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Evaluating the performance of biotechnology companies by causal recipes ☆

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ABSTRACT

This study empirically investigates six variables and their combinations that may affect revenues of Taiwan's biotechnology industry. Examine variables include annual government investment, annual private investment, number of national biotechnology incubator yearly, number of manufacturers that biotechnology incubators foster yearly, number of patents that listed companies own yearly, and listed companies' annual R&D expenses. Using original and incremental Taiwanese data, this study contrasts conventional multiple regression analysis (MRA) of net effects and fuzzy-set qualitative comparative analysis (fsQCA) of causal complexities. Results indicate that fsQCA outperforms MRA and successfully models both types of data with causal complexities.

1. Introduction

Initially in 1984, the US Office and Technology Assessment defined biotechnology as "The application of an organism (or part of an organism) by using technology to improve products, plants or animals, or to develop micro-organisms for specific use." In 1995, the US Commission on Science and Technology merged the original two definitions as "biotechnology is a powerful functional technique using part of organism(s) to make or improve products, plants, or animals, or to develop microorganisms' specific purposes are also treated as biotechnology."

Taiwan's Industrial Development Bureau defines biotechnology as "the use of life science methods (e.g., biotechnology cell, immunology, molecular biotechnology, genomics, and proteomics) and relevant knowledge and skills (e.g., protein engineering, cell engineering, genetic engineering, and tissue engineering) to develop and manufacture products" (MOEA, 2007).

Vital for maintaining human life and health (Oster, Shoulson, & Dorsey, 2013), biotechnology industry includes chemicals, electronics, materials, machinery, and other industries involving in medicine, medical supplies, marine, energy, agriculture, general foods, and health foods as well as environmental protection, and green energy. Biotechnology industry has five major markets: plant drugs, medical equipment, biotechnological applications (e.g., energy and environmental protection), agricultural biotechnology, and health food. With the aid of effective technology infrastructures and industrial policies, the United States was the first country to develop and promote the biotechnology industry. Organization for Economic Co-operation and Development (OECD) countries (mainly the U.S., Germany, France, Canada, and the UK), universities and public laboratories own thousands of biotechnology patents.

Intense research and development (R&D) and innovation are the primary characteristics of the biotechnology industry, which seeks to create corporate value by commercializing their results. Advance intellectual property—notably leading-edge patents—is biotechnology enterprises' central performance (Griliches, 1984).

Fig. 1 shows Taiwanese companies trading their shares publicly since 2006. In 2012, there were 71 companies of which 23 were listed and 48 were traded over the counter (OTC). In 2013, there were 21,208 employees in Taiwan's biotechnology industry, and annual market value exceeds US$53 billion (MOEA, 2013).

Since biotechnology is a growing as large-scale industry in Taiwan, understanding the factors affecting its performance is critical. This study explores those factors using multiple regression analysis (MRA) and fuzzy set qualitative comparative analysis (fsQCA). The next section reviews literature relevant to the performance of biotechnology companies. Successive section introduces the research methods involving MRA and fsQCA, compare empirical results, and conclude with discussion.

2. Literature review

2.1. Investment

Economists defines "investment" as spending on necessary resources to produce goods and services (Bishop, 2009). Private investment is crucial for biotechnology industry. Studies of Japanese small-to-medium size enterprises (SMEs) find a significant positive relation between investment and operating performance in Japan's high-tech industry (Morikawa, 2004). Government regulations influences biotechnology industry development, and government must maintain

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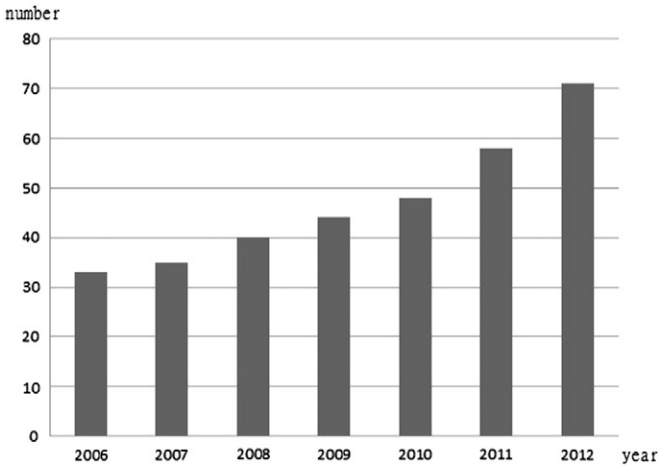

Fig. 1. Number of publicly trade Taiwanese biotechnology companies.

appropriate private R&D investment level because low R&D, small firm size, and lack of domestic competition erode international competitiveness (Marco, 2013).

Investing in technological R&D reduces the risk of technology development for manufacturers. U.S. makes clear conclusion that economies of scale also affect R&D results, which has better tax incentives, patent protections, low-interest loans, grants, and funding mechanisms to reduce development costs and increase revenue. Therefore, this study includes both government and private investments as research variables.

