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The Feedback Loop between Technology and Economic Development: An Examination of Japanese Industry

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ABSTRACT

The Japanese economy has grown remarkably because of the driving force of industrial development. This has been largely attributed to the feedback loop between technological development and economic growth. Japan may now face the prospect of the loop's deconstruction, however, because industry's research and development (R&D) investment has stagnated as a result of the "bubble economy" and its bursting. This paper first examines the possibility by reviewing systems of Japan's industrial technology. Second, it conducts an empirical analysis of the current state of R&D activities in Japan's manufacturing industry. Third, it analyzes the impact of such activities; and fourth, it explains the structural background of a stagnation of R&D activities.

Introduction

The remarkable development of the Japanese economy has largely been attributed to the driving force of industrial development and its consistent efforts to increase technological innovation [9]. To date, a number of studies have identified the sources supporting Japanese industry's technological advancement [6, 19]. None, however, has taken ecological perspectives into account as an inducing system for such sources. Similar to an ecosystem, Japan constructed a sophisticated system between technology and external technology [33], which can be distinctively observed in the feedback loop between technology and economic development. MITI stimulated and induced industry's efforts by establishing a sophisticated policy system, which has strengthened dynamism conducive to technological development [23, 25].

Following the "bubble economy" and its bursting, along with a change in technological paradigm, however, Japanese industry has been facing a structural stagnation of its research and development (R&D) activities, which may result in the deconstruction of the loop between technology and economic development. As an ecosystem demonstrates, once such a loop begins to deconstruct, remediation of the system becomes irreversible.

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Thus far, Japan has paid limited attention to this possibility, leading to insufficient empirical analyses of the impact of the above deconstruction and structural background of a stagnation in R&D activities on the Japanese manufacturing industry.

This paper examines the feedback loop between technology and economic development in the Japanese manufacturing industry from 1970–1992 and the fear of its deconstruction. Section 2 presents a brief review of Japan's path with respect to economic development and the contribution of technology in paving such a path. Section 3 introduces an empirical analysis and the current state of Japan's industrial technology. Section 4 outlines the impact of the current stagnation in R&D activities. Section 5 analyzes the structural background of the stagnation and Section 6 briefly summarizes the implications for future R&D.

The Role of Technology: Japan's Path

The Japanese economy has shown tremendous growth due to the motivating influence of industrial development and technological innovation [5]. Japan's world gross national product (GNP) share was 1.6% in 1950, 2.4% in 1955, and 3.1% in 1960. It increased to 14.2% in 1988 as illustrated in Figure 1. Despite many hurdles, Japan achieved sustainable development by focusing its efforts on improving the productivity of the relatively scarce resources in each respective era [9]. Technology's significant contribution to this achievement can be distinctly observed in the case of overcoming energy constraints after the energy crises in the 1970s as demonstrated in Figure 2 and Table 1 [29]. The contribution by technology for sustainable development in the face of various constraints proved to be significantly higher as compared to other advanced countries (see Figure 3).

When considering the circumstances of a "constrained economy," it has been pointed out that the majority of efforts to overcome constraints involved in the substitution of constrained (or limited) production factors by unlimited production factors [33]. This is similar to an ecosystem (Figure 4) in that in order to maintain homeostasis (checks and balances that dampen oscillations), when one species slows down, another speeds up in a compensatory manner in a closed system (substitution), while depending on supplies from an external system leads to a dampening homeostasis (complement) [20]. This concept of "substitution" provides informative suggestions to a "constrained economy" [36].

In this particular case energy is a constrained factor and technology is an unlimited production factor. Figure 5 illustrates trends in the substitution of energy for other production factors in the Japanese manufacturing industry [29]. The trends indicate that in order to overcome sharply increased energy constraints caused by the energy crises while maintaining sustainable development, Japan's manufacturing industry made intensive efforts over the last two decades to substitute technology for energy (such as energy conservation technology, oil alternative energy technology, and technologies for improving energy productivity) and later to substitute capital for energy (typically observed in energy conservation investments) [37]. Figure 6 illustrates the outcome of the author's analysis [36] concerning technology substitution's contribution to the dramatic improvement in energy productivity in Japan's manufacturing industry (Figure 2) from 1976–1990. Figure 6 indicates that the substitution of technology for energy caused 44% of the reduction in unit energy consumption, whereas research and development (R&D) intensity and energy price increases produced by the remaining contribution (47.5% and 8.5%, respectively). This analysis demonstrates my hypothesis that technology made a great contribution to improving the productivity of the relatively scarce resources by acting as a substitution resource.

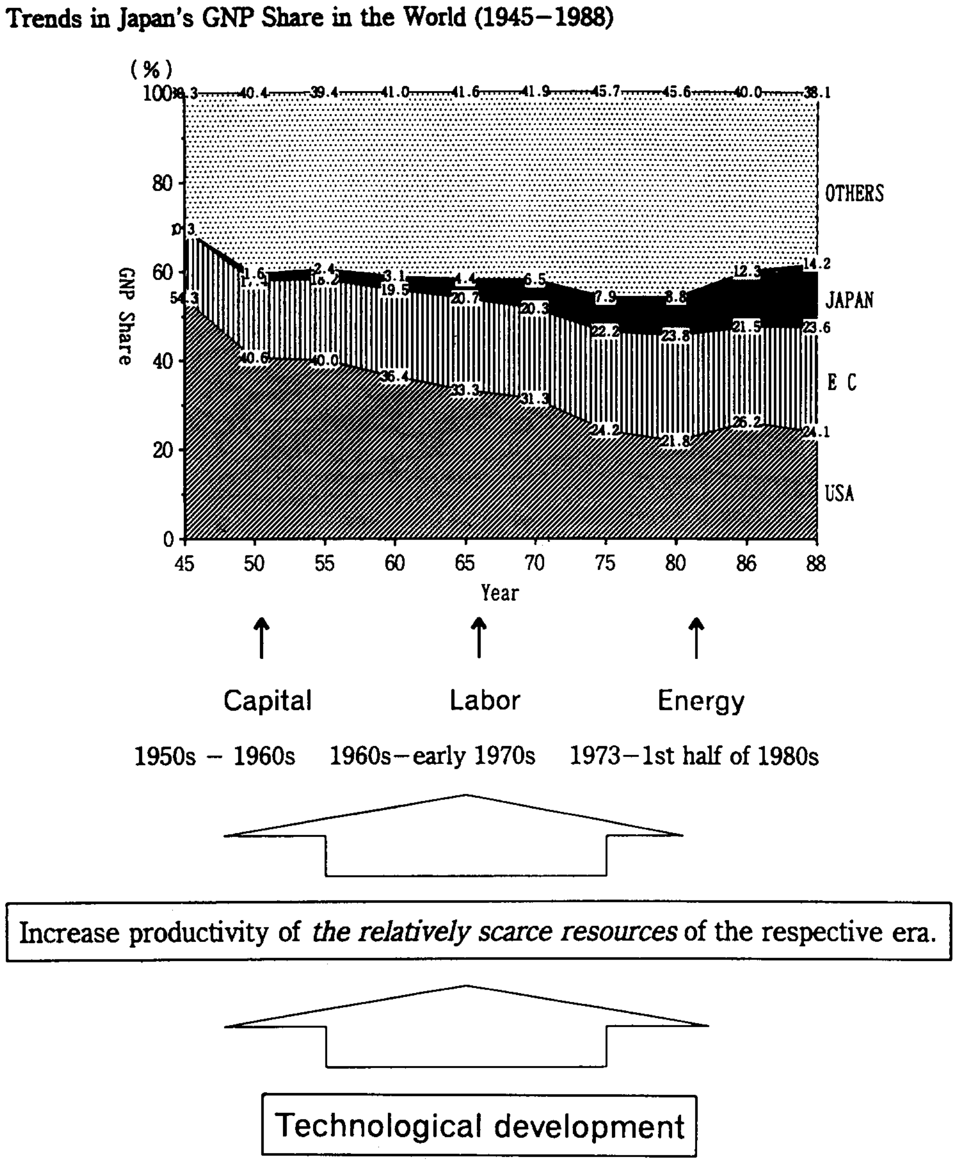

Fig. 1. Japan's economic development path in the Postwar era.
Source: Elaborations on data by the Institute of International Trade and Investment.

