The firms, thus, involve one after another. However, the factors leading to technical innovation in companies are complex and include accurate market prediction, competitive innovations, innovations in human resource development, and the innovation capital of firms. The external innovation environment, culture and any related regulations also affect incentives and the results of technical innovations within a firm.

There are very few studies on the sources of technical innovation in the biotech industry. The majority of prior studies tend to focus on R&D expenditure, R&D intensity, advertising expenses, or patent rights instead of the influence of external innovation on operational performance. Chesbrough (2003, 2007) suggested that companies must adopt an open innovation model and firms must fully apply internal and external creative ideas and commercialize them through the operational model. Moreover, products could be introduced to the market through licensing agreements for the application of internal creativity in the operational models of other firms in order to create greater value. Proxy variables that represent sources of corporate technical innovation (involvement) are R&D expenditure as well as royalty and technology licensing expenditures. R&D expenditure is related to the internal innovation system whereas royalty and technology licensing expenditure aims to create profits through external technique licensing or the purchase of domestic and foreign patents or know-how. Bowonder (1999) studied the R&D expenditure of firms around the world and found that with regard to R&D expenditure intensity, the software industry is ranked first (13.67%) and the pharmaceutical industry second (12.04%). These two industries continued to enjoy high profits even during the global economic decline. However, firms must consider changing techniques, market dynamics, and customer preference in order to ensure effective management. Lin et al. (2006) determinated that firms must adopt different innovation strategies at different technical stages. The corporate innovation performance of firms would be different due to different technical scales. Thus, in order to survive, enterprises must remain abreast of the trends in the market, meet short, medium, and long-term objectives, introduce external innovation, remain closely connected with corporate development strategies, utilize R&D resources, and enhance competitiveness. The Biotech industry in Taiwan has been under development for over 20 years, without significant results. Is the lack of results related to the source of technical innovation? The answer to this question is the motive of this paper.

Based on the aforementioned research and motives, the aims of this study are as follows: First, it tries to find the sources of technical innovation related to the current operational performance of firms. The test attempts to find: (1) Are R&D and Royalty and Technology Licensing expenditures and intensities related to the financial performance in the year implemented? (2) Are R&D and royalty and technology licensing expenditures and intensities related to market value in the year implemented? Second, it attempts to find the lag effect of the source of technical innovation on corporate operational performance; the test aspects include: (1) Are R&D and royalty and technology licensing expenditures and intensities related to financial performance in subsequent years? (2) Are R&D and royalty and technology licensing expenditures and intensities related to the market value in subsequent years?

The results of this research will demonstrate the influence of R&D involvement and royalty and technology licensing expenditure on operational performance in the biotech medicine industry; further, it will provide an in-depth managerial implication with respect to resource management and the innovation strategy of firms.

In section 1 relevant literature reviews and hypothesis development are presented. Section 2 specifies the data and methods, which include sample selection, measurement variables, and the estimation method. Section 3 presents the empirical results. The last section summarizes the empirical findings and provides concluding remarks.

1. Literature review and hypothesis development

1.1. Literature on operational performance. Venkatraman and Ramanujam (1986) suggested that operational performance was related to the economic goals of firms. However, apart from financial performance, companies must also target market value. Thus, the measurement of operational performance is not solely based on one index (Subramanian and Nilakanta, 1996). With regard to the financial performance index, the measurement in past literatures (Erickson and Jacobson, 1992; Venkatraman & Ramanujam, 1986) was based on the Return on Assets (ROA), Return on Equity (ROE), and Earnings per Share (EPS). The literature on market value (Griliches, Z., 1981; Ayadi et al., 1996) demonstrated that it is stable to measure corporate market value using Tobin's Q, which reflects the profits of R&D to the best possible extent. This paper is the first study to investigate the operational performance of the Biotech medicine industry in Taiwan from the technical innovation viewpoint.