2.2. R&D

R&D involves the systematic and creative increase of knowledge, including knowledge of mankind, culture, and society, and using knowledge to devise commercial applications (Manual, 2002). R&D encompasses product development and innovation (Yalcinkaya, Calantone, & Griffith, 2007), and R&D expenditures are the key indicators of government and private sector effort to gain scientific and technological advantage (OECD, 2011). Rapidly changing technology, innovation, and R&D have become the biotechnology industry's primary means of competition (Huarng, 2010). R&D influences firms' growth and profitability and produces sizable economic benefits (Jeon & Kim, 2011). When firms increases R&D investment, entry barriers also rise and become important determinants of differences in profitability (Sujit & Padhan, 2012). Therefore, this study employs R&D relevant variables to examine its research objective.

2.3. Patents

Patent is an interpretation of industrial property laws of the country which grants it. Thus, patents bestow a particular status of invention (Manual, 2002). Ernst defines patent as successfully developed technology listed in the patent database, protected by law, and not permitted to be imitated (Ernst, 2001). The number of patent applications validates company's R&D performance internationally and indicates national industrial competitiveness. Innovative capital investment and patents accumulation via R&D affect corporate performance and are relevant intangible assets (Lin, Lee, & Hung, 2006). Zeebroecka, Pottelsberghe, and Guellecd (2009) argue that the number of patent applications to the European Patent Office (EPO) is stable and reliable measure.

Innovation is a dominant concept in business (Kim & Huarng, 2011). Previous studies compare the number of patents and product sales within R&D output to establish a model for assessing the positive impact of R&D investment on output and income (Crépon, Duget, & Mairesse, 1998). Like the previous studies, this study emphasizes the number of patents as an indicator of performance, but unlike previous studies it examines their effects on revenues of Taiwan's biotechnology industry.

2.4. Incubator

Incubator is a facility that nurtures startup companies through strategic assistance and value-added monitoring (Hackett & Dilts, 2004). Experience in developed and developing countries reveals that successful incubator serve many functions, focus on intangible business services, employ qualify managers and staff, and are profit-oriented. Business incubator offer companies an affordable space and support, and assist their creation and survival during early stages of growth (Allen & McCluskey, 1990). Incubator counsel companies to obtain information about agglomeration effects and how technology, capital, and expertise accelerate product development by entrepreneurial manufacturers (Mian, 1996). Knowledge of how customers co-create value and how suppliers, R&D centers, and universities co-develop and transfer technologies is important in understanding service innovation (Huarng & Ribeiro, 2014). To match market needs and firms' requirements, the concept underlying an incubator is changing over time (Akçomak, 2009).

Most US biotechnology companies are SMEs (Scaramuzzi, 2002). Whether R&D investments, consumer surplus, and welfare are higher under cooperation depends on the degree of knowledge spillover and the slope of the marginal cost of R&D. Therefore, R&D cooperation, small investments, technology licensing, alliances, and other ways to develop the biotechnology industry are recommended.

Incubators generally receive funding from three resources: industry, government, and universities. They are crucial to biotechnology industry development and aid in establishing its ancillary industries

Table 1
Explanation of relevant variables.

Variable		Explanation
Dependent variable (y)	revenue	Annual revenue of biotechnology industry.
	revenue_ inc	Annual increase in revenue.
Independent variable (x)	g_invest	Annual government investment to the biotechnology industry. Annual increase in government investment.
	g_invest_inc	
	p_invest	Annual private investment to the biotechnology industry. Annual increase the amount of private investment.
	p_invest_inc	
	n_incubator	The number of national biotechnology incubators each year. Annual increase in the number of biotechnology incubators.
	n_incubator_inc	
	n_foster	The number of manufacturers that the biotechnology incubators foster each year. Annual increase in the number of manufacturers that the biotechnology incubators foster.
	n_foster_inc	
	n_patent	The number of patents own by the list companies each year. Annual increase in the number of patents.
	n_patent_inc	
	RD_expense	List company's annual R&D expenses. Annual increase in R&D expenses.
	RD_expense_inc	
Multiple regression models		
Original value model		(y)revenue = a + b* g_invest + c* p_invest + d* n_incubator + e* n_foster + f* n_patent + g* RD_expense (a, b, c, d, e, f, g are multiple regression coefficients)
Incremental value mode		(y)revenue_ inc = a + b* g_invest_inc + c* p_invest _inc + d* n_incubator _inc + e* n_foster _inc + f* n_patent _inc + g* RD_expense_inc
fsQCA models		
Original value model		revenue = f (g_invest, p_invest, n_incubator, n_foster, n_patent, RD_expense)
Incremental value mode		revenue_inc = f (RD_expense_inc, n_patent_inc, n_foster_inc, n_incubator_inc, p_invest_inc, g_invest_inc)