In terms of industry, we can understand this mechanism as a cyclical interaction between internal technology,[1] technological innovation and external technology[2] which-can be explained in the following loop [25]: input of R&D resources – output of technolog-

[1] Internal technology means qualification of the R&D environment and consists of quality and quantity of resources for R&D.

[2] External technology consists of the "economic environment," "physical and natural environment" (such as energy resources and geographical conditions), "social and cultural environment" (such as education, ethics of labor and entrepreneur, custom and tradition, and preference of consumer) and "policy system" [4].

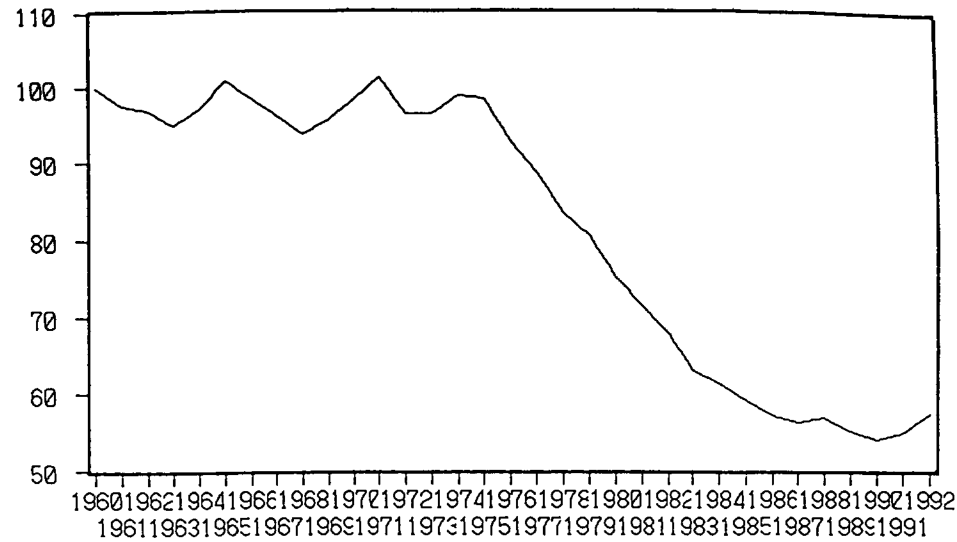

Fig. 2. Trends in unit energy consumption in the Japanese manufacturing industry (1960–1992)—Index: 1960 = 100.

Unit energy consumption = energy consumption per IIP (production weight).

ical innovation—improvement in external technology—further increase in input (see Figure 7).

Thus, I conclude that a feedback loop between technological development and economic growth (which was maintained by substituting technology for constrained production factors: key factors governing external technology), which resembles an ecosystem, formed the basis for Japan's successful development path over the last two decades.

Current State of R&D Activities in the Japanese Manufacturing Industry

Figure 8 summarizes the average increase in rate of R&D expenditure in the Japanese manufacturing industry over the period 1979–1992 by four periods: 1979–1982 (after the

TABLE 1

Comparison of the Contribution to Energy Productivity (E/IIP) Improvements by Autonomous Energy Efficiency Improvement (AEEI) and Technology Stock (T) in the Japanese Manufacturing Industry (1974–1988)

	adj. R^2	DW
AEEI		
$\ln E/IIP = 81.24 - 0.04\,t - 0.13 \ln Pe$	0.984	1.24
$(-16.74)\ (-2.68)$		
Technology stock		
$\ln E/IIP = 3.52 - 0.50 \ln T - 0.14 \ln Pe$	0.971	1.05
$(-12.19)\quad(-2.23)$		

where t: time trend, and Pe: energy prices.

Technology stock (T) is measured by the following equation:

$Tt = R_{t-m} + (1 - \rho)T_{t-1}$

where R_{t-m} = R&D expenditure in the period $t - m$,
m: time lag of R&D to commercialization,
and ρ: rate of obsolescence of technology.

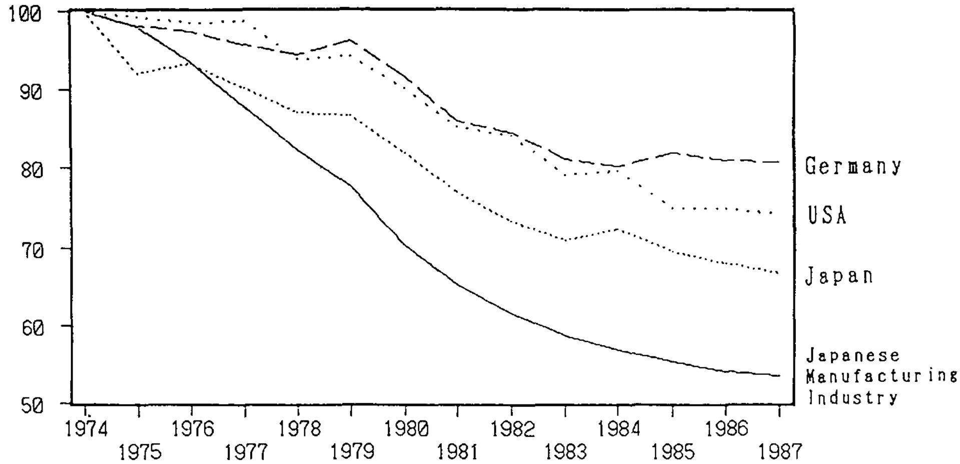

Fig. 3. Comparison of trends in unit energy consumption among Japan, the USA, and Germany (1974–1987) – Index: 1974 = 100.

Unit energy consumption – national level: energy consumption per GNP, manufacturing industry: energy consumption per value added.

second energy crisis and before the fall of international oil prices); 1983–1986 after the fall of international oil prices and before the "bubble economy"); 1987–1990 (during the period of the "bubble economy"); and 1991–1992 (after the "bubble economy"). Looking at Figure 8 we can note a significant decrease in R&D expenditure in Japan's manufacturing industry after the "bubble economy." Recent statistics published by the Management and Coordination Agency reveal that Japan's manufacturing industry first experienced a decrease in R&D expenditure in 1992 (a 2.4% decrease in comparison to the previous year in current prices). MITI's Industrial Structure Council has warned that R&D investment, previously regarded as a "sacrosanct field," is no longer applicable.

R&D strategy in firms can be well demonstrated in their R&D intensity (ratio between R&D expenditure and sales). In addition, in order to assess the state of their feedback loop, trends in sales cannot be overlooked. Figure 9 analyzes factors contributing to changes in R&D expenditure in the Japanese manufacturing industry driving the four periods by identifying contributions of "inducement by production increase" (increase in sales) and "inducement by R&D strategy" (increase in R&D intensity). Figure 9 also indicates that the increase in R&D expenditure in the period of the "bubble economy" was largely attributed to "inducement by production increase." After the "bubble economy," however, the contribution of "inducement by production increase" decreased dramatically and an increase in R&D expenditure was slightly maintained by the contribution of "inducement by R&D strategy." Similar trends can be observed in major sectors of the manufacturing industry (Figure 10). Figure 11 analyzes factors contributing to changes in sales in the same periods, which indicate that a stagnation of R&D activities in the period of the "bubble economy" led to a stagnation of technology stock during the period of the bursting of the "bubble economy," resulting in a decrease in the contribution of technology to sales. These analyses demonstrate the following structural fear of the feedback loop's possible deconstruction: a decrease in "inducement by R&D strategy" in the