1.2. Technology innovation, operational performance, and hypothesis development. The strategies for corporate technical innovation include two sources. One is to conduct their own research and the other is the external contracting of know-how or patents. These two sources of technical innovation will be examined in the following manner: The importance of expenditure on internal technological innovation and operational performance-research development has a significant influence on corporate performance. Edvinsson and Malone (1997) suggested that involvement in research development was the motive of corporate innovation and value and it revealed a positive influence on corporate operational performance (Lev and Sougiannis, 1996; Hsieh et al., 2003; Sher and Yang, 2005). Sougiannis (1994) studied the influence of R&D expenditure on previous year's profits and found that R&D expenditure was strongly related to earnings from 1974-1994; an increase of one dollar in R&D expenditure resulted in a two dollar ROI and a five dollar increase in market value in the subsequent 7 years. Deng et al. (1999) indicated the influence of R&D and patents on the B/M ratio in the subsequent 3 years and found a significant relationship between technological innovation and corporate operational performance. A large number of literatures have demonstrated the positive correlation between R&D intensity and corporate value (Dowell et al., 2000; Ballou et al., 2003; Konar and Cohen, 2001; Bauman, 1999). The studies of Woolridge (1988) and Chan et al. (1990) suggested that in the high-tech industry, an increase in R&D expenditure would reveal a positive effect on corporate operational performance; however, in the low-tech industry, the increase in R&D expense would reduce operational performance. Hsieh et al. (2003) investigated the returns of R&D expenditure in the pharmaceutical and chemical engineering industries and found a positive correlation between R&D intensity and corporate performance; the return of investment in R&D exceeded industry capital. R&D investment influences corporate market value and it would cost twice as much as the investment in fixed assets. These findings affected the investment strategies of firms. This implied that a greater amount of investment in R&D would lead to uniqueness and continuous competitive advantages for firms. Hall and Bagchi-Sen (2002) targeted 74 biotech firms in Canada and studied the correlation between R&D intensity, innovation, and performance from 1994-1997. Findings demonstrated that the development of new products and the introduction of manufacturing innovations could increase the total profits and sales of products, increasing overall profitability. Product or manufacturing innovation increased a company's competitive advantage and served as the base for operational performance (Brown, 1992; Hames, 1998). Qian and Li (2003) studied the small to medium enterprises in the biotech industry in the United States and represented their innovator's positions according to R&D intensity. The research found a significant and positive correlation between R&D intensity and corporate performance (ROA and ROE).

Royalty and technology licensing expenditure was defined as a technique owners (or those with disciplinary action rights) used to allow innovators to use all or part of the rights and resources available to them such as intellectual property, know-how, trademarks, patent rights, and professional techniques, within the agreed upon timeframe. When pursuing maximum profits, companies cannot rely merely on financial, marketing, and R&D abilities; they must cooperate with external strategic partners and combine creative ideas, knowledge, and resources in order to acquire the complementary resources required in finance, marketing, and R&D. Without strategic partnerships, companies would be more likely to only successfully develop new products. Moreover, after paying royalty or technique maintenance expenses for technical cooperation and licensing, the companies were not only able to reduce R&D cost and time, rapidly learn or absorb external techniques, enjoy new profits (Chesbrough, 2007), but also avoid violating the intellectual property rights of others.

Basant and Fikkert (1996) discussed the innovation of Indian companies and found a significant positive effect of royalty expenditure on the output of target firms. However, R&D expenditure did not reveal a significant effect on the output. Johnson (2002) suggested that with the interaction between licensing experience and R&D spill-over, research development permitted firms to increase their own R&D ability by absorbing and learning external techniques; corporate scale revealed a positive effect on R&D ability, absorption of spill-over and licensing techniques. Lin and

Chen (2005) targeted technology-intensive companies in the United States from 1976-1995 in order to study the relationship between technical combination strategies and research development performance. The research found that large-scale companies had significant advantages when developing technical innovation because their technical collaboration revealed a synergy effect. Leiblein et al. (2002) suggested that outsourcing or a self-manufacturing operation would result in prominent performance; additionally, the technical performance of firms depended on corporate policy and contract risks. Based on prior research, the following hypotheses are proposed:

H1: The sources of technical innovations are related to operational performance within the year implemented.

H1a: RDI and ROY are related to the financial performance within the year implemented.

H1b: RDI and ROY are related to the market value within the year implemented.

H2: The source of technical innovation reveals a lag effect on corporate operational performance.

H2a: RDI and ROY are related to the financial performance of subsequent years.

H2b: RDI and ROY are related to the market value of subsequent years.

