1C3 R&D as an engine of technological progress in IT

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Introduction

This paper tries to explain the role and importance of R&D in high-tech industries characterized by high level of uncertainty. To realize this, we will perform a comparative empirical analysis of representative aggregates of a sample of firms in the IT and the automobile industries.

In a relatively stable environment, Utterback and Abernathy who studied competition patterns through the story of the typewriter industry[1] and the automobile industry[2] introduced the concept of a dominant product design and suggested that its occurrence may alter the character of innovation in a firm and an industry. A dominant design has the effect of enforcing and encouraging standardization so that production of other complementary economies can be sought. Then effective competition begins to take place on the basis of cost and scale as well as of product performance.
Furthermore, Nelson and Winter, which studied the historic evolution of industries up to the beginning of the 80's, embody the exploration and development of the dominant design as the basic innovation patterns[3].

However, with the increase in market and technological uncertainties some technologies, such as IT, follow a diverging pattern of competition (Kodama, 1995).

Diverging patterns of innovation

The concept of dominant design appears less applicable and effective in a high-tech industry characterized by a high level of uncertainty. Therefore, this kind of industry is not following the converging pattern implied by the dominant-design theory. Instead, competition among high-tech firms appears to be following a diverging pattern.
Manufacturers cannot survive by selling the old products; *they must invest in R&D* to produce a new generation of products or go out of business. It shows, too, how destructive innovation can be to those who fail to catch the wave. Some companies would appear and others disappear[4]. The shift would occur because of different approaches to technology and management taken by firms in their respective industries[5].

Empirical analysis of the R&D situation in the IT and automobile industries

The data was compiled from annual reports of eight companies, i.e. four from the automobile industry and four from the IT industry[6] for a period raging from 1985 to 1997.

In order to perform this analysis, we will use the following indicators:

R&D intensity: $R\&D_t$ / $Sales_t$
Gives the rate of R&D investment at year t.

R&D efficiency: $Profit_{t+i}$ / $R\&D_t$
R&D efficiency indicates the return on R&D investment after a "*i*" number of years.

i represents the number of years within which a major technology of a designated industry gets obsolete and a new one is introduced. In other words it might be referred too as the technological innovation cycle. This indicator is very important since it shows also how fast a technological innovation would occur from one industry to another.
$i = 2$ for IT industry represented by the computer sector.
$i = 5$ for the automobile industry represented by the passenger car sector[7].
i values were calculated on the base technological innovation cycle for the automobile industry we calculated the life cycle by using the difference in time when a full model change of a product line occurs. On the other hand, for the IT industry we calculated the life cycle of main components i.e. the CPU and OS of a PC.

R&D Stock: $RDS_t = (1-d)\ RDS_{t-1} + RDE_t$

The treatment of R&D as a capital stock rather than a current input implies accumulation of these inputs, in the form of physical factors or stock of knowledge. The stock of R&D capital is the depreciated sum of R&D spending past and present.

R&D investment might depreciate due to many factors, for instance, competitors might develop the same technology at the same time framework. It might also indicate the obsolescence speed of the knowledge available[8].

RDS_t R&D Stock for year t.
RDE: New Expenditure at year t.
d = 1/i: the rate of depreciation; i.e. 50% for the IT industry and 20% for the automobile industry

In other words, R&D stock represents the *accumulation of knowledge* for a certain period. Since the automobile industry has a longer technological innovation cycle the accumulation of knowledge embodied in R&D stock would be more important than the IT industry. In order to compare the level of this ***accumulated knowledge*** we normalized this value by R&D investment value for each respective year.

On the other hand, we normalized R&D stock values by sales which gave a new value that we would call the "***knowledge intensity***", then we calculated its growth rate values which we would call ***"knowledge intensity growth rate"***.

A higher growth would lead to a lower investment in R&D, therefore a low R&D intensity.

Results and interpretation

The results of this analysis are summarized in table 1, where we observe that in average;

a. IT investment in R&D is much more important, i.e. almost double in terms of R&D intensity.
b. The return on R&D in terms of profit is much higher in the IT industry, i.e. R&D efficiency is almost 4 times higher for the IT than the automobile industry.
c. The accumulated knowledge over the studied period is much higher in the automobile industry, i.e. more than twice than the IT industry.
d. The growth of R&D stock intensity is almost nil for the IT industry i.e. -0.1%, and relatively high for the automobile industry, i.e. 10.2%.