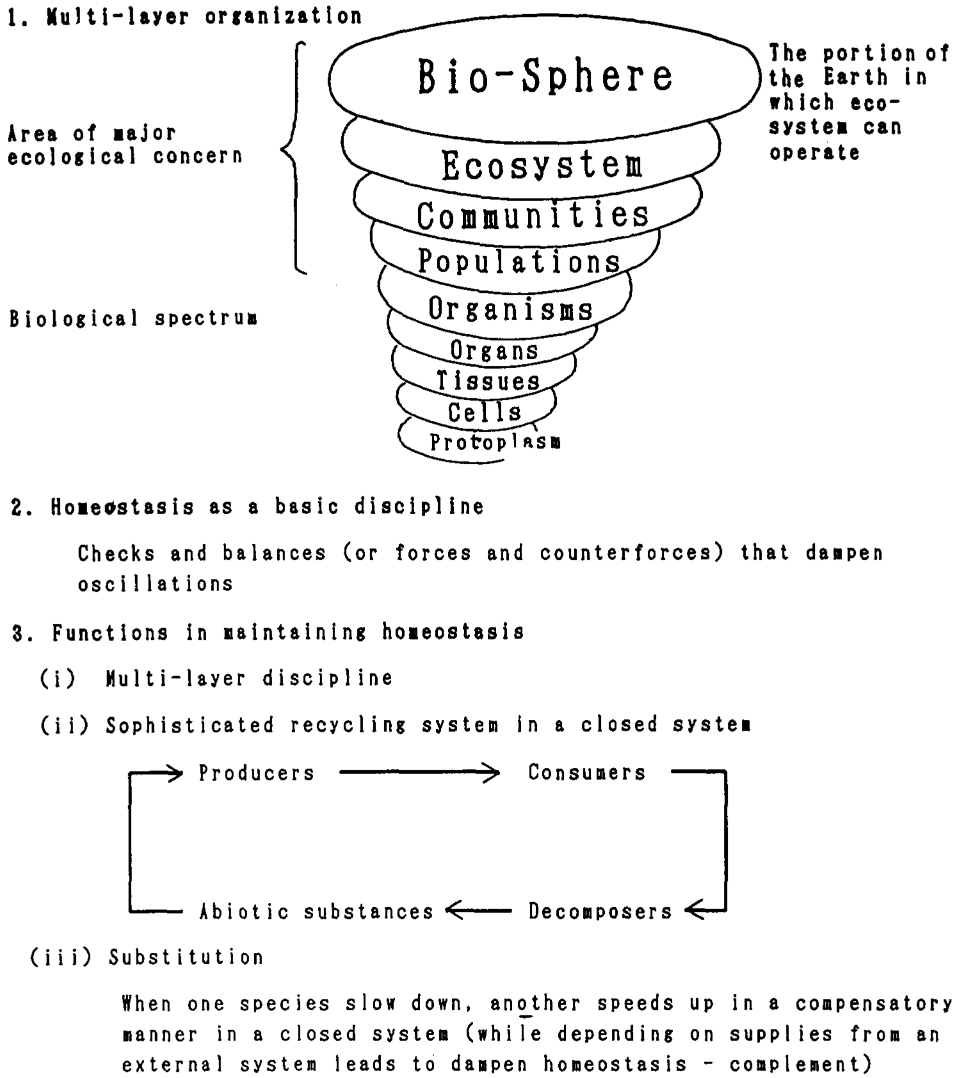

Fig. 4. Scheme of ecosystem discipline.

period of the "bubble economy"—stagnation of technology stock in the period of the bursting of the "bubble economy"—a decrease in the contribution of technology to an increase in sales—a decrease in "inducement by production increase"—stagnation of R&D expenditure.

Impact of R&D Activity Stagnation

R&D intensity (which represents a contribution of "inducement by R&D strategy" to an increase in R&D expenditure) has a strong correlation to R&D investment's share of total investment with a 1- to 2-year time-lag (see footnote in Figure 12). Considering the decreasing trend in R&D investment's share of total investment as illustrated in Figure

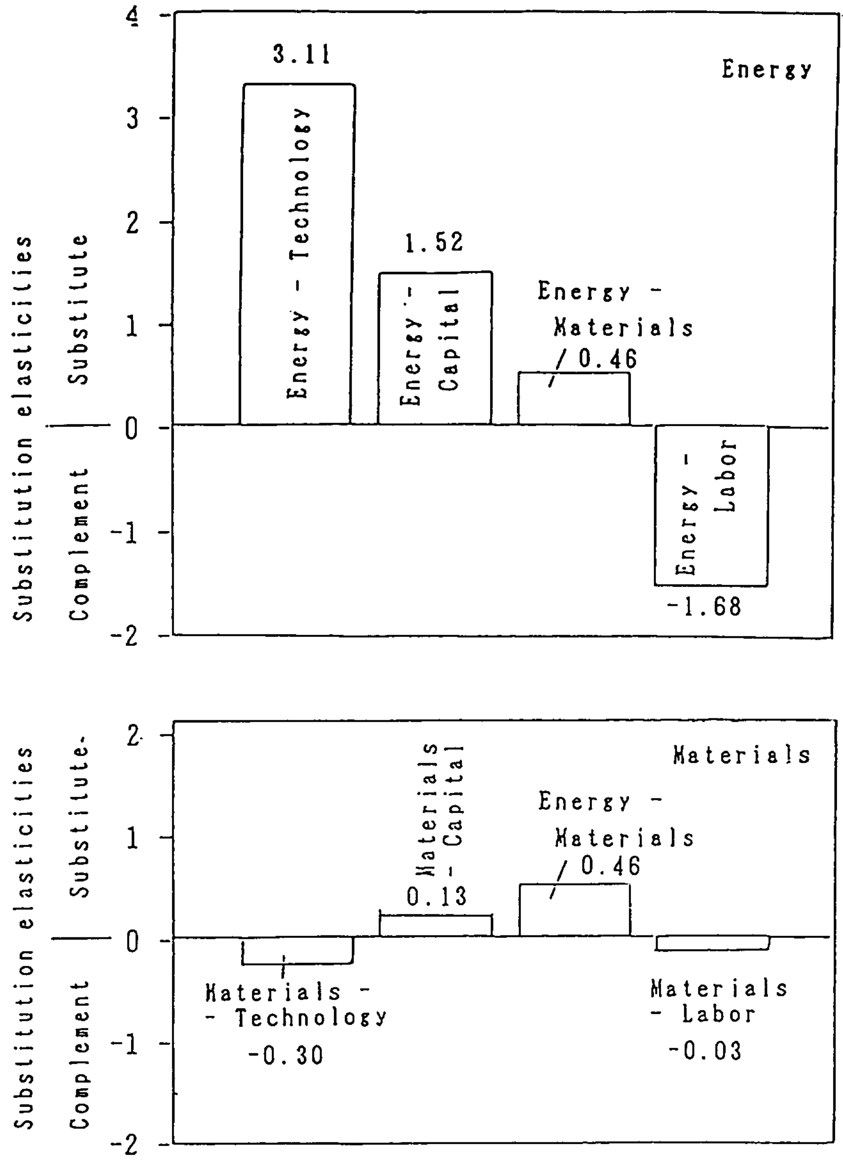

Fig. 5. Comparison of average substitution elasticities of energy and materials in the Japanese manufacturing industry (1974–1987).