2. Empirical design and data

2.1. Data and sample. This study focuses on publicly traded biotech and medicine companies from 1996 to 2007; samples are based on the industrial classification of public companies modified by the Taiwan Stock Exchange Corporation (TWSE) on June 14, 2007 and the stock classification of GreTai Securities Market in 2007. This study selected firms from the biotech and medicine industry (industry code 22). The financial data used was obtained from the Taiwan Economic Journal Co., Ltd. (TEJ) database. After eliminating firms that were not in the time frame of interest or had incomplete data, a sample comprising 217 firm-year observations was obtained.

2.2. Research design and variable definition. Since there are numerous indicators for evaluating corporate operational performance, this study applied ROE to measure financial performance; the market value was measured using Tobin's Q. In order to encourage R&D in the biotech industry, the Taiwanese government established regulations for investment rewards and tax credits. However, the conditions and tax rate for each firm may not be the same. In order to avoid errors caused by the taxation system, calculations are based on data obtained before the tax margin. In order to measure the relationship between R&D expenditure and operational performance, this study adopted the following variables and measurement techniques:

2.2.1. Dependent variables.

♦ Return on Equity (ROE_i, t)

This study measured the return capacity of shareholders on investment in company *i* in year *t*. This refers to the return on every one dollar invested by the shareholders. The more the ROE the better it is for a firm. The ratio of ROE, is a percentage of income before the income tax division of stockholder's equity.

♦ Tobin's *Qi, t*

Tobin's Q was proposed by Tobin and Brainard in 1968. Morck et al. (1988) suggested that Tobin's Q involved the time value of currency and that it was a positive index for the present value of future cash flow. The numerator of Tobin's Q is the market value of company *i* in year *t*, whereas the denominator is the replacement cost of tangible assets. The advantage of using Tobin's Q is that the calculation standard would not differ due to different accounting practices. The disadvantage was that it was not easy to acquire the cost data and the estimation of replacement costs of assets was complicated. Thus, we followed a simple formula that is similar to Tobin's Q (Approximate Q) developed by Chung and Pruitt (1994). The ratio demonstrated the operational efficiency of companies. When Approximate Q > 1, this implies better operational performance; when Approximate Q < 1, this implies operational performance has declined. The formula for calculating Approximate Q is as follows:

$Approximate\ Q = (EMV+LBV-CA)/TA$,
EMV = equity market value = common stock market value + preferred stock market value,
LBV = liabilities book value = long-run liabilities book value + current liabilities book value,
CA = current assets book value,
TA = total assets book value.

2.2.2. Independent variables.

♦ Research and development intensity ($RDI_{i,t}$)

In this paper, in order to measure R&D expenditure intensity, research development expenditure of company *i* in year *t* was divided by the net operating income as a proxy variable. Previous studies (Lev and Sougiannis, 1996; Hsieh et al., 2003; Ballou et al., 2003; Sher and Yang, 2005) demonstrated a positive correlation between R&D intensity and operational performance; DeCarolis and Deeds (1999) suggested that the biotech industry was a knowledge-intensive industry and the R&D intensity could be an index for innovation. R&D expenditure is significantly involved in the biotech industry and this expenditure serves as the basis for developing new products. Qian and Li (2003) studied medium and small scale biotech industries in the United States and found a positive correlation between R&D expenditure and profit. According to Ernst and Young (2009), the development of the biotech industry in the United States has earned USD $4 billion in 2008; it's the only profitable region in the world. However, the target of this paper is the biotech medicine industry in Taiwan, which is still in the initial stages of development involving high risk. Moreover, the industry involved time-consuming activities such as R&D, animal and human trials, and market entrance. It was an empirical issue and symbols were not expected.

♦ Royalty and technology licensing intensity ($ROY_{i,t}$)

Johnson (2002) investigated that the application of an innovation technique led to the application of a patent for increasing corporate performance. This paper treated royalty expenditure in company *i* in year *t* by dividing business income as a proxy variable to measure the royalty expenditure intensity. The expected sign for this was positive.

2.2.3. Control variables. In order to control the latent factors related to operational performance in the biotech medicine industry, this study introduced the following control variables:

♦ Leverage ($LEV_{i,t}$)

Companies tended to have debts and be restricted by contracts, which may affect their operational performance. Thus, this paper treated the debt ratio (Liabilities/Assets) of company *i* in year *t* as a proxy variable of $LEV_{i,t}$. The expected sign was negative.

