Title	Tracing Path of Agile Technology Spillover : A Matter of Fact on Japan Automotive Industry's Performance
Author(s)	Ane, Bernadetta Kwintiana; 渡辺, 千仭
Citation	年次学術大会講演要旨集, 17: 586-589
Issue Date	2002-10-24
Type	Conference Paper
Text version	publisher
URL	http://hdl.handle.net/10119/6790
Rights	本著作物は研究・技術計画学会の許可のもとに掲載するものです。This material is posted here with permission of the Japan Society for Science Policy and Research Management.
Description	一般論文

2D05

Tracing Path of Agile Technology Spillover:

A Matter of Fact on Japan Automotive Industry's Performance

○Bernadetta Kwintiana Ane，渡辺千仭（東工大社会理工学）

1. INTRODUCTION

1.1. Research Background

Japan auto manufacturers have attracted world attention since the end of the 1970s with respect to their capability in maintaining highly efficient new product development system and effective use of manufacturing technology. This excellent is characterized by short product development cycle, creation of diverse model variations, and launch of a number of new models at the same time. By launching a whole range of new models within a short period, the Japan auto manufacturers succeeded in stimulating new demand, and as a consequence enjoyed steady growth and supremacy in the industry worldwide. For instance, during the economic bubble period, domestic market expanded rapidly that induced Japan auto manufacturers doubled number of basic models from 200 to 400 within ten years, as depicted in **Figure 1.**

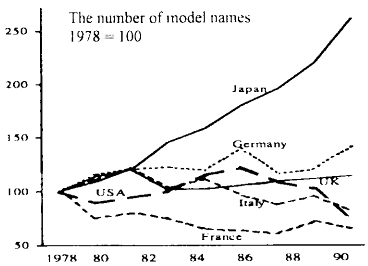

Figure 1. Trend in the Number of Automotive Nameplates.
(Source: Japan Automobile Manufacturing Association, 2000).

However, due to the collapse of "economic bubble" in the beginning of the 1990s, faced with plummeting domestic sales and substantial setback in international competitiveness, thus the Japan auto manufacturers had to focus on the product development system and technology as the target of their rationalization policy.

This paper attempts to provide empirical evidence on the Japan automotive industry performance in the period of 1990-2000 focuses on the primary factors of technology stock and propensity to patent as a proxy of the industry capability to generate innovation.

1.2. Existing Works

In 1995, Ikeda (2000) found that all of the auto manufacturers in Japan had introduced a new development system, which enabled to achieve central aim of 30 percent reduction in cost through (*i*) reduction in the variation of car models; (*ii*) reduction in parts variation by commonization and standardization; (*iii*) lengthening of model change cycles; and (*iv*) shortening of the development period. Theoretically, this newly-adopted development system is to feature an *agile product development* process (Anderson, 1998). In realization, the development system is well-suited to the design of robust manufacturing process-flow (Mishina, 1999), which provides capability to produce high quality products in a sustainable minimum lead time in a world of rapid-changing technology. This process-flow is ideally suited to *agile manufacturing* (Kidd, 1994).

With respect to the Iacocca Institute (1991), Heim and Compton (1992), Whitney (1996) and Anderson (1998), here we define ***agile technology*** as a technology used to design and to manufacture product utilizing precise and dimensionally interchangeable modules and standardized parts, which enable to accommodate a change of process, addition of parts, change of sequence, rearrangement of tooling, and adaptability to new configurations and production rates through an optimal balance of modularity and rapid customizability. Restructuring the product development system concurrently with the implementation of agile technology is to require Japan auto manufacturers to allocate huge of research and development (R&D) investment.

The level and rates of R&D expenditures growth are widely seen as indicators of innovative capacity and as important determinants of productivity gains. A number of studies on R&D, patent and productivity introduced by Bound *et al.* (1984), Pakes and Griliches (1984), Hall, Griliches and Hausman (1986), Scherer (1983), and Acs and Audretsch (1989) had obtained citation. In the construction and interpretation of measures (indices) of advances in knowledge, if one defines K as the level of economically valuable technological knowledge, and $\dot{K} = dK/dt$ as the net accretion to it per unit of time, then evaluation on the usefulness of several indicators of $\dot{K}$ can be done focus particularly on patents and value of the firm. Conceptually, $\dot{K}$ is produced through translating past R&D expenditures and a disturbance term into inventions. Meantime, patents are an imperfect indicator of the number of new innovation, which is generated from the existing K.