Substitution elasticities are measured based on the following price function (Watanabe 1992):

$$Ml = \underset{(98.15)}{0.1471} + \underset{(12.86)}{0.0996} \ln Pl + \underset{(1.71)}{0.0091} \ln Pk - \underset{(-10.30)}{0.0891} \ln Pm - \underset{(-6.97)}{0.0277} \ln Pe + \underset{(6.87)}{0.0082} \ln Pt$$

$$Mk = \underset{(34.84)}{0.1591} + \underset{(1.71)}{0.0091} \ln Pl + \underset{(7.72)}{0.0723} \ln Pk - \underset{(-7.93)}{0.0837} \ln Pm + \underset{(1.16)}{0.0058} \ln Pe - \underset{(-2.47)}{0.0035} \ln Pt$$

$$Mm = \underset{(234.24)}{0.5952} - \underset{(-10.30)}{0.0892} \ln Pl - \underset{(-7.93)}{0.0837} \ln Pk + \underset{(12.14)}{0.2093} \ln Pm - \underset{(-5.62)}{0.0260} \ln Pe - \underset{(-6.73)}{0.0104} \ln Pt$$

$$Me = \underset{(27.97)}{0.0831} - \underset{(-6.97)}{0.0277} \ln Pl + \underset{(1.16)}{0.0058} \ln Pk - \underset{(-5.62)}{0.0260} \ln Pm + \underset{(12.59)}{0.0455} \ln Pe + \underset{(2.78)}{0.0023} \ln Pt$$

$$Mt = \underset{(23.96)}{0.0156} + \underset{(6.87)}{0.0082} \ln Pl - \underset{(-2.47)}{0.0035} \ln Pk - \underset{(-6.73)}{0.0104} \ln Pm + \underset{(2.78)}{0.0023} \ln Pe + \underset{(5.31)}{0.0033} \ln Pt$$

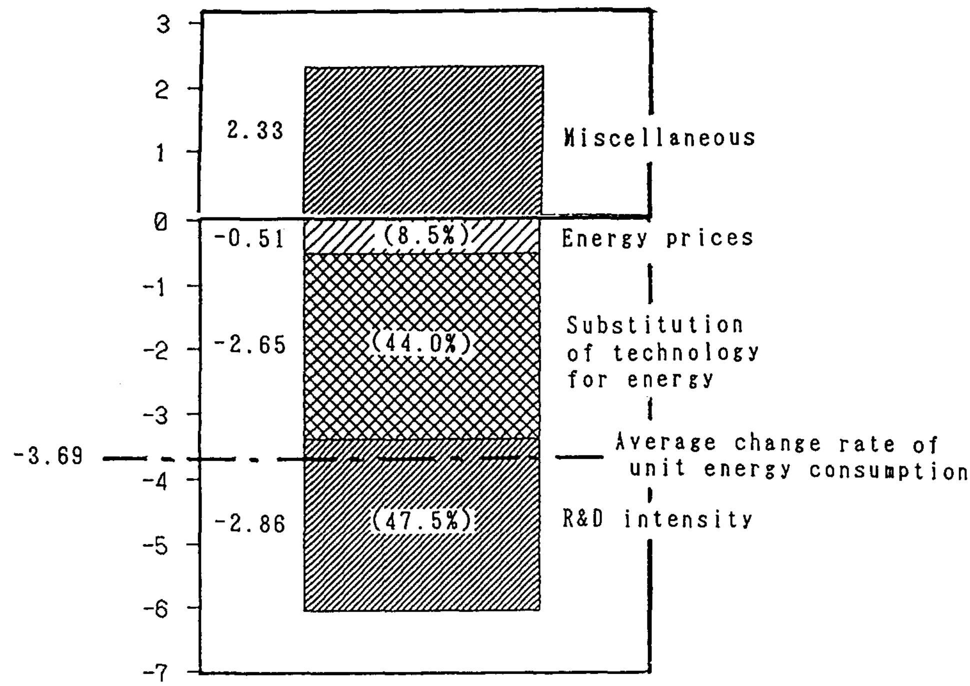

Fig. 6. Factors contributing to change in unit energy consumption in the Japanese manufacturing industry (1976–1990).

Magnitude of contribution is measured by the following equation:

$$\sigma te = (Bte + Mt \cdot Me)/(Mt \cdot Me) = 1 + Bte(GC/GTC)(GC/GEC)$$

$$\sigma te - 1 = Bte(GC/R)(GC/E \cdot Pe) = Bte(S/R)(GC/S)(IIP/E)(GC/IIP)(1/Pe)$$

$$E/IIP = Bte \cdot (\sigma te - 1)^{-1}(R/S)^{-1}(Pe)^{-1}(GC/IIP)(GC/S)$$

$$\ln E/IIP = \ln Bte - \ln(\sigma te - 1) - \ln R/S - \ln Pe + \ln(GC/IIP)(GC/S)$$

$$\Delta E/IIP = -\Delta(\sigma te - 1) - \Delta R/S - \Delta Pe + \eta$$

where σte = substitution of technology for energy; Bte = coefficient; Mt and Me = cost share of technology and energy, respectively; GC = gross cost; GTC = gross technology cost; GEC = gross energy cost; R = R&D expenditure (= gross techology cost); E = energy consumption; Pe = prices of energy; S = sales; IIP = index of industrial production; η = miscellaneous.

Contribution of respective factors to reducing unit energy consumption is as follows (average change rate: %): $\Delta E/IIP$ (Unit energy consumption) = −3.69; $\Delta(\sigma te - 1)$ (substitution of technology for energy) = −2.65; $\Delta R/S$ (R&D intensity) = −2.86; ΔPe (energy prices) = −0.51; η (miscellaneous) = 2.33. (A value for 1980 is not included because of inconsistently drastic change due to the second energy crisis in 1979.)

12, it is strongly feared that R&D intensity may further decrease due to the bursting of the "bubble economy." This could not only cause a decrease in the quantity of R&D activities as discussed in Section 3, but could also significantly affect the quality of R&D activities. Table 2 demonstrates an analysis with respect to an such impact on both basic research and energy and environmental R&D. Table 2 summarizes the outcome of the analysis regarding correlations between R&D intensity and ratio of R&D expenditures for basic research in Japan's chemical, iron and steel, general machinery, electrical machinery, and transport equipment industries. The table indicates that the ratio of R&D expenditures for basic research has a strong correlation to R&D intensity in all the industries examined. Although there have been some indications that full-scale efforts to promote research on basic technology seriously began as Japan's industrial technology ap-

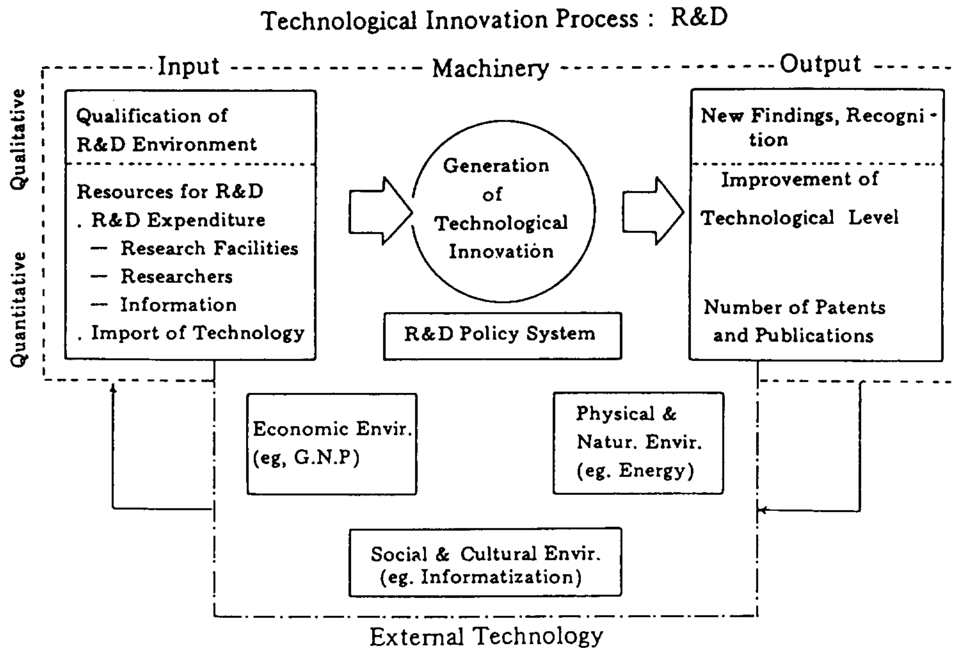

Fig. 7. Mechanism of technological innovation—A concept of external technology.

proached the technological frontier [17], the data in this table warns us that such efforts have again stagnated.[3]

Table 2 also compares inducing factors for energy R&D, R&D for environmental protection, and R&D for information technology (R&D aiming at improving manufacturing processes) in Japan's manufacturing industry during the period 1976–1990. The table shows that both environmental protection R&D and energy R&D are sensitive to the level of R&D intensity, which contrasts information technology R&D.