♦ Firm size ($SIZE_{i,t}$)

When firm size was larger, the companies had more resources, which benefited corporate development. Lin and Chen (2005) indicated that large-scale companies tended to have advantages in the development of technical innovation. This paper treated the log of total assets in company *i* of year *t* as a proxy variable of firm size. The expected sign was positive.

♦ Year of establishment ($AGE_{i,t}$)

From the resource-based view, well established companies have more experience and resources, which results in a positive effect on operational performance. $AGE_{i,t}$ is the firm age, equal to current year minus year of establishment for company *i* in year *t*. The expected sign was positive.

2.3. Models for estimation. In order to validate the influences of R&D and ROY on operational performance, this study estimated the influence of the source of technical innovation on corporate operational performance using OLS regression analysis. The estimation model is described as follows:

2.3.1. Current effect of source of technical innovation.

$$ROE_{i,t} = \alpha_0 + \alpha_1 RDI_{i,t} + \alpha_2 ROY_{i,t} + \alpha_3 LEV_{i,t} + \alpha_4 SIZE_{i,t} + \alpha_5 AGE_{i,t} + \varepsilon_{i,t}, \quad (1)$$

$$TOBIN'SQ_{i,t} = \alpha_0 + \alpha_1 RDI_{i,t} + \alpha_2 ROY_{i,t} + \alpha_3 LEV_{i,t} + \alpha_4 SIZE_{i,t} + \alpha_5 AGE_{i,t} + \varepsilon_{i,t}, \quad (2)$$

where $ROE_{i,t}$: return on equity for firm *i* in year *t*; *TOBIN'S Q*: market value for firm *i* in year *t*; $RDI_{i,,t}$: R&D expenditure intensity for firm *i* in year *t*; $ROR_{i,,t}$: royalty and technology licensing intensity for firm *i* in year *t*; $LEV_{i,t}$: leverage for firm *i* in year *t*; $SIZE_{i,t}$: total assets for firm *i* in year *t*; variable is given by natural logarithm; $AGE_{i,t}$: firm age for firm *i* year *t*; $\varepsilon_{i,t}$: error term for firm *i* year *t*.

2.3.2. Lag effect of sources of technical innovation. The model for measuring the lag effect of sources of technical innovation is as follows:

$$ROE_{i,t} = \alpha_0 + \alpha_1 RDI_{i,t-k} + \alpha_2 ROY_{i,t-k} + \alpha_3 LEV_{i,t} + \alpha_4 SIZE_{i,t} + \alpha_5 AGE_{i,t} + \varepsilon_{i,t}, \quad (3)$$

$$TOBIN'SQ_{i,t} = \alpha_0 + \alpha_1 RDI_{i,t-k} + \alpha_2 ROY_{i,t-k} + \alpha_3 LEV_{i,t} + \alpha_4 SIZE_{i,t} + \alpha_5 AGE_{i,t} + \varepsilon_{i,t}, \quad (4)$$

where $ROI_{i,t-k}$: R&D expenditure intensity for firm *i* in year *t-k*; $ROY_{i,t-k}$: royalty and technology licensing intensity for firm *i* in year *t-k*; *K*: number of lags.

3. Empirical results and discussion

The empirical results include three parts: descriptive statistics, correlation test, and regression analysis.

3.1. Descriptive statistics and correlation. This study targets the biotech medicine industry in Taiwan with 217 firm-year observations. Table 2 presents the descriptive statistics of the variables in this study. The mean value of the ROE is 9.8% and the mean value of the Tobin's Q is greater than 1; the mean value of the R&D intensity is 15.467, the mean value of the royalty and technology licensing intensity is 0.036; means of control variables LEV, SIZE, and AGE are 30.815%, 14.159, and 23.53 years, respectively. Minimum return on equity is 162.273% and maximum is 59.113%; the standard deviation is 20.213. This implies that the shareholders' returns in this industry are significantly different. The minimum market value is -0.071 and maximum is 6.318; the standard deviation is 1.056. This indicates a significant difference in corporate value. R&D intensity is between 0~567.561 and standard deviation is 58.533. The evidence shows that certain companies are not willing to invest in R&D and others invest large amounts, which results in significant differences. Royalty and technology licensing intensity is 0~1.801 with a standard deviation of

