SYSTEM MODELLING ON ANALYSIS OF RESOURCE ALLOCATION OF TECHNOLOGICAL INNOVATION

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ABSTRACT

Technological innovation is a decisive element with high value in modern economic society, and the effect of technological innovation has a great bearing on enterprise's performance. Over recent years evidence has been accumulated to demonstrate that for a enterprise it is necessary to take on a strategic plan, allocating the enterprise's limited resource to R&D to promote technological innovation and monitoring the coordination among the new & existing products under the certain R&D expenditure. The issue is that management traditionally employs the static and experimental method to determine the input of R&D in terms of the ratio to sales. In China there existed a tendency of underestimating the role of technological innovation giving impact to the growth of the firm, e.g. in high-tech industry take only 1-2% or less R&D on sales into tech inno activity, and fixed to almost all kinds of industry with the same ratio of input.

In this paper, two system models are developed to solve such problems, which results in the conclusion of individual ratio is required for different industries.

I. INTRODUCTION

Technological innovation is a decisive element with high value in modern economic society. From the point of view of microeconomics, it makes enterprise to develop more stably and perseveringly, to foster the ability to render a service for self-development of enterprise and social-economic construction.

The efforts of tech inno in enterprise have a great bearing on the enterprise's behavior. The growth rate of productivity is, in the sense of statistics, of great concern to the intensity of expenditure on erterprise's innovation activity. What is called "intensity of expenditure" refers to the ratio of tech inno expenditure to main economic output index, for example, sale.

The ability for enterprise to innovate concerns to expenditure on

technological innovation. Furthermore, productivity does so, too. There exists, however, that whether this particilar relation is inevitable to every enterprise. This problem can be transfered to another one: How to promote technological innovation in enterprise? What is the appropriate range over the ratio (R&D expenditure / sale) for the technological innovation activity in different industries?

In the meanwhile, under the decided total R&D expenditure, it is necessary to coordinate the new products through technological innovation with the existing products, balancing the portfolio of the existing products to improve the performance of the enterprise better. To analyzing this problem, all of the products of a enterprise are divided into four kinds according to theory of the product life cycle (here, "A" stands for the products of infancy, "B" stands for the existing products in the stage of development, and "C" and "D" for the maturity and decline correspondingly). Optimal combination of these four kinds of products the formulate another problem.

In a word, it is necessary to reach a conclusion of appropriate expenditure ratio to R&D and technological innovation in the light of reality in China. We hold that the research and its results in this paper may establish the new field in problem of optimum R&D expenditure.

II. Establishing expenditure policy-making systems

1. Total R&D resource allocation model

Every innovative activity, in every enterprise and every development stage, indicates three types of inputs: capital, researchers and expenditure on R&D to promote technological innovation. Generally speaking, the advancement of technological innovation is, in a great extent, affected by some indeterminate factors, which formulate one of the important features to innovation activity and are related to the probability of expenditure on R&D. To solve such problem, total R&D resource allocation model (TRDRAM) is developed.

First, general framework of TRDRAM is provided as Fig. 1 shows. In fact, technological innovation in enterprise has more and more widespread and profound influences on economy. In a general sense, technological innovation not only offers economic benefits, but also gives long-term benefits to heighten technology level, establish innovation ability and exert a strategic influences on transfering potential strength to real one.

The scale and structure of technological innovation affect the growth rate, direction and type of economic growth. From the point of view of economy, technological innovation is an actual input which can take place of labor and capital, and becomes the first key factor, though scale of economy is another inneglectible one. There are points for attention that total investment is an intermediate and support to increase of productivity. Most innovation results require investment on production, without that there's no effective results from innovation on economic growth. Similarly, scale of economiy depends on investment, too. In a word, the most common and active element for productivity increase is the effect of innovation.