Currently Japan's economy again faces the prospect of energy and corresponding environmental capacity constraints after the fall of international oil prices and the succeeding "bubble economy" [36].[4] Concerns on the prospect have remained relatively small due to Japan's success in overcoming energy and environmental constraints in the 1960s, the 1970s, and the early 1980s. Contrary to this optimistic view, this analysis warns us

[3] A survey undertaken by MITI in March 1993 regarding the focus of R&D by type of activities to be undertaken by leading Japanese firms in the next few years time demonstrates such a fear as follows:

	Increase	Stable	Decrease	Not decided	Total
Basic research	18.9	43.2	14.9	23.0	100%
Applied research	22.7	49.3	10.7	17.3	100
Development research	42.7	34.7	10.7	12.0	100

[4] A survey undertaken by MITI in June 1993 regarding the change rate of expenditure for R&D for environmental protection in Japanese leading firms demonstrates such a fear as follows:

	1990	1991	1992
Change rate of average expenditure (%)	37.7	26.9	14.4

Correlation analysis between R&D intensity and energy productivity (E/IIP) in the Japanese manufacturing industry (1974–1990) demonstrates similar fear.

$$\ln(E/IIP) = 2.00 - \underset{(-13.24)}{0.77}\ln(RS) - \underset{(-7.36)}{0.39}\ln(Pe) \quad \text{adj. } R^2\ 0.968 \quad DW\ 1.41$$

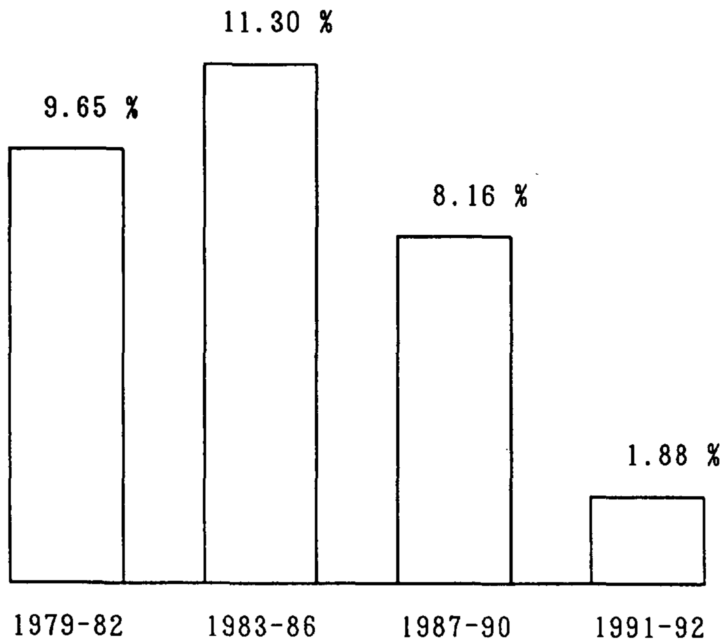

Fig. 8. Average increase in rate of R&D expenditure in the Japanese manufacturing industry (1979–1992); % per annum using constant prices.

Sources: 1979–1991: Report on the Survey of Research and Development (Management and Coordination Agnecy). 1992: Investment Plan of Industry in 1993 (Industrial Structure Council of MITI – June 1993).

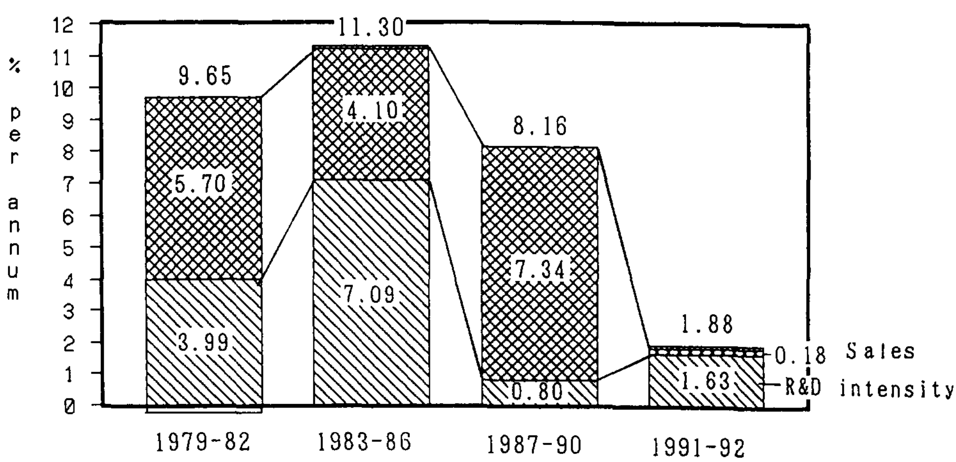

Fig. 9. Factors contributing to change in R&D expenditure in the Japanese manufacturing industry (1979–1992).

Magnitude of contribution is measured by the following equation: $\Delta R = \Delta R/S + \Delta S$ where R = R&D expenditure; R/S = R&D intensity; and S = sales.

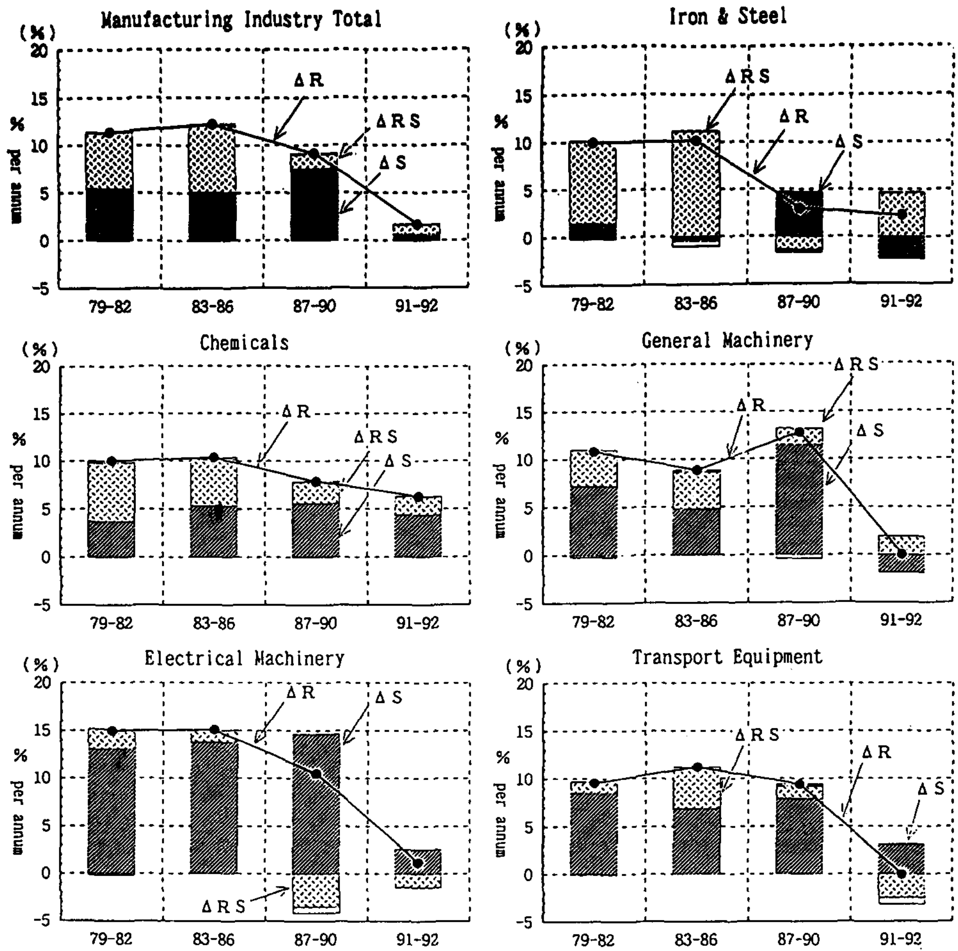

Fig. 10. Factors contributing to change in R&D expenditure in the Japanese manufacturing industry (1979–1992).