Tab.1 : **Arithmetic Mean values of representative indicators**

	R&D intensity	R&D efficiency	Accumulated knowledge	Growth of R&D stock intensity
IT	8.4%	204%	162%	-0.1%
Automobile	4.5%	56%	369%	10.2%

Although IT firms have been heavily investing in R&D (see fig. 1) the level of accumulated knowledge is relatively low (see fig. 3), this is due to the very low level of the growth of R&D stock intensity i.e. -0.1% compared to 10.2% for the automobile industry. This means that the speed of knowledge accumulation is faster in the automobile industry which leads to its technological stability[9].

Since the growth in knowledge for the computer industry is almost nil, in the contrary to the automobile industry, a need to give relatively more importance to R&D investment is a logical consequence as shown in fig.1 of R&D intensity.

Fig. 2 of R&D efficiency shows how important for high-tech industries to invest in R&D. The figure shows that R&D efficiency is higher in the IT industry than the automobile industry, where we suggest that in high-tech industries the main engine for change is technological progress through R&D.
Therefore, where the growth in knowledge is relatively high (see fig. 4: Growth of R&D Intensity Stock), growth in these industries accumulates so fast, that it leads to a situation of a relative technological stability, and the competition direction shifts away from R&D towards other factors that might be cost or diversification, where they are driving the competition.

Conclusion

In this paper, we postulated that in high-technology industries characterized by high degree of uncertainty the main engine for change is technological progress through R&D.
The stabilization direction shifts competition away from R&D towards other factors such as cost and diversification, where they are driving the industry.
We attempted to show this by using R&D indicators. However, this research is not complete and more clarification is needed in order to investigate cost and diversification indicators in these industries.

References:

[1] J.M. Utterback, *"Mastering the Dynamics of Innovation: How Companies Can Seize Opportunities in the Face of Technological Change"*, (Boston, Harvard Business School Press, 1994), Introduction: p.XX, pp.23-55.

[2] J.M. Utterback and W.J. Abernathy, *"A Dynamic Model of Product and Process Innovation"*, (Omega, Vol.3, no.6, 1975), pp.639-656.

[3] R. Nelson and S. G. Winter, *"An evolutionary theory of economic change"*, (Cambridge, Belknap Press of Harvard University Press, 1982).

[4] C. Allani and F. Kodama, *"Product Development Challenge in IT: going through uncertainty and complexity"*, (13th Scientific Conference of The Japan Society for Science and Research Management, Tokyo, 1998).

[5] F. Kodama, *"Emerging Patterns of Innovation: Sources of Japan's Technological Edge"*, (Boston, Harvard Business School Press, 1995), p.99, pp.103-107.

[6] Honda Motor, Mitsubishi Motors, Mazda and Ford for the automobile industry; and NEC, Compaq, Hewlett Packard and Intel for the IT industry.