When we further study the structures and relations concerning enterprise's economic growth and technological innovation, we have the general cause and

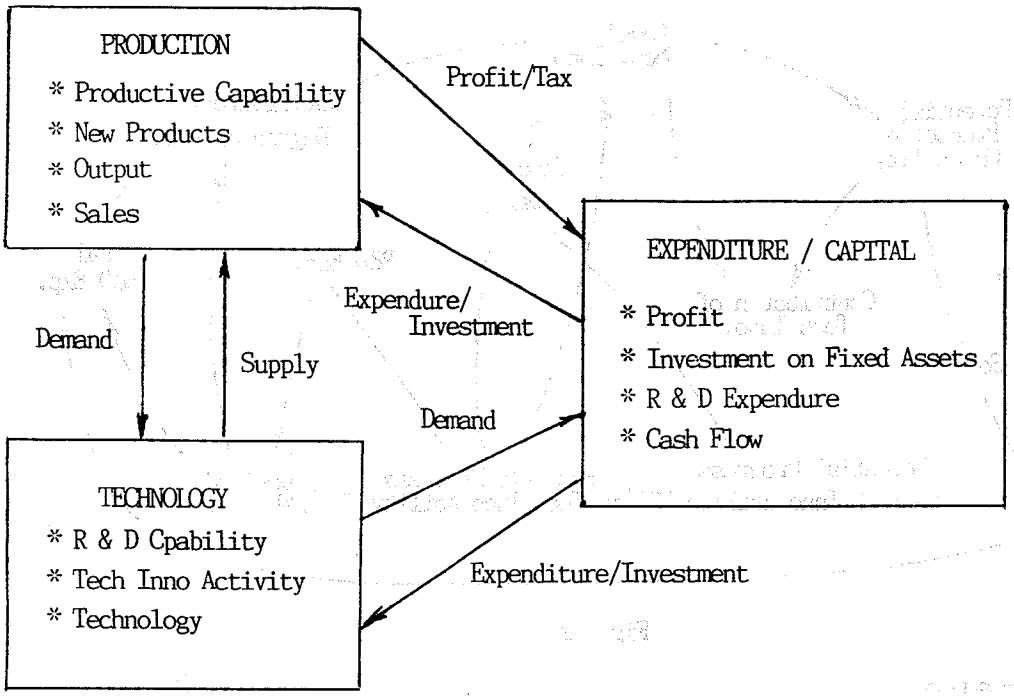

Fig. 1

effect diagram as Fig. 2. In this diagram, workforce (labor), fixed assets and technological innovation level constitute independent variables determining the output.

In fact, loop.1 (output-investment on fixed assets) is a positive feedback. On the other side, loop.2 is a negative one because capital (materialized labor) will gradually substitute for labor (workforce) in virtue of the innovation effects, and finally restrains growth rate of output and increase of fixed assets as well.

If we make detailed research into structure of innovation in Fig.2, we'll find that technological innovation activity itself can be regarded as a subsystem. From a systematical view, technological innovation exerts structural pressure on economic system and is absolutely not a "remainder" of economic activity. From this view point, technological innovation forcefully depends both on special economic condition and on evolution of technological system itself.

1) basic behavior of TRDRAM

In TRDRAM, we are aimed to obtain the optimum range of expenditure on R&D, from which we can better understand the features of technological innovation. The several curves from S.D. model are presented as followings:

From the results (curves in Fig. 3) above, it is clear for us that the proportion of expenditure on R&D from sale increases and gradually stablizes.

The proportion of contribution from technological innovation, fixed assets, and labor for enterprise's growth rate, over time reach the stable limit (see Fig. 4), that is the dynamic equilibrium of technology change and scale

