5. Technological Strategy of Firms and Nations

Why strategy?

- Technological trend given
  - general imperatives
  - exploration along technological trajectories
- Heterogeneity (diversity) of firms and nations
  - no strategy required among identical firms

5.1. R&D investment

What is R&D?

- Firm's activities involved in technology acquisition and creation
  - "collection of not-very-well-defined activities" (Rosenberg 1976: 77)

  "It may involve solutions to problems which, from a technological point of view, may be neither difficult nor interesting, but economically very important." (Rosenberg 1976:76)

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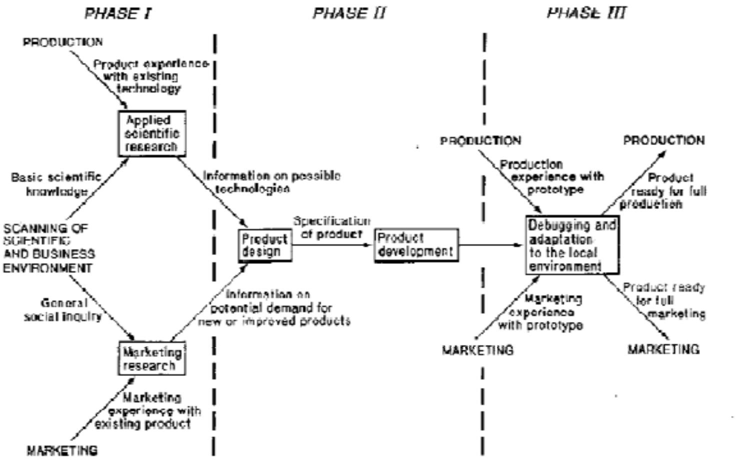

Figure 7.7 Elements of the research and development process (*Source*: Buckley and Casson (1976), Figure 2.7)

Dicken

Uncertainty and components of R&D

- The importance of 'development' component

- less than 15%: basic research
- over 20%: applied research
- over 2/3: development (Rosenberg 1976: 76)

"Only a few firms perform any basic research and this accounts for less than 5 per cent of all industrial R&D expenditure in most OECD countries." (Freeman & Soete 1993: 255)

	Researchers no.	Distribution of R&D time (%) Fundamental research	% of researchers who perform the activity	Applied research	% of researchers who perform the activity	Experimental development	% of researchers who perform the activity	Type of researcher Scientists (%)	Engineers (%)	Average age
Food and textiles	187	9	53	34	94	57	94	0	2.4	40.4
Metallurgy	264	2	18	49	94	49	94	1.4	2.0	42.2
Mechanical eng.	1,669	10	41	56	100	35	83	6.9	6.0	37.0
Electrical eng.	644	8	28	55	88	37	67	4.1	6.7	31.8
Electronics telecom.	3,056	8	30	41	86	51	85	10.1	20.8	36.2
Transport vehicles	1,209	8	44	51	91	41	82	12.4	11.3	35.9
Pharmaceuticals	2,139	17	62	55	94	28	68	31.2	15.9	36.2
Chemicals	2,328	11	43	43	86	45	83	11.9	14.8	40.5
Rubber and fibres	868	10	39	51	93	39	80	6.0	3.9	38.3
Research companies	1,083	10	47	53	93	38	77	13.8	10.1	35.1
Other manuf. sectors	1,564	8	35	43	98	49	96	2.3	6.0	38.4
Total	15,010	11	43	49	91	41	79	100.0	100.0	37.4
% researchers who perform the activity	—	—	—	—	—	—	—	—	—	—
Scientists	3,248	16	57	69	98	15	58	100.0	—	35.4
Engineers	11,762	9	39	43	89	48	86	—	100.0	37.8
Junior researchers	5,959	12	46	49	88	38	76	61.5	33.7	34.1
Project leaders	7,154	9	40	48	93	43	82	34.2	51.4	38.1
Directors	1,808	11	45	50	93	39	83	4.3	14.9	43.4

Source: Sirilli (1982).

"... if we examine R&D expenditures among OECD member countries in the early 1960s, we find that the U.S. had a higher proportion of expenditures on the development component than any other country." (Rosenberg 1976: 77)

→ high degree of uncertainties surrounding R&D activities

→ high failure rate

Is R&D basically defensive?