Magnitude of contribution is measured by the following equation: $\Delta\dot{R} = \Delta RS + \Delta S$ where R = R&D expenditure; RS = R&D intensity; and S = sales.

of the potential stagnation in challenges to technological breakthroughs for overcoming energy and environmental constraints.

Structural Background of a Stagnation

As analyzed in Section 3, a decrease in R&D intensity in the period of the "bubble economy" triggered fear of a possible deconstruction of the feedback loop between technological development and economic growth. R&D intensity has a strong correlation to R&D investment's share of the total investment as analyzed in Section 4. Figure 13 summarizes trends in investment objectives in the Japanese manufacturing industry from 1986–1990. Figure 13 indicates that the R&D investment's share of total investment decreased dramatically (12.9% in 1986 to 10.5% in 1990) with its peak in 1987 (13.2%). It is believed that this resulted from firms focusing their investment behavior on increasing production capacity by means of noninnovative investment (this share increased from 22.8% in 1986

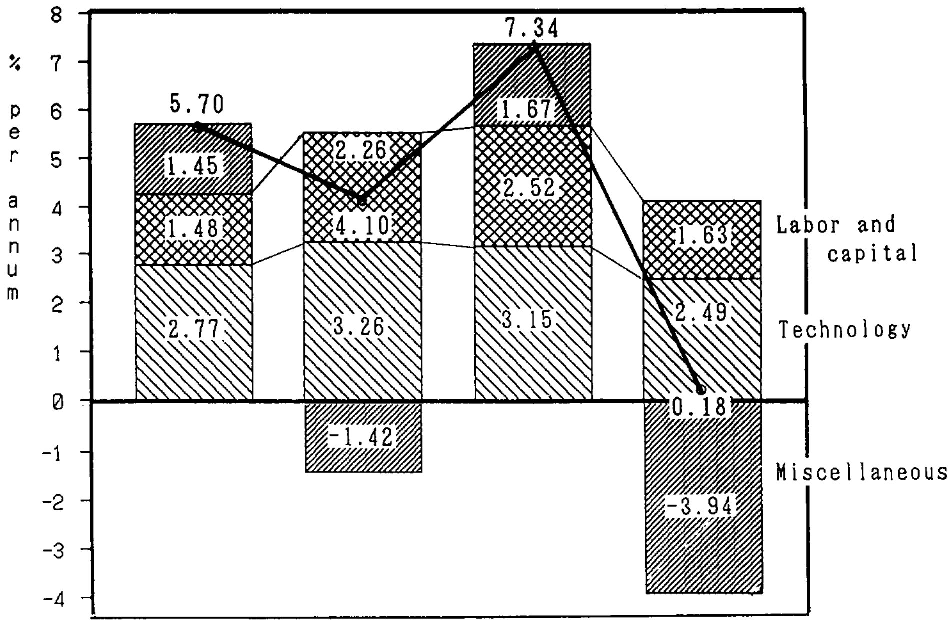

Fig. 11. Factors contributing to change in sales in the Japanese manufacturing industry (1979–1992). Magnitude of contribution is measured by the following equation:

$$\ln(S/L) = -0.19 + 0.24\ln(K/L) + 0.39\ln(T/L) \quad 1974\text{–}1992 \text{ adj. } R^2\, 0.983 \quad DW\, 1.39$$
$$(2.28) \qquad (4.74)$$

$$\Delta S = 0.37\Delta L + 0.24\Delta K + 0.39\Delta T + \eta \qquad Tt = R_{t-m} + (1-\rho)T_{t-1}$$

where S = sales, L = labor, K = capital stock, T = technology stock, η = miscellaneous, R_{t-m} = R&D expenditure in the period t-m, m = time lag of R&D to commercialization, and ρ = rate of obsolescence of technology.

to 32.0% in 1990) rather than R&D investment, which required consistent innovative efforts with high-risks during the period of the "bubble economy."

Another factor leading to a decrease in R&D intensity (stagnating "inducement by R&D strategy") was an illusion between nominal and real prices. Firm strategy is generally developed by examining current figures and increasing trends based on current figures. This behavior can be applied to their efforts in maintaining increasing trends in R&D intensity, which is considered to be a symbolic indicator for challenging investment in the future. This indicator is also generally measured by current figures (a ratio calculated by current prices). Because this indicator is a ratio, there was an illusion that the ratio represented real R&D efforts. In actuality, the ratio does not necessarily represent real R&D efforts due to a discrepancy of deflators between R&D expenditures and sales. As indicated in Figure 14, an R&D deflator can consist of buildings and land, labor (researchers), materials, machinery, instruments and equipment. Due to a sharp increase in the prices of buildings and land as well as labor during the period of the "bubble economy," the R&D deflator exceeded the sales deflator as illustrated in Figure 15; causing R&D intensity in current prices to be higher than the ratio in constant prices (which represent real efforts in challenging R&D). Figure 16 compares trends in R&D intensity both in current prices (nominal) and constant prices (real) in total and major sectors of Japan's manufacturing industry over the period 1976–1990. Looking at Figure 16 we can note that R&D intensity stagnated or decreased in real terms derived from the "bubble economy,"

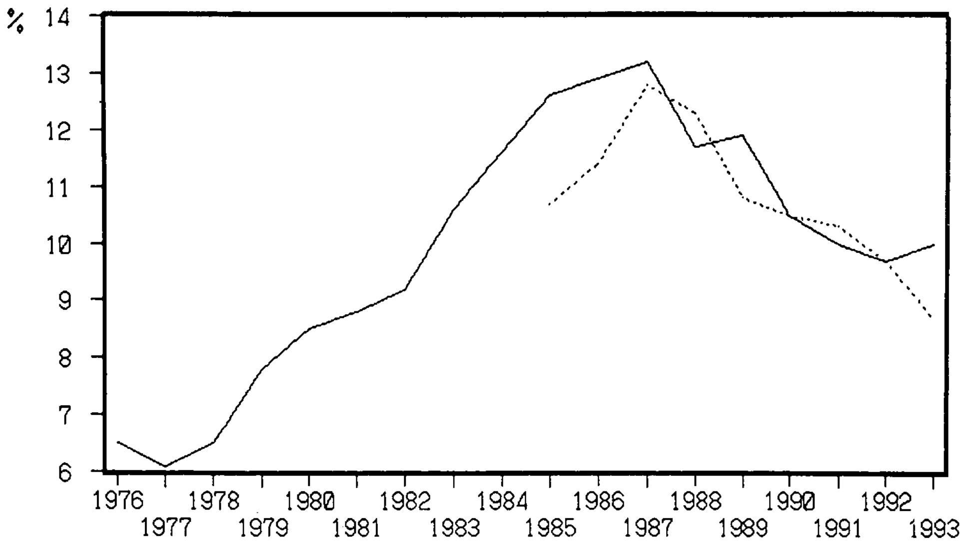

Fig. 12. Trends in the R&D investment share of total investment in the Japanese manufacturing industry (1976–1993) – %.

Shares are as follows:

	1985	1986	1987	1988	1989	1990	1991	1992	1993
——— Japan Develop. Bank	12.6	12.9	13.2	11.7	11.9	10.5	10.0	9.7	10.0
- - - - - Ind. Struc. Council	10.7	11.4	12.8	12.3	10.8	10.5	10.3	9.7	8.7

(Shares in 1993 are projections at August and March 1993, respectively.)