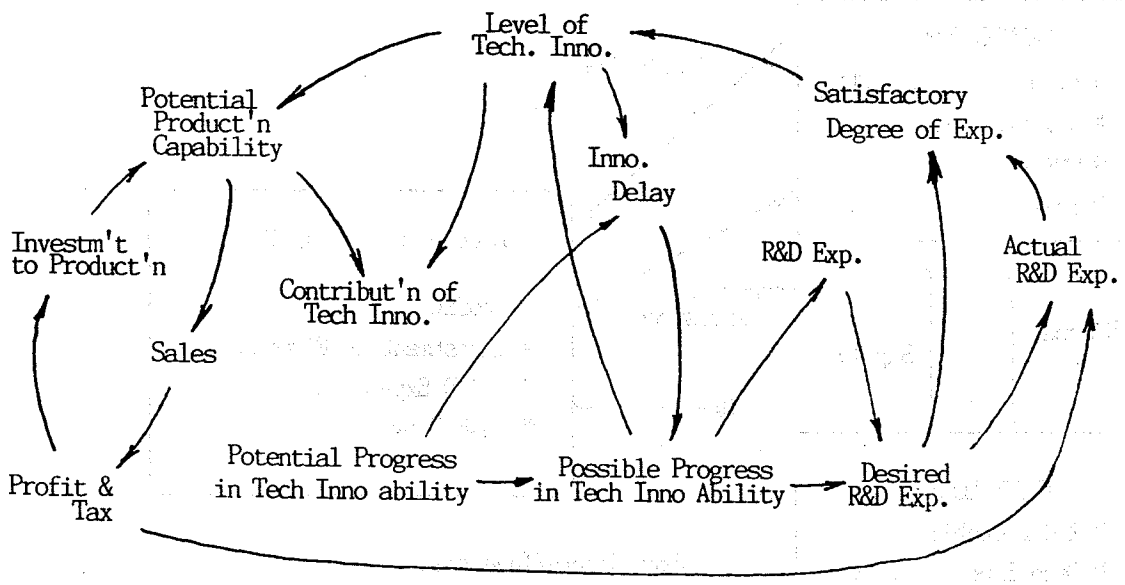

Fig. 2

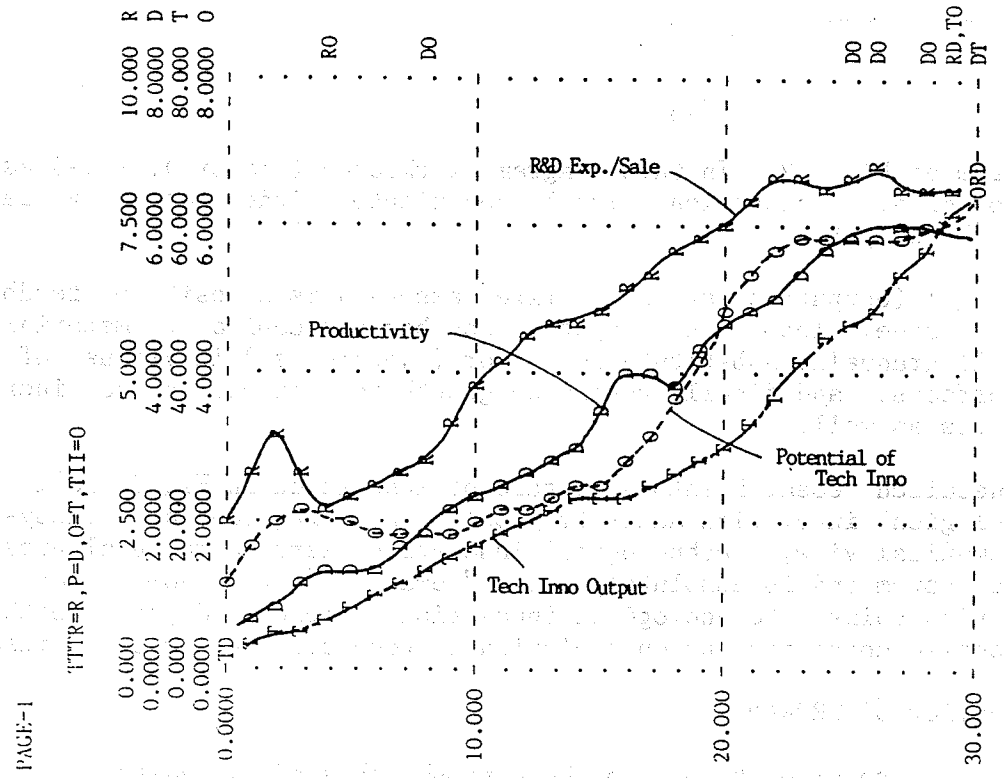

Fig. 3

economy. In the early development, for the enterprise, the contribution of fixed assets is larger than that of technological innovation, but, several years later, the level of technological innovation increases very fast, the contribution of technological innovation plays the dominant role.