"... the nature of the uncertainty associated with innovation is such that most firms have a powerful incentive most of the time not to undertake the most radical type of product innovation and to concentrate their industrial R&D on defensive, imitative innovations, product differentiation and process innovation." (Freeman &Soete 1993: 244-245)

Why do firms do basic R&D?

- Characteristics of basic R&D

(1) the most uncertain part of R&D component

- 'long-term investment'

(2) output: 'intermediate goods'

"... most firms that have engaged in it [basic research] have had fairly strong and well-entrenched positions of market power. Precisely because the potential pay-off to basic research is so long term, only firms that were reasonably confident of being around in the long term would be likely to consider the possibility of making such commitments." (Rosenberg 1990: 167)

: it's all right if "the firm capture *enough* of these benefits…" although the results of R&D investment become easily non-appropriable.

"... the output is some form of new knowledge that has no clear dimensionality. The output is a peculiar kind of intermediate good that may be used ... to play some further role in the invention of a new final good." (168-169)

Why do firms do basic R&D?

(1) expecting ‘unexpected and unplanned benefit’

- “the distinction between basic research and applied research is highly artificial and arbitrary”

Why do firms do basic R&D?

(2) ‘A ticket of admission to an information network’

- high degree of interactivity between basic and applied research
- basic knowledge about basic research is necessary in communication in the research community

Why do firms do basic R&D?

(3) Providing basic knowledge for applied research

"to understand better how and where to conduct research of a more applied nature."

Why do firms do basic R&D?

(4) evaluation of the outcome of applied research

(5) monitoring technological trend

(6) incentives by the government

"... to improve their visibility and their eligibility for government military procurement contract." (172)

Is R&D an insurance or a speculation?

- The insurance view

"... the firm is in effect using its R&D budget as a form of insurance against the risks of technical change" (Freeman & Soete 1993: 259)

$\rightarrow$ applicable to large established firms

Is R&D an insurance or a speculation?

- The speculative game view

- venture business

cf. high investment in 'basic research' in biotechnology firms

* “[They] are engaged in basic research that is believed to be close to the commercialization stage. ... What appears to be driving the small firms that perform basic research in biotechnology is the first-mover advantages – or at least an expectation that first-mover advantages may be critical.” (Rosenberg 1990: 168)

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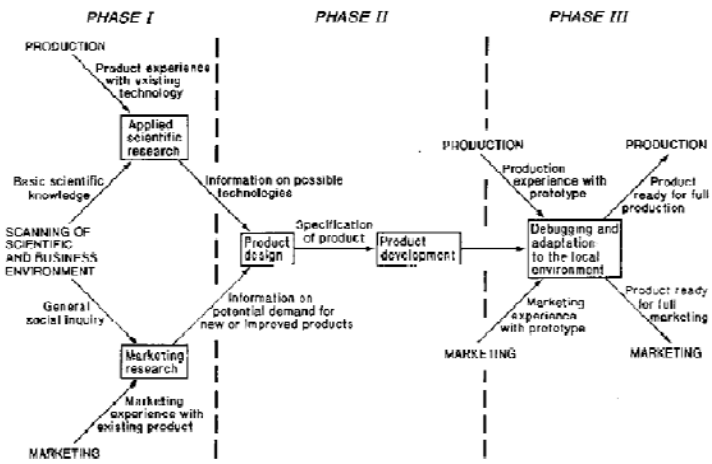

Figure 7.7 Elements of the research and development process (*Source*: Buckley and Casson (1976), Figure 2.7)

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Management of R&D investment

- Portfolio investment

"What management is looking for is a portfolio of projects rather than a series of separate projects. By thinking in terms of a portfolio rather than a project it is possible to select a blend of safe and high risk projects ..." (Freeman & Soete 1993: 255)

Management of R&D investment

- Total volume

"... most large firms allocate annual funds to the R&D function on a rule-of-thumb basis such as percentage of sales. The actual budget rule often evolves through decision-makers learning what is the 'appropriate' budget for their firm." (Kay 1988: 285)