0.192. This implies that few companies are willing to pay royalties. This study reveals that since 2002, there have been few companies that have paid royalty and technology licensing fees in order to facilitate external technical innovation. In other words, in the initial years, domestic companies in the biotech medicine industry tended to conduct their own R&D in order to create a competitive advantage. Some of these companies were probably in the stage of strategic experiment. With regard to the control variables, standard deviations of LEV and AGE are 15.433% and 12.080, respectively. The gaps between minimum and maximum are 72.2% and 47, which demonstrates a significant difference with regard to debts and firm age. Firm sizes are between 11.553 and 15.832 with a standard deviation of 0.864, which suggests that the scales are not significant in the sample.

Table 3 reports the Pearson correlation coefficient analysis, which examines the correlation between the independent variables in the study. In Table 3, there is an insignificant negative correlation between R&D expenditure intensity and royalty and technology licensing intensity, and the correlation coefficients of the variables are less than 0.395 (absolute value). This indicates the low level of correlation between independent variables, which will not significantly influence regression analysis result.

3.2. Regression analysis. *3.2.1. Current effect of the technical innovation source on operational performance.* This paper regresses the dependent variable (ROE, TOBIN'S Q) on the independent (RDI, ROY) and control (LEV, SIZE, AGE) variables. The result of regression analysis is presented in Table 4. In Table 4, adjusted R-squared value in Models 1 and 2 are 0.351, 0.067, respectively. The F-values are significant in the two models (24.335, 4.108) which indicates that these models reasonably fit the data. In order to further recognize the collinear effect of the independent variables in the model to avoid the lack of marginally-explained ability of regression coefficients, this paper determines the collinear effect among variables through the variance inflation factor (VIF). In Table 4, the VIF of the variables is less than 5. This implies that there is no significant collinear effect among the independent variables in regression.

The results of Model 1 show that RDI is negatively related to ROE and ROY is positively related to ROE. Control variables include LEV, SIZE, and AGE, only SIZE is positively related to ROE. This indicates that RDI significantly decreases financial performance in the year implemented, and ROY increases financial performance within the year. In Model 1, one unit increase in RDI intensity decreases the predicted ROE by 0.176, and a one unit increase in ROY intensity increases the predicted ROE by 11.085. SIZE exhibits a strongly positive effect on ROE which demonstrates that larger sizes will lead to richer resources that increase financial performance. The results are not consistent with prior research (Woolridge, 1988; Chan et al., 1990; Qian and Li, 2003 and Hsieh et al., 2003).

In Model 2, RDI and ROY are not related to Tobin's Q. LEV and AGE are negatively related to Tobin's Q, and SIZE is positively related to Tobin's Q. The evidence shows that RDI and ROY can enhance market value but are not statistically significant. The result is not consistent with Hsieh et al. (2003), who compare the return of one US dollar invested in fixed assets in the pharmaceutical and chemical engineering industries and find a positive correlation between R&D intensity and market value. Thus, H1a is supported and H1b is not. In other words, RDI is significantly negatively related to financial performance within the year, but ROY cannot improve the accounting value in the short time. RDI and ROY are not significantly related to market value in the short time.

3.2.2. Lag effect of source of technical innovation on operational performance. Table 5 presents the lag effect of the technical innovation source on operational performance. In the table, the panels indicate that the VIF of the variables is less than 5, which suggests no significant collinear effect. The F-values are significant in the models which indicate that they fit the data reasonably. In model 3, Panels A~C present the RDI is negatively related to ROE. This indicates that R&D expenditure decreases financial performance in subsequent years. The ROY coefficient is positive and noteworthy at a 10% significance level in Panels A and D, Panels B and C are positive but not statistically significant in Model 3. This indicates that ROY exhibits a slightly positive effect on ROE in subsequent years. This suggests that although the involvement in R&D and royalty payments cannot immediately enhance firms' performance, it can reduce the uncertain financial risk of R&D through royalties. The LEV coefficient is negatively related to ROE (Panels B and C). SIZE coefficient is positive and considerable at a 1% significance level in Model 3. AGE has a negative effect on ROE (not significant). The results indicate that lower leverage and large firm size can improve financial performance in subsequent years.

