ELSEVIER
Technovation 23 (2003) 879–900
technovation
www.elsevier.com/locate/technovation

Virtuous cycle between R&D, functionality development and assimilation capacity for competitive strategy in Japan's high-technology industry

C. Watanabe *, B. Asgari, A. Nagamatsu

Department of Industrial Engineering and Management, Tokyo Institute of Technology, 2-12-1 Ookayama, Meguro-ku, Tokyo 152-8552, Japan

Abstract

Under an unexpected long-lasting economic stagnation, R&D activities in Japan's leading industries have been stagnating leading to destruction of Japan's ambitious virtuous cycle between technology and economic growth. Considering that Japan is undergoing a paradigm shift from an industrial society to an information society that emerged in the 1990s, structural sources of such economic stagnation can be attributed to qualitative heterogeneous nature of such paradigm shift.

Provided that new functionality development, the globalization of the economy and consequent global technology spillovers increase as an information society emerges, R&D activities, functionality development and assimilation capacity for effective utilization of spillover technology construct a subtle dynamic structure essential for the firms' competitive strategy and decision-making policy.

This article, in order to reconstruct competitive strategy for Japan's high-technology industry by shifting a vicious cycle to a virtuous cycle between R&D, functionality development and assimilation capacity, analyzes the dynamism regarding the impacts of functionality development on assimilated spillover technology leading to gross technology stock with significant contribution of sales and R&D intensity.

Keywords: Functionality development; Versatality; Competitive strategy; Self-propagating structure; Japan's high-technology industry

1. Introduction

Japanese society has been undergoing a paradigm shift from an industrial society in the 1980s to an information society in the 1990s (Watanabe and Kondo, 2002). On the other hand, due to an unexpectedly harsh economic stagnation, R&D activities in Japan's leading industries have been suffering from this stagnation resulting in the destruction of Japan's ambitious virtuous cycle between technology and economic growth (Watanabe, 1995).

In the context of the globalization of the economy, an information society induces functionality development and enhances global technology spillovers as a fruit of R&D activities (Watanabe et al., 2001; Griffy-Brown and Watanabe, 1998). Essentially, functionality development, a similar concept to innovation waves, particularly innovations involving new multifaceted functions, with assimilation capacity for effective utilization of spillover technology construct a subtle dynamic structure for the firms' competitive strategy and decision-making policy.

To date, a number of studies have identified the role of R&D activities, and the sources of the inducement of such R&D activities. In addition, some works have already studied the significance of assimilation capacity and the relationship between R&D activities and assimilation capacity (Suzuki, 1993; Bernstein, 1998; Cohen and Levinthal, 1989; Watanabe et al., 2002a). However, none have identified the link between R&D activities, functionality development and assimilation capacity in a systematic way. Jaquemin and Berry (1979) analyzed the entropy as a proxy to measure the state of versatility, which is considered the main source of functionality development. In addition, Kodama (2000) and Watanabe et al., 2002b traced the logistic growth function within a dynamic carrying capacity approach to identify func-

* Corresponding author. Tel.: +81-3-5734-2248; fax: +81-3-5734-2252.
E-mail address: chihiro@me.titech.ac.jp (C. Watanabe).

0166-4972/$ - see front matter © 2002 Elsevier Ltd. All rights reserved.
doi:10.1016/S0166-4972(02)00041-X

tionality development of IT. Meyer and Ausbel (1999) postulated that dynamic carrying capacity depicts the orbit of innovation waves. Since functionality development is a similar concept to innovation waves, its features could be traced by an orbit of innovation waves. Thus, logistic growth within a dynamic carrying capacity approach can be applied to measure functionality development. These works provide constructive suggestions to measure functionality development, thereby correlating this with R&D activities and assimilation capacity for the effective utilization of spillover technology.