- Distribution within R&D activities

Management of R&D investment

- Diversity across firms
  - according to capability, industry, willingness to take risks ...
- Diversity across countries
  - according to capability, government policies towards R&D …

Changing uncertainties and the degree of internalisation of R&D

- Initial trend towards internalisation of R&D
  - starting from the situation where there was no close interaction between science and technology and demand for R&D investment was low
  - some reasons favouring internalisation
    : close interaction between R&D and production, secrecy, willingness to take risks involved in R&D …

Changing uncertainties and the degree of internalisation of R&D

- Increasing externalisation of R&D

- still, large chunk of basic research done by universities or public institutes

(1) increasing market size for R&D → increasing specialisation

(2) standardisation of technologies

Changing uncertainties and the degree of internalisation of R&D

(3) Increasing fusion across technologies

→ increasing cross-fertilisation of technologies

→ need to maintain broader portfolio of technological competencies

→ technology alliances

Changing uncertainties and the degree of internalisation of R&D

(4) increasing financial risk involved in new technology development

eg. Fuel cell research, semiconductor research alliances

→ again, extremely diverse strategies towards the combination of internal & external R&D

5.2. National innovation system and technology policy

Why Do Governments Support R&D?

- Trend by countries
  - Significant involvement by the government in R&D activities
  - Variations across countries
- Historical importance of defense related R&D spending

Table 1. *Estimated gross expenditure on research and development as a fraction of GNP, (GERD/GNP ratio) 1934–1983*

	1934	1967	1983	1983 civil R&D only
USA	0·6	3·1	2·7	2·0
EC*	0·2	1·2	2·1	1·8
Japan	0·1	1·0	2·7	2·7
USSR	0·3	3·2	3·6	1·0

*Estimated weighted average of 12 EC countries.

Source: Author's estimates based on Bernal (1939) adapted to 'Frascati' definitions (1963), OECD statistics, and adjustments to Soviet statistics based on Freeman and Young, (1965).

Freeman

Economic reasons behind government R&D supports

- Nelson (1959), Arrow (1962)
- 'The cost-plus contract'
  - 'Moral hazard' at first glance
    → No incentive for contractors to reduce costs because payment is independent of quality of products they supply.
  - But a common practice in defense-related contracts
  - Why?

Economic reasons behind government R&D supports

- High degree of uncertainty in R&D
  - Payments by result involve great risk for the innovators
  - Difficulty in hedging
  - Problems with appropriability
    → Under-investment in R&D if the free market alone decides on resource allocation
    → social returns from R&D >private returns

Economic reasons behind government R&D supports

- Problems in the government's involvement
  - How much is the government intervention needed?
  - How can we ensure efficiency of government's spending on R&D?

Pros and Cons of Technology Policy

- Market failures
  - uncertainties, externality, indivisibility, non-excludability …
  - investment in specific assets

Pros and Cons of Technology Policy

- Government failures
  - interest group influence
    : Marxism, regulatory-capture theory …
  - self-seeking bureaucrats
  - information problems

Pros and Cons of Technology Policy

- Swings of pendulum

- "In the real world, both state intervention and market transaction are costly."

  → a need for 'contextual analysis'

  → studies of national innovation systems

National innovation systems

- Policy and implementation
  cf. strategy and organization
- Institutional dependence of innovation
  - uncertainties
  - learning
  - 'embeddedness'

Freeman (1987, 1988)

- Started from explicating NIS of one country, Japan, and tried to draw more general implications.
- Friedrich List (1841) *The National System of Political Economy*
  - The German NIS in the late 19th century

Freeman (1987, 1988)

- The NIS of Japan
  - 'the relative intensity of *civil* industrial R&D' and '... lead in exploiting the *results* of R&D' (1988: 330)
  - (1) the role of the government (MITI)
  - (2) the role of firms, especially the *keiretsu*
  - (3) other social and educational innovations
    - high level of general education and scientific culture
    - close integration of industrial training with product & process innovation: 'factory as a lab'

Table 1. *Estimated gross expenditure on research and development as a fraction of GNP. (GERD/GNP ratio) 1934 1983*

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Japan	0·1	1·0	2·7	2·7
USSR	0·3	3·2	3·6	1·0

*Estimated weighted average of 12 EC countries.