The importance of technology diffusion and externalities (spillover) in the innovation process has long been recognized. Early empirical works of Mansfield *et al.* (1977, 1985) and Bresnahan (1986) have explicitly modeled the channels of transmission of spillovers by constructing measures of technology flows or introducing an outside knowledge stock as an input into the manufacturing process alongside a firm's (or industry's) own accumulated R&D stock or expenditures.

In the following parts, Section 2 explains analytical framework that introduce the research proposition and model development, Section 3 clarifies the research findings, Section 4 describes the analysis, and Section 5 summarizes conclusions and its implications.

2. ANALYTICAL FRAMEWORK

2.1. Research Propositions

Relative importance of innovation-based (direct) and diffusion-based (indirect) technology inputs differs widely amongst countries. Investigating technology balance payments amongst major countries between 1995-2000, we find evidence that spillover of automotive technology flows from Europe (US$26,316) to Japan, then diffuse to North America (US$1,499,436) through an assimilation process along with the indigenous technology.

With respect to this evidence, we postulate these following research propositions:

Proposition 1 :

The imported automotive technology is a primary factor, which governs spillover pool of Japan automotive industry.

Proposition 2 :

Technology stock of the Japan automotive industry depends heavily on its indigenous technology.

It is well-recognized that R&D activity is a major source of technological progress and productivity benefits from innovations are not fully appropriated by innovating firms but instead diffuse throughout the industry and country.

2.2. Model Development

Technology flows based on patent data emphasis the role of patents as "carriers" of underlying R&D expenditures. Referring to Pakes and Griliches (1981), relationship between patent, $\boldsymbol{P}$, and past research expenditures, $\boldsymbol{R}$, could be formulated into a statistical model, which combine the properties of both the knowledge production function (*KPF*) and the indicator function relating to P and $\dot{K}$, as illustrated in **Figure 2**.

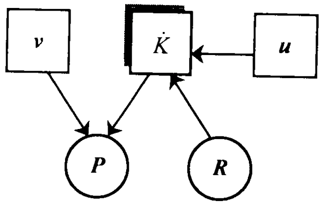

Figure 2. KPF : A Simplified Path Analysis Diagram.

In this paper we introduce a geometric distributed lag model used to measure the indigenous technology (***Ti***) of Japan automotive industry. Theoretically, our model is formulated through synthesizing the technological knowledge stock model of Griliches *et al.* (1981)

$$\dot{K}_{i,t} = a + bt + \sum_{\tau=0}^{5} \theta_\tau r_{i,t-\tau} + u_{i,5} \qquad (1)$$

and the indigenous technology model of Watanabe *et al.* (2000)

$$Ti_t = R_{t-m} + (1-\rho)Ti_{t-1} \qquad (2)$$

then, substituting it into the original distributed lag model of Pyndick *et al.* (1991), which results in this following equation

$$Ti_t = \alpha + \beta \sum_{\tau}^{2} \theta^\tau R_{t-\tau} + \gamma(1-\rho)Ti_{t-1} + \varepsilon_t \quad . \qquad (3)$$

Meantime, in order to test reliability and validity of the model, we compared the geometric model with its polynomial distributed lag model

$$Ti_t = \alpha + \beta\left[c_0(R_t + R_{t-1} + R_{t-2}) + c_1(R_{t-1} + 2R_{t-2}) + c_2\left(R_{t-1} + 4R_{t-2}\right)\right] + \gamma(1-\rho)Ti_{t-1} + u_t \qquad (4)$$

where $\dot{K}_{i,t}$: net accretion to technological knowledge per unit of time; $\boldsymbol{a}$ and $\boldsymbol{\alpha}$: constants; $\boldsymbol{b}$, $\boldsymbol{\beta}$ and $\boldsymbol{\gamma}$: coefficients of related explanatory variables; $\boldsymbol{t}$: time trend effect; $\boldsymbol{\theta_\tau}$, $\boldsymbol{\theta^\tau}$ and $\boldsymbol{c_i}$: weights of distributed lag variables, $\boldsymbol{r_{i,t-\tau}}$ and $\boldsymbol{R_t}$: research expenditures; $\boldsymbol{m}$: time-lag to commercialization; $\boldsymbol{\rho}$: rate of technology obsolescence; and $\boldsymbol{u_i}$ and $\boldsymbol{\varepsilon_t}$: disturbance terms.