This article, in order to reconstruct the competitive strategy for Japan's high-technology industry shifting a vicious cycle to a virtuous cycle between R&D, functionality development and assimilation capacity, analyzes the dynamism regarding the impacts of functionality development on assimilated spillover technology leading to gross technology stock with significant contribution of sales and R&D intensity.

Section 2 analyzes the dynamic interaction between sales, R&D intensity and technology spillover, leading to the significance of functionality development. Section 3 develops the concept of functionality development and its measurement. Section 4 demonstrates the impacts of functionality development on spillover technology. Section 5 identifies the contribution of functionality development to operating income to sales. Section 6 briefly summarizes the concluding remarks.

2. Dynamic interaction between sales, R&D intensity and technology spillover, leading to the significance of functionality development

In the 1980s, during the catching-up process, Japan has been able to achieve a rapid promotion of its technology and has raised the productivity level by concentrating on improving productivity of the relatively scarce production factors in each respective era. Such significant promotions can be largely attributed to the industry's vigorous efforts to invest in R&D, resulting in a rapid enhancement of its technology contributing to improvement in industry productivity levels. Improved productivity and increase in production induced further vigorous R&D investment, which in turn resulted in further enhancement of technology, leading to the creation of a virtuous cycle between technology and economic development. This virtuous cycle is really a source of Japan's competitiveness (Watanabe, 1999; Takayama et al., 2002a,b).

Among the industries undertaking vigorous R&D investment, the pharmaceutical industry with 8.07% of R&D intensity ranks first, while the average R&D intensity in Japan's industry was 3.06% in 1999. Electrical machinery industry shares 34.0% of total industry R&D expenditure with 5.75% of R&D intensity is another R&D intensive industry making these two industries the leading high-technology industries in Japan.

However, after the burst of the bubble economy in 1991, R&D stagnation was intensified. That is why effective utilization of technology from global marketplace gathered from multiple resources has become an important competitive strategy leading to greater concern for assimilation capacity. In fact, how to effectively utilize this substitution potential and maximize multiplier effects with indigenous R&D has become one of the most crucial R&D strategies for the industries (Watanabe et al., 2001).

In order to assess the current state of such virtuous cycle between R&D investment and economic growth as well as the degree of effectively utilizing spillover technology, Fig. 1 presents key perspectives on the dynamic interaction between sales, R&D intensity and technology spillover in the Japanese R&D intensive 30 pharmaceutical and 24 electrical machinery firms (see Appendix B; 54 firms analyzed) over the last two decades (see the details of corresponding analyses Watanabe et al., 2002a; Watanabe and Asgari, 2002).

Analyzing Fig. 1 we note that the sales of both industries continued to increase over the last two decades. Contradictory correlations between sales and R&D intensity demonstrate that in the pharmaceutical firms R&D intensity decreases as the size of the firms in terms of sales increases, while R&D intensity increases as the size of the firms increases in electrical machinery firms. However, we note that change rate of R&D intensity in the electrical machinery firms changed to negative from 1987 (start of the bubble economy) and continued to be negative over the period examined, while this change rate in pharmaceutical firms, although decreased after the bursting of the bubble economy, has been maintained positive over the whole period examined.

The unique correlation between changes in sales and R&D, and change rate of R&D intensity, which are reverse between pharmaceutical and electrical machinery as illustrated in Fig. 2 are summarized in the upper part of Table 1.

Such intricate structure involving contradictory behaviors in different industries displays a unique R&D structure, as demonstrated in Fig. 2, prompting us to develop an equation, which characterizes the unique behavior of R&D intensity as a function of sales with dynamic elasticities as follows:

$$R/S = AS^{be^{ct}} \quad (1)$$

where A is the scale factor; b, c the coefficients and t the time trend.

Taking the logarithm and differentiating Eq. (1) with respect to S, we obtain

$$\frac{\partial \ln(R/S)}{\partial \ln S} = be^{ct} \quad (2)$$

where $b < 0$ for pharmaceutical industry, $b > 0$ for electrical machinery and $c < 0$ for both industries.