In Model 4, Panels A~D show the RDI and ROY coefficients are positive, and RDI is substantial at a 1% significance level in Panels A~C. This evidence provides that RDI exhibits a strong positive effect on TOBIN'S Q. The result demonstrates that greater R&D and ROY payment in TOBIN'S Q will lead to greater market value. LEV exhibits a negative and significant effect on TOBIN'S Q (at 1% significance level). SIZE is positive and significant at 1% significance level in Panels A and B, Panels C and D are positive and insignificant. AGE is negatively related to TOBIN'S Q (not significant). The empirical results demonstrate that less leverage and large firm size can improve market value in subsequent years. Thus, RDI is strongly related to financial performance and market value in subsequent years. ROY is not related to ROE and Tobin's Q.

Based on the above account, R&D expenditure intensity reveals a significant negative deferred effect (three periods) on financial performance; however, higher R&D expenditure intensity reveals a positive and significant effect on market value except in the fourth deferred period. In other words, RDI decreases financial performance while at the same time it increases market value in subsequent years. ROY cannot improve operating performance in Models 3 and 4. Thus, different sources of technical innovation will result in different effects, advantages, and disadvantages. This is similar to the view of Leiblein et al. (2002), who suggest that R&D or an outsourcing model will lead to prominent performance. The empirical results are similar to those of Ou (1998), who suggests that R&D and operating performance of Taiwanese manufacturing firms, had a deferred effect. The reason for this may be the fact that the biotech medicine industry involves enormous devices, manpower, funds, and time.

Conclusions

Based on the technical innovation perspective, this study examines the influence of R&D expenditure and royalty and technology licensing on operational performance in an emerging industry — the Biotech medicine industry in Taiwan. Noticeably, this paper finds that R&D expenditure in the biotech medicine industry does not increase annual financial performance within the year implemented or subsequent years. This is similar to Ernst & Young's (2008) suggestion that the global Biotech industries are still in deficit. The study differs from previous literatures (Lev and Sougiannis, 1996; Sher and Yang, 2005) which tended to study the e-industry and investigate the relationship between R&D expenditure, patent rights, advertising expenditure, and operational performance. This study follows the new industry classification and considers the influences of different sources of technical innovation on operational performance. It also probes into the influences of internal and external innovative strategies on operational performance. The empirical results are similar to those of Leiblein et al. (2002), who suggest that different operational models reveal different advantages. Royalty and technology licensing reveal a positive effect on financial performance and market value in current and subsequent years. However, the improvement is the most noteworthy in the fourth year. The reason for this may be that the industry invests enormous devices, manpower, funds, and time from the R&D stage to the commercialization stage. Therefore, they cannot expect returns in the short term. For sustainable operations, they must pay royalties in order to acquire licensing or know-how and accelerate their commercialization in order to reduce the uncertainty of R&D investment. This paper finds the complementary effects of the sources of technical innovation on financial performance; thus, this suggests that when firms establish the core value of sustainable operation through R&D technical innovation, they can introduce or transfer techniques as well as apply an external environment and a variety of open innovation models. Thus, they will be able to accelerate commercialization and enjoy higher returns. The contribution of this study can supplement the influence of external innovation on operational performance, which has rarely been mentioned in previous literatures.

With regard to managerial implication, in terms of organizational management, any acquisition model on sources of technical innovation involves advantages and disadvantages. The results of this paper can function as important criteria for managers to evaluate acquisition models of technical innovation sources. Thus, in practice, this paper provides a more complete decision-making model.

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Table 1. Growth in global biotechnology in 2006-2007

Growth in global biotechnology in 2006-2007								
REGION	GLOBAL		USA		EUROPE		ASIA-PACIFIC	
	2006	2007	2006	2007	2006	2007	2006	2007
Revenue (US $ million)	78,354	84,782	58,600	65,200	13,791	12,920	3,289	3,970
Research & development expenditure (US $ million)	29,860	31,806	24,400	25,800	4,246	4,603	401	488
R&D intensity (%)	38.11	37.52	41.64	39.57	30.79	35.63	12.19	12.29
Net income (US $ million)	–7,382	–2,694	–5,600	–300	–857	–1,666	–331	–6
Size of work force (number)	195,640	204,930	141,200	145,300	44,881	47,720	12,970	-
Listed companies (number)	743	798	366	386	159	181	136	149
Non-listed companies (number)	3,717	3,616	1144	1,116	1,589	1,563	602	615
Total number of companies	4,460	4,414	1,510	1,502	1,748	1,744	738	764

Source: Ernst and Young (2008).