Source: Author's estimates based on Bernal (1939) adapted to 'Frascati' definitions (1963), OECD statistics, and adjustments to Soviet statistics based on Freeman and Young, (1965).

Freeman

Lundvall (1985; 1988) - 'interactive learning'

- Institution as agent of learning

→ technological progress is determined by the volume and quality of the interaction between users and producers

- Nation as a unit of analysis

- geographical proximity
- language and cultural proximity
- the existence of the national government

Nelson (1987; 1988)

- More general analysis of the combined public and private character of technology, the role of firms, government, and universities in the production of new technology
- Focusing on the U.S. system
- Later, case studies of 15 countries (Nelson 1993)

Expansion of NIS studies

- Globalisation of NIS
- Regional innovation systems
- Sectoral innovation systems

Common theme

- Components and their interface
  : determinants of system efficiency
  - working of individual components
  - synergy among them

Components of NIS

- Narrow definition: R&D institutions
  - firm: R&D dept. intra-firm organisation of R&D
  - private R&D labs
  - university: doing basic & applied research, training & supplying scientists and engineers
  - public R&D labs
  - public R&D policy: infrastructure, patent policy, specific R&D programmes, benefits & subsidies ...

Components of NIS

- Broad definition: all the institutions related to innovation
  - firm: learning-by-doing in the production process
  - competition and cooperation among firms: market structure vs. innovation, subcontracting network, M&As and alliances ...
  - diffusion of innovation within a country
  - capital investment: related to diffusion of embodied technologies
  - general education and skill development in a country
  - broad technology (industrial) policy: infrastructure, sector-specific policy, demand-side stimulation …

Diversity of NIS

(1) Difference in R&D intensity
(2) Difference in the share between basic and applied research
(3) Difference in the share between public and private sector
(4) Difference in the importance of patents

How to analyze diversity?

- Two kinds of causality

(1) Homogeneous causality

- same functions are realised by same institution, but their performance is different according to how well they work

→ analysis of commonality, not much different from functional analysis

(2) Heterogeneous causality

- components & relations: some missing components and different relations

→ The crux of diversity

5.3. Strategy of firms

Starting point

- Technological trajectory + Heterogeneity of firms

"One possible approach ... is to look at the various strategies open to a firm when confronted with technical change". (Freeman & Soete 1993: 265)

Common imperatives

(1) Bounded search along technological trajectory

"Given its highly differentiated nature, firms will instead seek to improve and to diversify their technology by searching in zones that enable them to use and to build upon their existing technological base. ... What the firm can hope to do technologically in the future is heavily constrained by what it has been capable of doing in the past." (Dosi 1988: 225)

Heterogeneity

(2) Differences in technological capability

(3) Differences in risk-taking preference

(2)+(3):

① offensive strategy

② defensive strategy

③ imitative strategy (substituting strategy)

④ dependent strategy (complementing strategy)

Offensive strategy

- "… designed to achieve technical and market leadership by being ahead of competitors in the introduction of new products". (268)

  → confined only to a small number of firms

(1) R&D

- research intensive

  → 50% of total costs in launching a new product
- basic research

  - highly important
  - not pure basic research, rather 'oriented fundamental research or background fundamental research' (269)

- ‘experimental development work’
  - design engineering + applied research
  - “... must have a very strong problem-solving capacity in designing, building and testing prototypes and pilot plants.” (271)
  - the area of the heaviest R&D expenditure
  - → secondary and follow-up patents

(2) Patent

- high importance
- → by being first in the world, aiming at acquiring patent protection, and thereby covering the heavy R&D costs

(3) Education

"At a later stage these functions [of educating both customers and its own personnel] may be socialized as the new technology becomes generally established, but in the early stages (which may last for some decades) the innovating firm may have to bear the brunt of this educational and training effort." (272)

eg. Marconi school for wireless operators, the BASF agricultural advisory stations, the IBM and ICL computer training and advisory services ...

- requires a generally higher level of education

Defensive strategy

- Close (responsive) catching-up strategy

"... do not wish to be the first in the world, but neither do they wish to be left behind by the tide of technical change." (273)

" ... do not normally aim to produce a carbon-copy imitation of the products introduced by early innovators. On the contrary, they hope to take advantage of early mistakes to improve upon the design .." (276)

- Why defensive?