Correlations between R&D investment share out of total investment (IR) and R&D intensity (RS) are as follows (1978–1990):

R&D	Equation	adj. R^2	DW	D
Manufact. total	$\ln(RS) = -0.59 + 0.66\ln(Lag2(IR)) + 0.07\,D$ (22.86) (2.58)	0.980	1.59	1990 = 1
Chemicals	$\ln(RS) = -0.02 + 0.52\ln(Lag2(IR))$ (12.96)	0.933	2.53	
Iron & steel	$\ln(RS) = 0.07 + 0.30\ln(Lag1(IR)) + 0.21\,D$ (7.36) (4.14)	0.907	1.58	1985–1987, 1990 = 1
Ceramics	$\ln(RS) = -0.16 + 0.48\ln(Lag1(IR)) - 0.32\,D$ (10.87) (−5.39)	0.943	1.68	1978, 1979 = 1
Machinery	$\ln(RS) = -0.24 + 0.58\ln(Lag2(IR)) + 0.06\,D$ (8.74) (2.66)	0.886	1.51	1986, 1990 = 1

whereas R&D intensity in nominal terms increased, thereby demonstrating the above illusion. In addition to the above structural factors, we should not overlook the cyclical factors, typically observed in the current stagnation of electrical machinery and transport industries resulting from demand stagnation derived from stagnation of innovative products.

Implications for Future R&D

The remarkable growth of the Japanese economy has been largely attributed to the feedback loop between technological development and economic growth. This loop has been developing consistently both in quantitative and qualitative aspects. An ecosystem, which is respected as a prime example of such a loop, demonstrates that consistent efforts

TABLE 2

Impact of R&D Stagnation on Future R&D Activities in the Japanese Manufacturing Industry

Basic research: Correlations between R&D intensity (RS) and ratio of R&D expenditures for basic research (BR) in the Japanese manufacturing industry are analyzed as follows:

R&D/Equation	adj. R^2	DW	D
Chemicals (1974–1990)			
$\ln(BR) = 1.19 + 0.94\ln(Lag1(RS)) + 0.14D$	0.862	1.88	1983, 1984 = 1
(9.45) (2.87)			
Iron & steel (1977–1990)			
$\ln(BR) = 1.73 + 0.72\ln(Lag3(RS)) - 0.30D$	0.831	1.65	1986 = 1
(7.79) (−3.28)			
General machinery (1975–1990)			
$\ln(BR) = -2.36 + 3.76\ln(Lag0(RS)) - 0.43D$	0.858	2.57	1979, 1980 = 1
(6.40) (−2.06)			
Electrical machinery (1974–1990)			
$\ln(BR) = 0.11 + 0.84\ln(Lag1(RS)) - 0.20D$	0.835	1.26	1983, 1984 = 1
(6.96) (−5.48)			
Transport equipment (1978–1990)			
$\ln(BR) = 0.67 + 0.71\ln(Lag0(RS)) - 0.60D$	0.893	1.79	1978, 1979 = 1
(2.48) (−9.64)			

Energy and environmental R&D: Correlations between R&D objectives and R&D strategy, R&D intensity (RS) and energy prices (Pe) are analyzed as follows (1976–1990):

R&D/Equation	adj. R^2	DW	D
Energy			
$\ln(ERT) = 2.12 + 0.77\ln(ENERS) + 1.50\ln(RS) + 0.45\ln(Pe) + 0.12D$	0.918	1.54	1990 = 1
(2.64) (3.70) (1.29) (1.34)			
R&D for environmental protection			
$\ln(EVT) = 2.86 + 1.07\ln(ENVRS) + 2.08\ln(RS) + 0.21\ln(Pe) - 0.14D$	0.847	1.85	1986 = 1
(7.94) (8.97) (1.57) (−1.77)			
R&D for information technology			
$\ln(INT) = 2.75 + 1.53\ln(INFRS) + 0.87\ln(RS) + 0.27\ln(Pe)$	0.999	2.44	
(23.10) (6.25) (4.92)			

ERT, EVT, and INT = R&D expenditures for energy R&D, R&D for environmental protection, and R&D for information technology, respectively. ENERS, ENVRS, and INFRS = the ratio of R&D expenditures for energy, environmental protection, and information, respectively.

to improve quality are indispensable. Similarly, in order to maintain Japan's loop, it is necessary to consistently initiate creative technological innovation so as to induce broad new scientific invention and discoveries.

Although there are indications that full-scale efforts to promote research on basic technology seriously began as Japan's industrial technology approached the technological frontier [17], efforts might be limited due to a stagnation of R&D investment following the bursting of the "bubble economy" and the current economic recession [10, 35]. Moreover, such a stagnation brought a limit in R&D efforts to relax energy and environmental constraints [35]. Japan successfully overcame both energy and environmental constraints in the 1960s, 1970s, and the first half of the 1980s. Despite this success, Japan's economy once again faces prospective constraints following the fall of international oil prices and the succeeding "bubble economy." Stagnation of R&D investment has accelerated this fear, resulting in a stagnation of sustainable growth [31, 33].

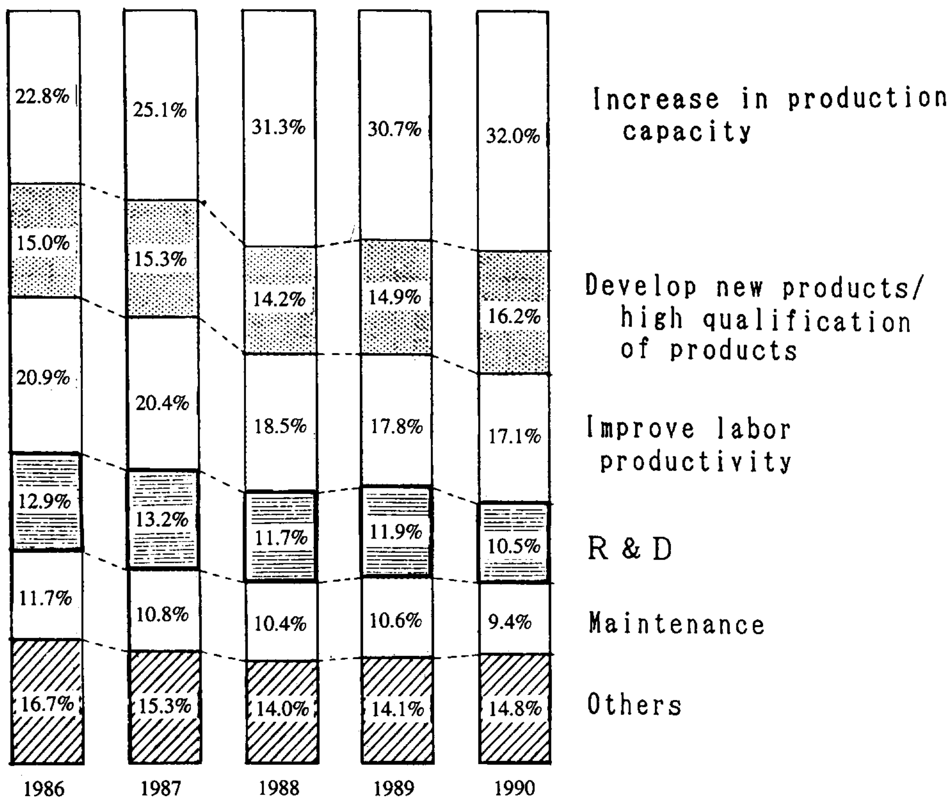

Fig. 13. Trends in objectives of investment in the Japanese manufacturing industry (1986–1990).
Source: Japan Development Bank.