The return on investment in technological innovation, as the basic run behavior shows, declines and stablizes at a constant, for the accumulation of output of technological innovation and the improvement of the level of

technological innovation, the ability of settle the technological problem is more stronger than that of tranferring the output of technological innovation to commidities. (see Fig. 4)

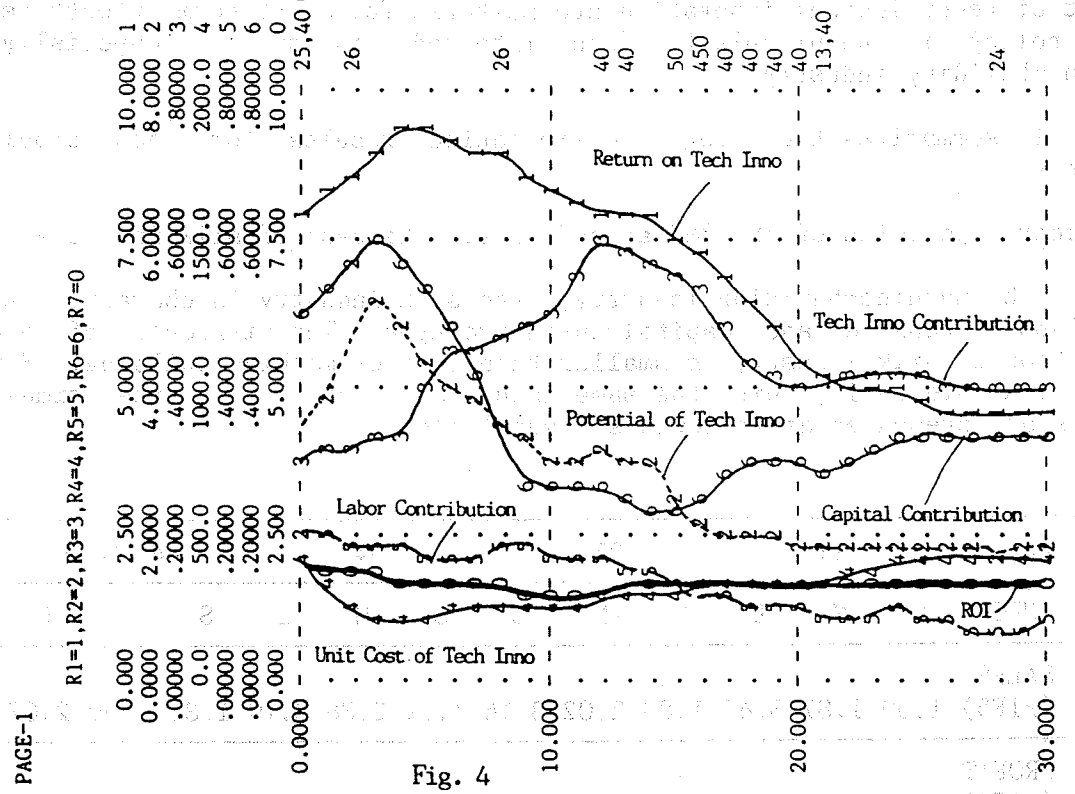

Fig. 4

2) Policy test

In the policy tests, we will analyse what the suitable range of expenditure on R&D from the sale is, and the different characteristics of different industries on technological innovation.

(1) Control policies of R&D expenditure, the case of machine-building industry

The main characteristics of machine-building industry lies in the fact that tech development is in the state of maturity and the high rate of technological innovation. The simulation shows the bahavior when we set up 1% of sales to promote technological innovation as followings: (compared with the situation of 3% investment on R&D)

In the early development stage, the sales decreases 5.5%, so does the profit with the number of 8%. The reason for such conclusion is that the insufficient investment on R&D will cause the inadequate push force for technological innovation, and the total tech level declines 14.7% or so. But at the same time, the innovation focuses on the profit in the near future, the actual application rate of the output of technological innovation goes up, and the proportion of new products only declines 1%.

In the late of development, the insufficient investment on R&D becomes very obvious, the sales, compared with the situation in 3% investment, increseas 10.1%, but the profit do decline 21%, the productivity follows the the profit and declines 18.5%.

In short, from the total process of development, 1% investment on R&D takes a negative effect in short time, let alone in the far future. Though the output of technological innovation are suitable for short-term effecttiveness, this policy is unsuitable for tech intensed industries, especially for machine-building industry.

Table 1 summarizes the integrated simulation results for machine-building industry.