In the second stage, we presume that the spillover pool is influenced by *(i)* R&D funds received; *(ii)* R&D funds paid outside; and *(iii)* value of technology import. Therefore, technology stock in Japan automotive industry can be measured using the following equations:

$$T_t = Ti_t + zTs_t \tag{5}$$

meanwhile

$$Ts_t = \delta + \xi Tr_t + \eta Tp_t + \lambda \, \mathrm{Im}_t + v_t \tag{6}$$

$$z = \frac{T_i / T_s}{1 + \dfrac{\Delta T_s / T_S}{\Delta T_i / T_i}} \tag{7}$$

where T_t: technology stock; z : assimilation capacity; Ts_t: technology spillover pool; δ: constants; ξ, η and λ: coefficients of related explanatory variables; Tr_t: technology generated from R&D funds received; Tp_t: technology generated from R&D funds paid outside; and v_t : disturbance terms.

Finally, in the third stage, measurement on the propensity to patent is allowed through modifying model of Pakes *et al.* (1981) using the existing technology stock as an input of patent equation

$$p_t = \varphi + \chi t + \psi T_t + \omega_t \tag{8}$$

where p_t: number of patents; φ: constant; χ and ψ: coefficients of related explanatory variables; and ω_t: disturbance terms.

3. RESEARCH FINDINGS

Applying time-lag to commercialization, $m = 3.3$ years, and the obsolescence rate of automotive technology, $\rho = 0.105$ (Watanabe Database, 2001), we find that value of indigenous technology, both of the geometric and the polynomial distributed lag model, are similar. **Table 1** and **Figure 3** demonstrate the statistical results.

Table 1 Constants and Variables of *Ti* Model

Constants/ variables		Model of *Ti* Geometric	Polynomial
α	:	-20883	-20883
		(-2132.59)	**(-2132.59)**
β	:	0.134	0.134
		(11947.58)	**(11947.58)**
Weights	:	$\theta = 0.937$	$c_1 = -0.597$
		(-9129.82)	**(-2492.70)**
			$c_2 = 0.358$
			(-3103.90)
γ	:	1.24	1.24
		(2311490.83)	**(2311490.83)**

adj.R^2 = 0.99; ***DW*** = 1.27.

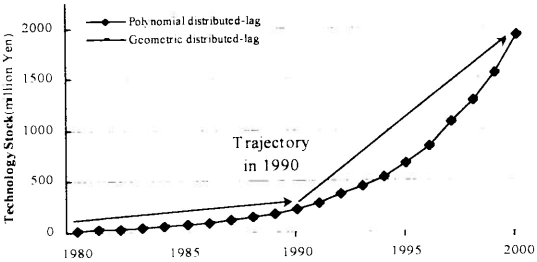

Figure 3. Value of Indigenous Technology, 1980-2000.

Analyzing value of *Ti* between 1980-2000, we find a trajectory in 1990, whereas in the consecutive year its value sharply increases in an exponential growth rate. With respect to this findings, technology spillover in the Japan automotive industry can be determined based on a regression equation as follows:

$$Ts_t = 79088 + 46.2\, Tr_t + 0.289\, Tp_t + 61.5\, Im_t + v_t \tag{9}$$

(0.29) **(4.82)** **(0.32)** **(2.51)**

adj.R^2 = 0.99 ***DW*** = 1.86

Figure 4 and **5** demonstrate the growth of assimilation capacity and technology stock, respectively.

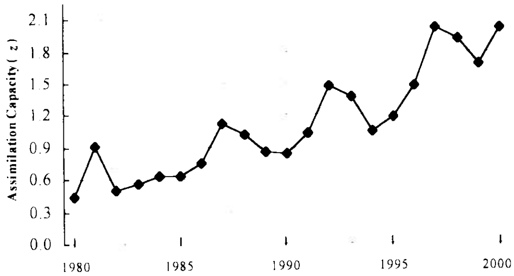

Figure 4. Assimilation Capacity of Japan Automotive Industry, 1980-2000.

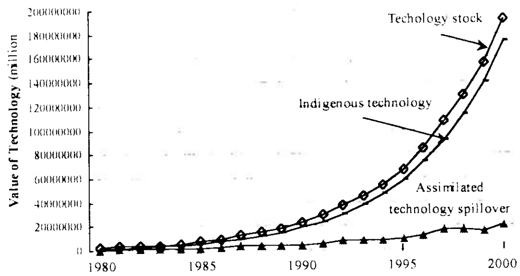

Figure 5. Performance of Japan Automotive Industry, 1980-2000.