Table 2. Descriptive statistics for all variables

Descriptive statistics for all variables					
Variables	N	Mean	Std. dev.	Minimum	Maximum
$ROE_{i,t}$	217	9.755	20.213	–162.273	59.113
TOBIN'S $Q_{i,t}$	217	1.203	1.056	–0.071	6.318
$RDI_{i,t}$	217	15.467	58.533	0	567.561
$ROY_{i,t}$	217	0.036	0.192	0	1.801
$LEV_{i,t}$	217	30.815	15.433	2.072	74.272
$SIZE_{i,t}$	217	14.159	0.864	11.553	15.832
$AGE_{i,t}$	217	23.530	12.080	2	49

Notes: $ROE_{i,t}$ = return on equity for firm i in year t; TOBIN'S $Q_{i,t}$ = Approximate Q=(EMV+LBV-CA)/TA; $RDI_{i,t}$ = (research and development expenditure/net sales) for firm i in year t; $ROY_{i,t}$ = (royalty and technology licensing fees/sales) for firm i in year t; $LEV_{i,t}$ = the ratio of liabilities to total assets for firm i in year t; $SIZE_{i,t}$ = natural logarithm of the total assets for firm i in year t; $AGE_{i,t}$ = year of current period - year of establishment.

Source: The annual reports of biotechnology medicine companies from Taiwanese Security Exchange Committee and Taiwan Economic Journal databases.

Table 3. Pearson correlation of the independent variables

Pearson correlation of the independent variables					
	$RDI_{i,t}$	$ROY_{i,t}$	$LEV_{i,t}$	$SIZE_{i,t}$	$AGE_{i,t}$
$RDI_{i,t}$	1				
$ROY_{i,t}$	–0.013	1			
$LEV_{i,t}$	0.043	0.096	1		
$SIZE_{i,t}$	–0.310**	0.061	0.172 *	1	
$AGE_{i,t}$	–0.223 **	0.301**	0.236 **	0.395 **	1
N = 217					

Notes: $RDI_{i,t}$ = (research and development expenditure/net sales) for firm i in year t; $ROY_{i,t}$ = (royalty and technology licensing fees/sales) for firm i in year t; $LEV_{i,t}$ = the ratio of liabilities to total assets for firm i in year t; $SIZE_{i,t}$ = natural logarithm of the total assets for firm i in year t; $AGE_{i,t}$ = year of current period - year of establishment. ** and * indicate significance at the 1% and 5% levels, respectively, using one-tailed tests.

Table 4. Regression analysis of technology innovation and operation performance – current effect

Variables	Expected sign	Model 1	Model 2	VIF
Intercept	?	–49.555** (–2.499)	–1.189 (–0.957)	
$RDI_{i,t}$	?	–0.176*** (–8.701)	0.001 (0.732)	1.141
$ROY_{i,t}$	+	11.085* (1.829)	0.433 (1.140)	1.107
$LEV_{i,t}$	-	–0.099 (–1.325)	–0.015*** (–3.287)	1.086
$SIZE_{i,t}$	+	4.677*** (3.218)	0.225** (2.473)	1.285
$AGE_{i,t}$	+	–0.065 (–0.608)	–0.015** (–2.218)	1.370
N		217	217	
Adj R-squared		0.351	0.067	
F-value		24.335***	4.108***	

Notes: Model 1 = $ROE_{i,t}$ = return on equity for firm i in year t; Model 2 = Tobin's $Q_{i,t}$ = Approximate Q=(EMV+LBV-CA)/TA; $RDI_{i,t}$ = (research and development expenditure/net sales) for firm i in year t; ROY $_{i,t}$ = (royalty and technology licensing fees/sales) for firm i in year t; $LEV_{i,t}$ = the ratio of liabilities to total assets for firm i in year t; $SIZE_{i,t}$ = natural logarithm of the total assets for firm i in year t; $AGE_{i,t}$ = year of current period - year of establishment; N is sample size. ***, ** and * indicate significance at the 1%, 5% and 10% levelы, respectively, using one-tailed tests. t-values are in parentheses.