(2) Control policies of the R&D expenditure, the case of silk industry

Unlike the machine-building industry, the silk industry is characterized by its labor-intensive and capital-intensive type. The difficult of average innovation of silk industry is smaller than that of machine-building. Similar to the analysie in 1), with the same inputs and tech level, the simulation results are presented as followings (see Table 2).

RATIO	1%			2%			3%			4.5%		
INDEX	S	M	L	S	M	L	S	M	L	S	M	L
SALES (x1E5)	1.69	1.87	3.46	1.89	2.02	3.16	1.79	2.86	3.19	1.86	1.99	2.67
PROFIT (x1E5)	0.61	0.66	1.04	0.68	0.17	1.12	0.64	0.78	1.32	0.66	0.71	0.94
PRODUCTIVITY (1E4/Per Capita)	0.69	0.78	1.43	0.77	0.92	1.53	0.79	0.96	1.76	0.81	0.89	1.44

Table 1. R&D expenditure policy analysis in machine-building industry

(Notes: S--- short-term; M--- middle-term; L--- long-term)

RATIO	0.35%			0.5%			0.7%			1.0%		
INDEX	S	M	L	S	M	L	S	M	L	S	M	L
SALES (x1E5)	2.82	3.27	4.79	2.82	3.16	4.22	2.82	3.16	4.43	2.97	3.15	3.02
PROFIT (x1E5)	0.31	0.33	0.42	0.31	0.35	0.45	0.31	0.35	0.48	0.31	0.34	0.40
PRODUCTIVITY (1E4/Per Capita)	2.12	2.22	3.16	2.23	2.35	3.44	2.00	2.23	2.52	3.79	2.23	2.34

Table 2. R&D expenditure policy analysis of silk industry

As productivity is a very important factor for enterprises as well as for our nation, we will analysis the proper range of R&D expenditure which can improve the productivity. Here, according to the policy test, 2-3% R&D expenditure to sales, is the best choice for machine-building industry. For silk industry, 0.5-0.7% is the candidate.

2. Coordinated allcation model to new & existing products (CAMNE)

With the help of a dynamic analysis, another system dynamic model (CAMNE) is constructed, focusing on the coordination of the existing products under the certain total R&D expenditure. This model is composed of three subsystems, including the finance, existing products and new products R&D. Fig. 5 describes the general skeleton of CAMNE.

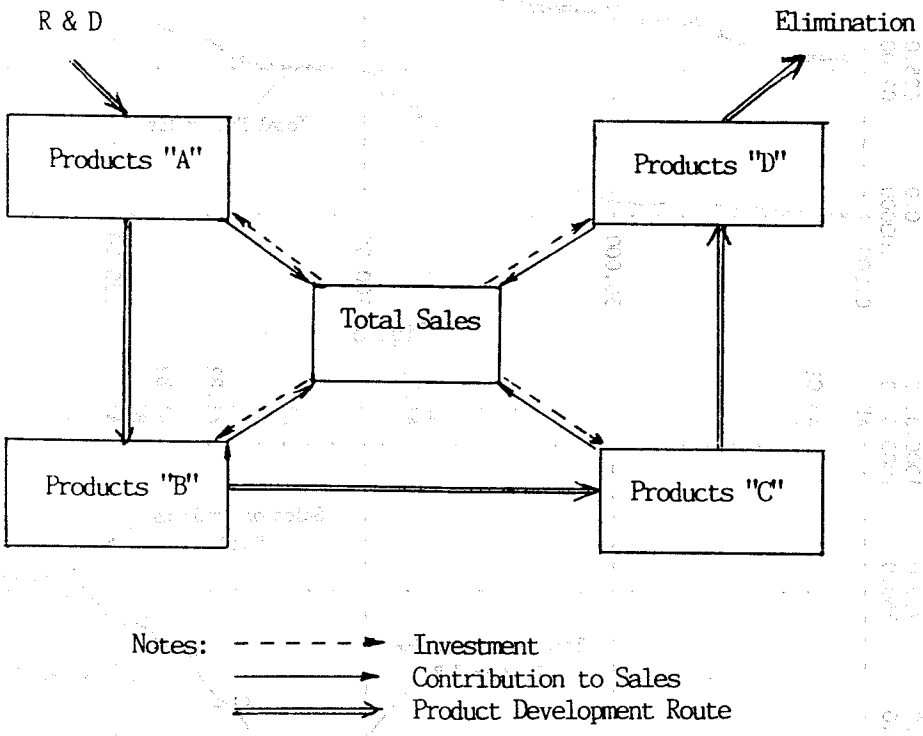

Fig. 5

Under a set of assumption and control policies, the basic behavior of CAMNE in 200 months is simulated as follows: (See Fig. 6)