① risk-averse

: do not want to take risk of being the first, and want to profit from forerunner’s mistake

② lack of original innovation capability (but only a small gap)

③ having particular strength in production engineering and marketing

④ ‘involuntary’: simply outpaced by competitors

- Strategy for a larger number of firms

“... in all the leading countries, most industrial R&D is defensive or imitative in character and concerned mainly with minor improvements, modifications of existing products and processes, technical services and other works with short time horizons.”

Eg 1. GM

“It was not necessary to lead in technical design or run the risk of untried experiments [provided that] our cars were at least equal in design to the best of our competitors in a grade.” (Alfred Sloan, quoted in Freeman & Soete 1993: 145)

Eg 2. IBM

- Sperry Rand (Univac) took offensive strategy
- difficulty in ‘breaking ice’: ‘New Combinations’ and swarming

(1) R&D

- basic R&D

  : (probably) less important than offensive strategy

- 'experimental development work'

  : (probably) more important

  → 'speed' is crucial

(2) patent

- less important but 'a bargaining counter to weaken monopoly position'
- buying license or develop alternative patents

(3) education

- possible to emphasise more on education to catch-up

(4) marketing

- more important

Imitative strategy

- Distant latecomers in competition with forerunners

" ... does not aspire to 'leap-frogging' or even to keeping up with the game. It is content to follow some way behind the leaders in established technologies, often a long way behind." (276)

- Some advantages over forerunners

"The imitator must enjoy certain advantages to enter the market in competition with the established innovating firms." (277)

① captive market through linkage effect (rubber – tyre company)

② tariff protection, subsidies, other government policies

③ low costs (in labour, plant investment, energy supplies, materials ...)

④ managerial efficiency from low overhead costs and low investment in R&D

- Entry at the ‘mature’ stage of product development

cf. product life-cycle (Hirsch 1965; Vernon 1966; Perez & Soete 1988)

(1) R&D

- less investment in R&D

but need to be good at ‘adaptive R&D’ (279), gearing at reducing production costs

(2) patent

- little concern, but becoming important as the firm moves towards defensive strategy

(3) emphasis on production efficiency

- utilising various advantages of latecomers
- need to invest heavily in production facilities & related development of technological capabilities

(4) education

- (probably) general education and on-the-job training

Dependent strategy

- Distant latecomers subcontracting to forerunners

"A dependent strategy involves the acceptance of an essentially satellite or subordinate role in relation to other stronger firms. The dependent firm does not attempt to initiate or even imitate technical changes in its product, except as a result of specific requests from its customers or its parents." (280)

(1) R&D

- initially, no R&D facilities and no initiative in design
- typically, less R&D than imitative firms
- enlarging R&D capacity as it moves towards the category of innovative firms “by the upgrading of their specialized knowledge in a narrow field.”

cf. subcontractors, OEM, ODM (own-design manufacture), contract manufacturing (or foundry in the semiconductor industry) ...

(2) patent

- little concern

(3) production efficiency

- important
- technical assistance from customers
- often high profit rates

“In spite of their apparently weak bargaining position, they may enjoy good profits for considerable periods, because of low overheads, entrepreneurial skill, specialized craft knowledge or other peculiar local advantages.” (281)

Penrose's 'intersticies' and comparative advantage

- 'Interstices'

: small gaps or cracks where small firms can exploit even if they are absolutely inferior in competition with large firms

Growth of large firms creates numerous new business opportunities. They can seize some of them, but not all because of 'a limit on the rate of expansion'. The expansion should be supported by concurrent increase in managerial capacity, but it takes time to a create new capacity. (learning process)

"Essentially, the interstices are created because there is a limit on the rate of expansion of every firm, including the larger ones; the nature of the interstices is determined by the kind of activity in which the larger firm find their most profitable opportunities and in which they specialize, leaving other opportunities open." (223)

- The principle of comparative advantage

  - large firms have pressure to concentrate on competition with their major competitors. If they are too extended, profit pressure $\rightarrow$ weakening competitive position