Table 5. Regression analysis of technology innovation and operation performance – lag effect

Panel A (lag 1 period)	Expected sign	Model 3	Model 4	VIF
Intercept	?	–85.761***	–2.053	
		(–3.538)	(–1.579)	
$RDI_{i,t-1}$	?	–0.133***	0.004***	1.143
		(–4.539)	(2.758)	
ROY $_{i,t-1}$	+	12.636*	0.318	1.047
		(1.944)	(0.911)	
$LEV_{i,t}$	-	–0.142	–0.016***	1.067
		(–1.592)	(–3.342)	
$SIZE_{i,t}$	+	7.13***	0.271***	1.265
		(4.061)	(2.878)	
$AGE_{i,t}$	+	–0.038	–0.011	1.281
		(–0.303)	(–1.602)	
Adj R-squared		0.236	0.098	
F-value		12.259***	4.956***	
N = 183				
Panel B (lag 2 period)	Expected sign	Model 3	Model 4	VIF
Intercept	?	–42.9**	–2.287	
		(–2.316)	(–1.627)	
RDI $_{i,t-2}$	?	–0.059***	0.008***	1.102
		(–2.685)	(5.004)	
ROY $_{i,t-2}$	+	11.155	0.329	1.113

Table 5 (cont.). Regression analysis of technology innovation and operation performance – lag effect

Panel A (lag 1 period)	Expected sign	Model 3	Model 4	VIF
		(1.603)	(0.624)	
$LEV_{i,t}$	-	–0.131**	–0.014***	1.045
		(–2.000)	(–2.754)	
$SIZE_{i,t}$	+	4.178***	0.264***	1.212
		(3.147)	(2.624)	
$AGE_{i,t}$	+	–0.082	–0.005	1.311
		(–0.877)	(–0.719)	
Adj R-squared		0.128	0.18	
F-value		5.305***	7.445***	
N = 148				
Panel C (lag 3 period)	Expected sign	Model 3	Model 4	VIF
Intercept	?	–41.015*	0.416	
		(–1.857)	(0.251)	
$RDI_{i,t-3}$	?	–0.111**	0.011***	1.119
		(–2.058)	(2.748)	
$ROY_{i,t-3}$	+	15.39	0.532	1.137
		(1.539)	(0.708)	
$LEV_{i,t}$	-	–0.147*	–0.016***	1.021
		(–1.964)	(–2.860)	
$SIZE_{i,t}$	+	4.165***	0.077	1.204
		(2.665)	(0.655)	
$AGE_{i,t}$	+	–0.135	–0.005	1.327
		(–1.278)	(–0.580)	
Adj R-squared		0.105	0.104	
F-value		3.696***	3.666***	
N = 116				
Panel D (lag 4 period)	Expected sign	Model 3	Model 4	VIF
Intercept	?	–84.163***	0.99	
		(–3.673)	(0.823)	
$RDI_{i,t-4}$	?	–0.116	–0.006	1.064
		(–1.489)	(–1.387)	
$ROY_{i,t-4}$	+	25.34*	1.302*	1.124
		(1.983)	(1.943)	
$LEV_{i,t}$	-	–0.219***	–0.015***	1.018
		(–2.708)	(–3.591)	
$SIZE_{I,t}$	+	7.316***	0.043	1.182
		(4.502)	(0.507)	
$AGE_{i,t}$	+	–0.214*	–0.009	1.311
		(–1.952)	(–1.492)	
Adj R-squared		0.232	0.138	
F-value		6.21***	3.749***	
N = 87				

Notes: Model 3 = $ROE_{i,t}$ = return on equity for firm i in year t; Model 4 = Tobin's $Q_{i,t}$ = Approximate Q = (EMV+LBV-CA)/TA; $RDI_{i,t}$ = (research and development expenditures/net sales) for firm i in year t; $ROY_{i,t}$ = (royalty and technology licensing fees/ sales) for firm i in year t; $LEV_{i,t}$ = the ratio of liabilities to total assets for firm i in year t; $SIZE_{i,t}$ = natural logarithm of the total assets for firm i in year t; $AGE_{i,t}$ = year of current period - year of establishment. ***, ** and * indicate significance at the 1%, 5%, and 10% levels, respectively, using one-tailed tests. t-values are in parentheses.