According to the simulation in Fig. 6, we will see that under the 3% of total R&D expenditure ,with existing products proportion of 2:4:2:2, the ratio of investment in the new products to enterprise' sales will reach the upper limit (alout 9.0) during the time prior to month 100, so the profit increase gradually with 11 percent growth rate. But the return on investment decreases (from 2.5 to 1.8) because too much investment in products A.

Fig. 7 shows the dynamic behavior of the new & existing products under the decided total R&D expenditure (3%).

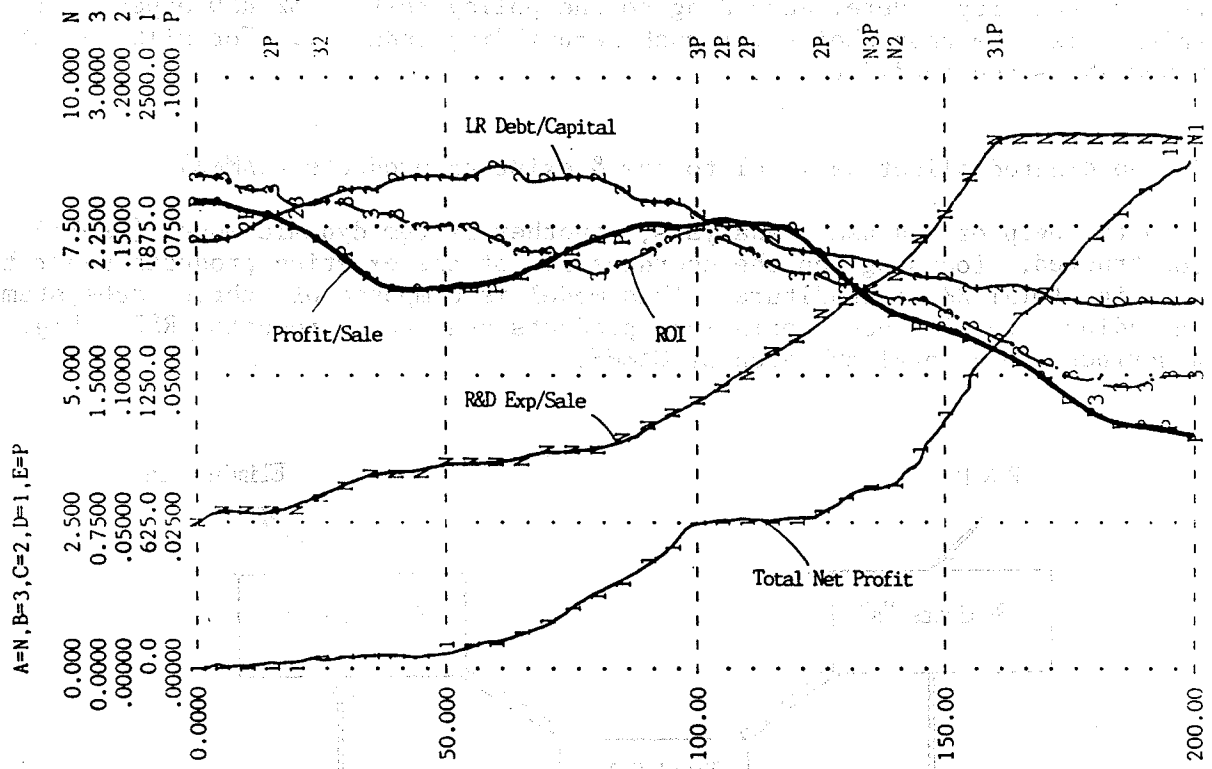

Fig. 6

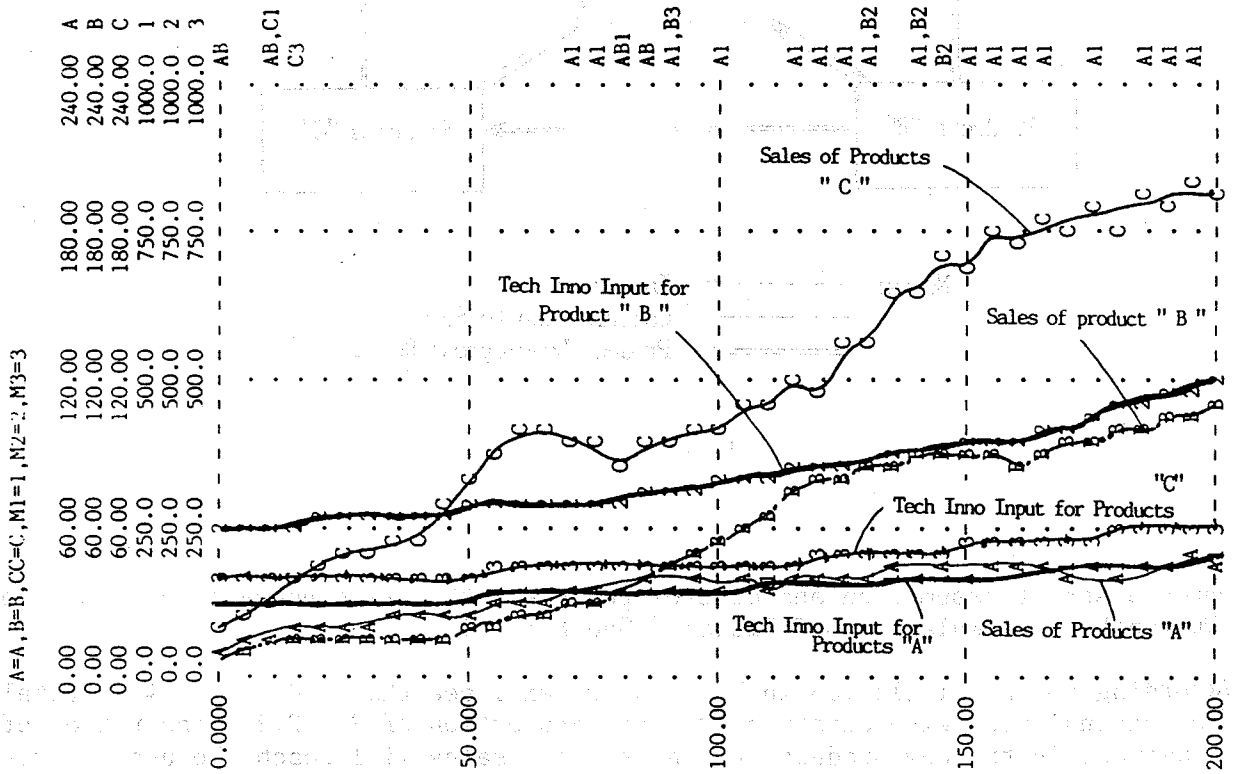

Fig. 7

III. Conclusion

No matter how the enterprises inside condition or outside environment is, there always exist many recognized or unknown factors more or less affecting the economic development and tech advancement. As a development country, enterprises in China must make a rational policies to promote the technological innovation, maintaining homogeneous relationship between economic development and tech advancement, keeping a suitable proportion expenditure on R&D to promote technological innovation.

Under the existing condition of economy and science & technology in China, the general process of enterprise's development and tech advancement abides by the "s" type discipline. According to the simulation, in the early stage, slow speed of innovation exists because of the lag of tech level and the insufficient capital for technological innovation. Afterwhile, with the relaxation of these two restraint factors, innovation will grow fast, and enters the stable state because of the limitation of tech level itself.

So, for enterprises in China, either high or low expenditure on R&D to promote technological innovation is unsuitable, for machine-building industry, as the simulation shows, 2%-3% is advised as a proprotion of expenditure on R&D from sales, and for silk industry, takes 0.5%-0.7%. The different results is due to the different industries, which we must know while making the expenditure policy for R&D.

Under the definite R&D expenditure to promote technological innovation, it is better to pay special attention for the rational new & existing products structure for the better performance of the enterprise. 2.5:4.0:1.0:0.5, which through many tests, is advised as proper investment ratio for the four kinds of new & existing products, such has been the case when the percent of R&D expenditure to total sales is 2.5 for the medicine industry.

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