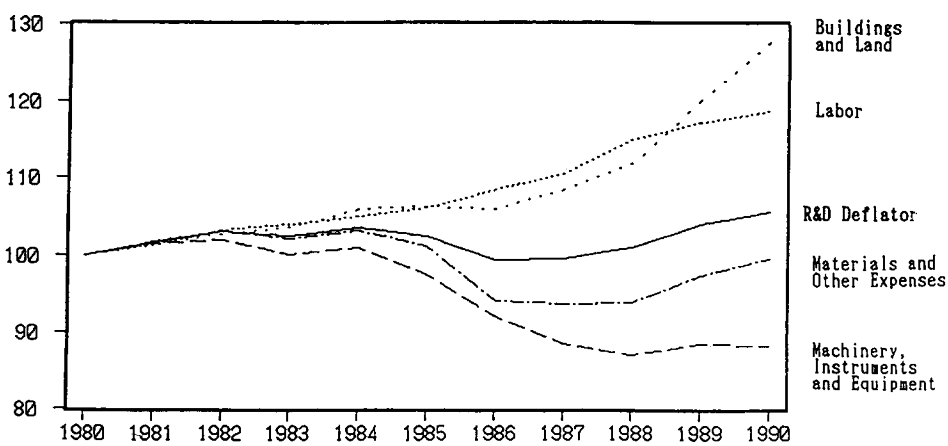

Fig. 14. Trends in R&D deflator and its components in the Japanese manufacturing industry (1980–1990)—Index: 1980 = 100.

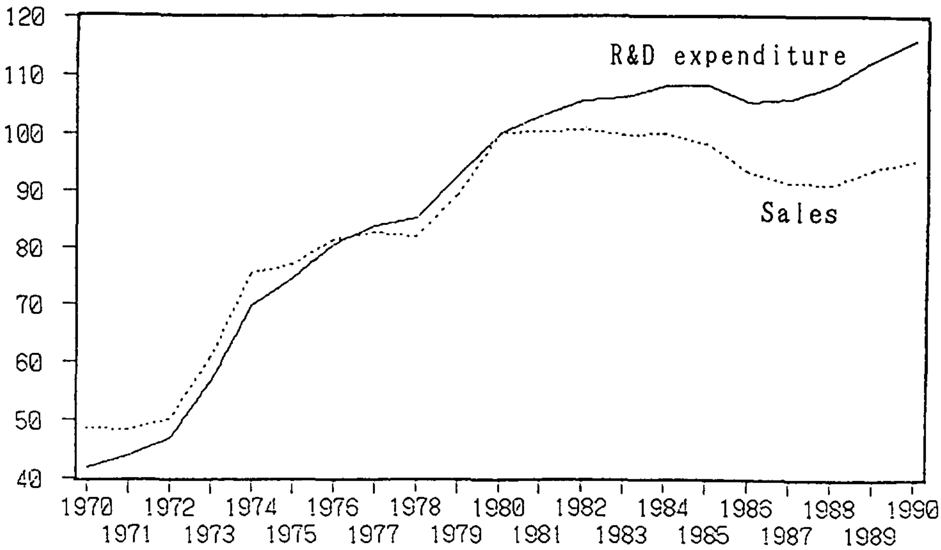

Fig. 15. Trends in deflators of R&D expenditure and sales in the Japanese manufacturing industry. Index: 1980 = 100 using 1980 constant prices.

Industry recognizes the need for fundamental research as well as the acceleration of energy and environmental R&D in order to prevent stagnation, which could lead to a dramatic improvement in increasing productivity and overcoming increasing energy and environmental constraints. Even so, a stagnating trend in R&D investment could result in a shift from basic research to applied and development research, and also a decrease in energy and environmental R&D. Recognizing this trend and realizing its role in an international context, MITI has made extensive efforts to encourage, stimulate, and induce vitality from academia, national research laboratories, and industries through full utilization of its restructured National R&D Programs.[5]

The basic principle for this challenge can be summarized as follows: First of all, we should remember "recognition of commitments from the future—the day after tomorrow for tomorrow." Second, in order to construct a feedback loop that encourages a consistent challenge, the following three points are essential:

[5] In order to respond to a paradigm change surrounding Japan's industrial technology, MITI restructured its existing R&D programs into the following two comprehensive programs in April 1993 [42]:

1. Industrial Science and Technology Frontier Program:
   This program aims at restructuring the National R&D Program (Large-Scale Project: 1966), the R&D Program on Basic Technologies for Future Industries (1981) and the R&D Program on Medical and Welfare Equipment Technology (1976) by including: (a) Fundamental and creative R&D, which will contribute to further development of the economy and society by building a new technology paradigm with a new concept, philosophy and approach and also by making technological breakthroughs, and (b) Mission—oriented R&D to attain the social goal of meeting public demand and a quality of life common to the international community as well as realizing real human life [1].
2. The New Sunshine Program:
   This program, on the basis of a recognition of the two-sided nature of the global environment issue and energy consumption, aims at a comprehensive approach for overcoming global energy and environmental constraints while maintaining sustainable growth by integrating the Sunshine Project (R&D on new energy technology: 1974), the Moonlight Project (R&D on energy conservation technology: 1978), and the Global Environmental Technology Program (1989) [15].

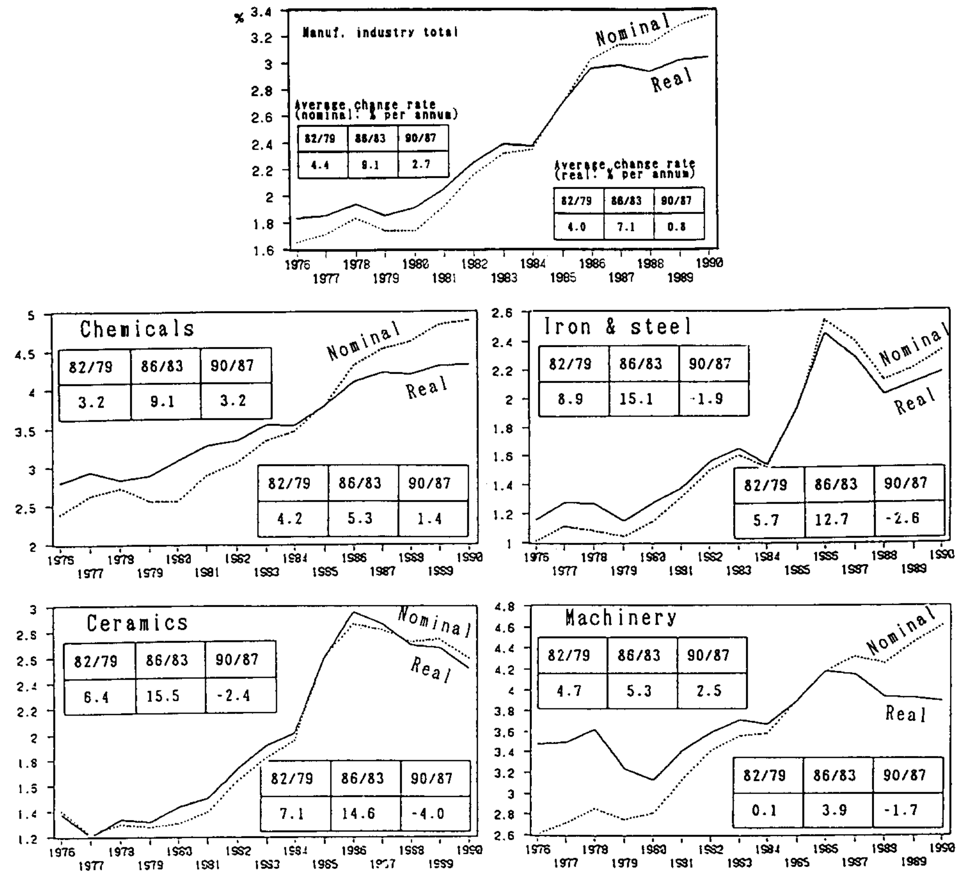

Fig. 16. Trends in the ratio of R&D expenditure and sales in the Japanese manufacturing industry (1986–1990). Current prices and 1985 constant prices (% per annum).

Sources: Report on the Survey of Research and Development (Management and Coordination Agency), White Paper on Japanese Science and Technology (Science and Technology Agency), and Economic Statistics Annual (The Bank of Japan).

1. Encouragement for ambitious targets;
2. A comprehensive approach among sectors, and
3. Harmony between competition and cooperation.

In order to realize such a principle, the government's role will become more significant in terms of identifying prospective basic, creative, and fundamental research subjects. In addition to priorities in energy and environmental R&D, subjects that instill confidence and develop general consensus will become more significant.

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