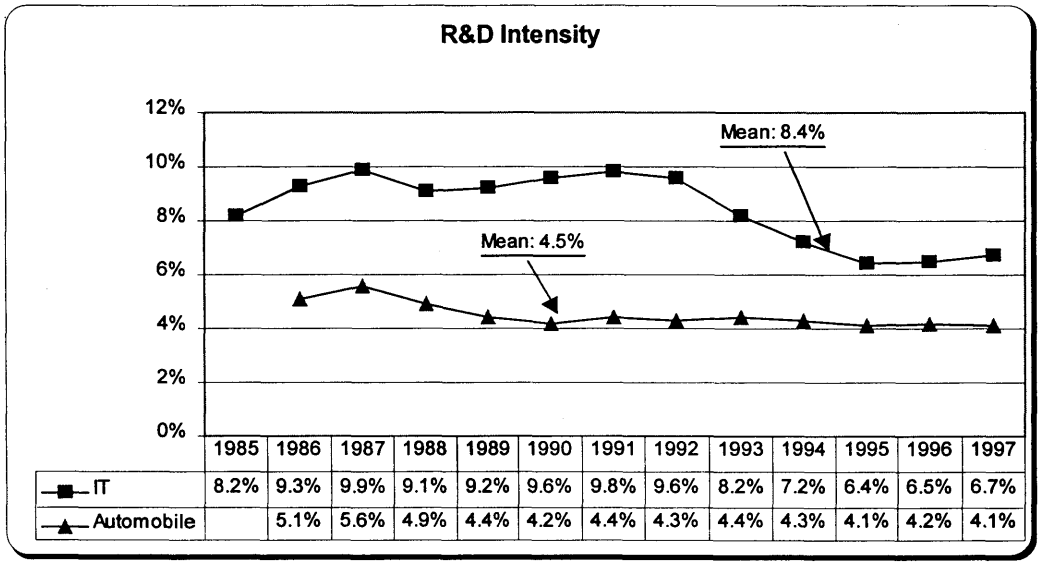
[7] 13th Scientific Conference of The Japan Society for Science and Research Management, *op. cit.*, Ref. 4.

[8] Thomas Hatzichronoglu, *"Revision of the high-technology sector and product classification"*, OECD, STI Working Paper, 1997, p.8.

[9] 13th Scientific Conference of The Japan Society for Science and Research Management, *op. cit.*, Ref. 4.

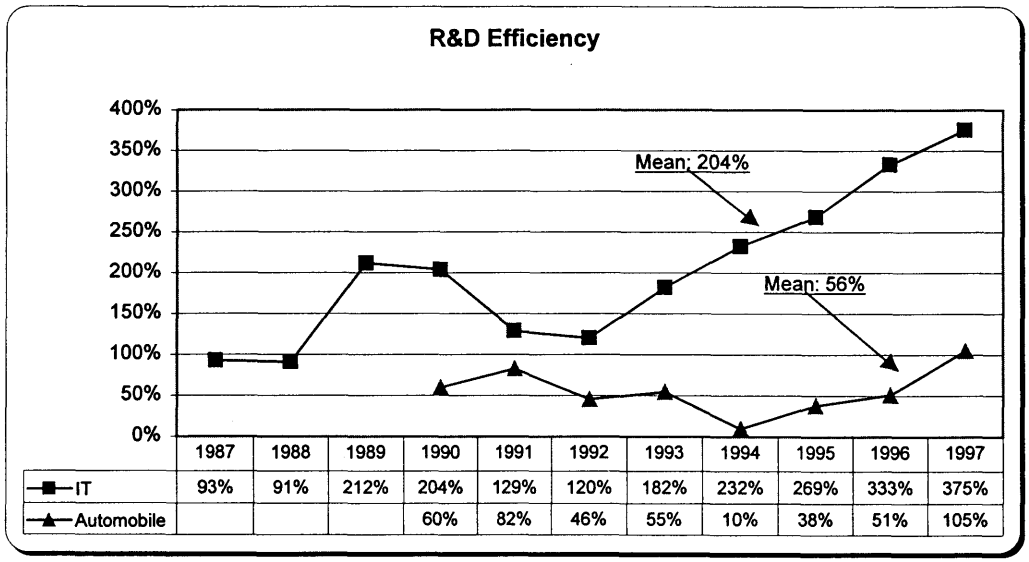
Appendix

Fig. 1:



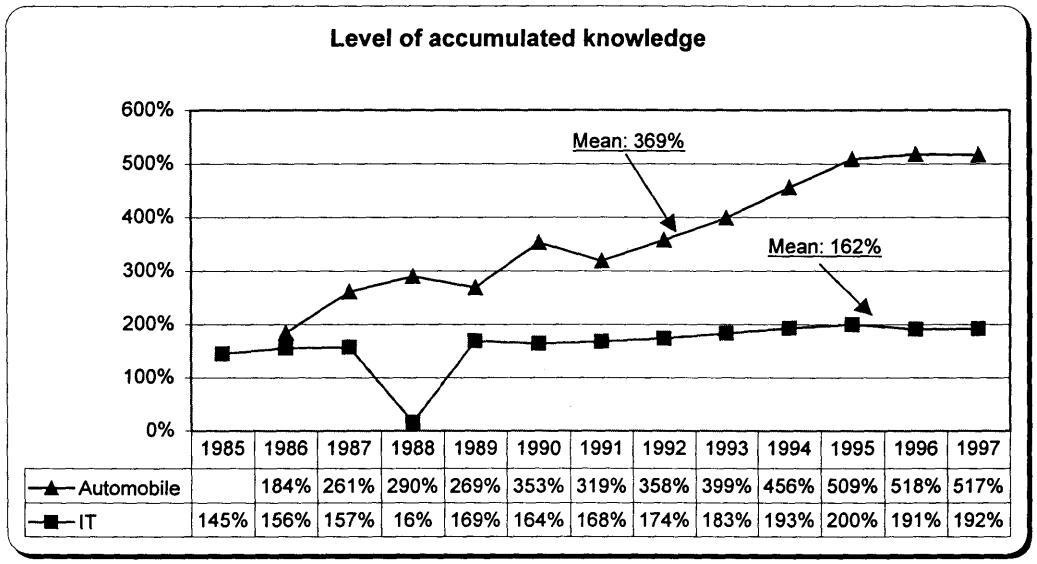
	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
IT	8.2%	9.3%	9.9%	9.1%	9.2%	9.6%	9.8%	9.6%	8.2%	7.2%	6.4%	6.5%	6.7%
Automobile		5.1%	5.6%	4.9%	4.4%	4.2%	4.4%	4.3%	4.4%	4.3%	4.1%	4.2%	4.1%

Fig. 2:



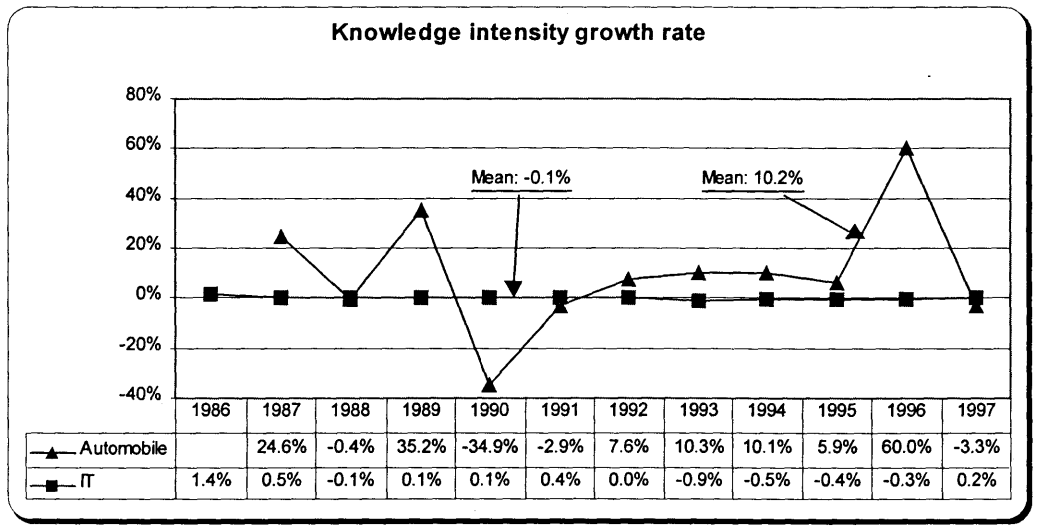
	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
IT	93%	91%	212%	204%	129%	120%	182%	232%	269%	333%	375%
Automobile				60%	82%	46%	55%	10%	38%	51%	105%

Fig. 3:



	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Automobile		184%	261%	290%	269%	353%	319%	358%	399%	456%	509%	518%	517%
IT	145%	156%	157%	16%	169%	164%	168%	174%	183%	193%	200%	191%	192%

Fig. 4:



	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Automobile		24.6%	-0.4%	35.2%	-34.9%	-2.9%	7.6%	10.3%	10.1%	5.9%	60.0%	-3.3%
IT	1.4%	0.5%	-0.1%	0.1%	0.1%	0.4%	0.0%	-0.9%	-0.5%	-0.4%	-0.3%	0.2%