In turn, the technology stock along with the time trend effect in the period of 1990-2000 are transformed into a number of patent, which can be estimated using the following regression equation

$$p_t = 25.12 + 1.96t + 0.00000003T_t + 16.25D + \omega_t \quad (10)$$

(2.79) (1.24) (0.23) (1.31)

$adj.R^2 = 0.70 \qquad DW = 1.75$

In fact, a subset of innovations is not transformed into patents, which leads to low propensity to patent (0.00000003) of Japan automotive industry. In order to eliminate bias, we take into account a dummy variable in the patent equation. **Figure 6** demonstrates the actual and the estimated number of patent of agile technology in the Japan automotive industry between 1980-2000.

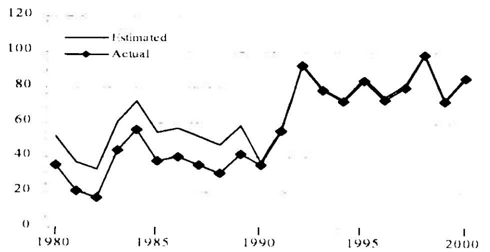

Figure 6. Trend in Patent of Agile Technology, 1980-2000.

4. ANALYSIS

Regarding research proposition 1, based on statistical findings on the spillover pool we find that variables of Tr_t and of Im_t have significant influence on the value of technology spillover. While Im_t, value of technology import, provide more dominant contribution (61.5) in the creation of technology spillover. This findings support to the proposition 1 that imported automotive technology governs spillover pool of Japan automotive industry.

Meanwhile, according to proposition 2, we find that after faced technological trajectory in 1990 value of technology stock in the Japan automotive industry growth exponentially in parallel with the indigenous technology. Meantime, growth of the assimilated technology spillover had no significant contribution to the growth of technology stock. In this regard, we presume it is sourced from the weakness of the assimilation capacity. Therefore, we point out that accumulation of technology stock in the Japan automotive industry depends heavily on its indigenous technology, which support to research proposition 2.

Coping with the assimilation capacity, **Figure 7** depicts relationship between components of assimilation capacity, which implies dependency of Japan auto manufacturers towards their own research organization.

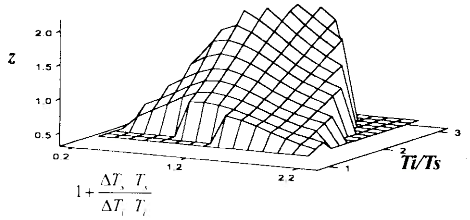

Figure 7. Relationship between Components of Assimilation Capacity, 1980-2000.

5. CONCLUSIONS

On the basis of an empirical analysis on the Japan automotive industry after the collapse of the "economic bubble" period, the following noteworthy findings are obtained:

a. Technology stock of Japan automotive industry is governed by value of indigenous technology and technology spillover amongst auto manufacturers in domestic market, whereas each auto manufacturers depends heavily on their own research organization.

b. Technology import has dominant contribution in governing technology spillover pool of Japan automotive industry. Unfortunately, there is resistance in the adoption of foreign technology, which leads to the need to improve assimilation capacity.

c. In improving the assimilation capacity, Japan auto manufacturers needs to increase level of modularity, and to restructure their product development and manufacturing system to enable development of platform, body styling, and the rest of vehicle body and its interiors concurrently.

d. Through the implementation of newly-adopted development system, auto manufacturers are able to innovate focus particularly on the *preferred modules* or *parts*, which in turn leads to the increase of the industry propensity to patent.

Bibliography

1. Anderson, D.M., 1998, ***Agile Product Development for Mass Customization***, McGraw-Hill, New York.
2. Ikeda, M., 2000, ***The New Product Development System of the Japanese Automobile Industry***, Springer, Berlin.
3. Jurgen, U., 2000, ***New Product Development and Production Networks***, Springer, Berlin.
4. Kidd, P.T., 1994, ***Agile Manufacturing : Forging New Frontiers***, Addison-Wesley Publisher Ltd., Wokingham.
5. Lung, Y., J.J. Chanaron, T. Fujimoto and D. Raff, 1999, ***Coping with Variety***, Ashgate Publishing Ltd., Vermont.
6. Mishina, K., 1999, ***Beyond Flexibility : Toyota's Robust Process-Flow Architecture***, Ashgate Publishing Ltd., Vermont.
7. Papaconstantinou, G., N. Sakurai and A. Wyckoff, 1996, ***Embodied Technology Diffusion : An Empirical Analysis for 10 OECD Countries***, STI Working Papers, OECD.
8. Watanabe, C., 2001, ***Economics Analysis of Technology Innovation***, Dept. of Industrial Engineering and Management – TIT, Tokyo.