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TECHNOLOGICAL INNOVATION VIS-À-VIS R&D: A MANAGEMENT CONFLICT

(THE CASE OF THE OECD)

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INTRODUCTION : DECIPHERING THE SEMANTICS

The innovation process and its management is a determining and crucial element in the success, continuity and competitiveness of industrial and non-industrial activities, as:

- it enables products to be differentiated from similar competing ones
- it contributes to giving those products a leading edge in the marketplace
- failure to match the successful innovations of competitors can have detrimental consequences.

Technological innovation is commonly referred to as *'research and development'* or simply R&D. This convenient labelling is somewhat limiting and overlooks some important issues.

Firstly, there seems to be no general agreement on what the term R&D means. It is often interpreted differently by different organisations, and by activities within the same organisation such as corporate management, middle management, design, production and marketing.

Secondly, and more pivotal, the label suggests that the process of technological innovation is confined to two phases only. However, in reality it ranges from probing and extending the frontiers of knowledge in academia to developing proven know-how to manufacture and test artefacts and processes.

Thirdly, from an economic point of view, R&D expenditure is in fact an overhead expense until the results are commercially exploited. R&D is but the first stage in the innovation process, and the importance is now recognised of a continuous innovation chain linking scientific research, marketing research, invention, development design, tooling, first production and marketing of the new product.

Typical distribution of costs in successful product innovation (Fig. 1) indicates that the share of different stages are:

- R&D is about 5 - 10%
- engineering and designing the product 10 - 20%
- tooling, manufacturing engineering (i.e. getting ready for manufacture) 40 - 50%
- manufacturing start-up expenses 5 - 15%
- marketing start-up expenses 10 - 25%.

Related projects would verify the potential of the technological concept(s) examined at the previous level in terms of product differentiation. The outcome of these projects is usually in the form of a working demonstration or prototype for the product range, in addition to a report evaluating the project results in terms of design and product development parameters.

Product development and design

Projects in this category are mainly aimed at a ***single product*** within the chosen product range. They usually take the form of a verified manufacturing description of a specific product which meets predetermined functional, performance and cost specifications.

The subtle difference between ***development*** and ***design*** depends on the position of the observer. The car industry gives a relevant example. Consider the technological innovation of a new car which incorporates, among other novel aspects, a new engine. From the perspective of the team responsible for ***designing the car as a whole*** product, the new engine is a novel sub-product which needs to be ***developed***. On the other hand, the team concerned with the engine views it as a ***design task*** since it entails creating a new product from established and proven components, some of which may be novel, such as a new cam shaft or engine management system.

INNOVATION AND THE ORGANISATIONAL PROFILE

The perceived need to innovate varies between organisations. Successful manufacturers of microelectronics, computers and biotechnology products are highly innovative and produce a steady flow of new products, whereas those manufacturing, for example, soft drinks and foodstuffs for the consumer market frequently enjoy long periods of maintained growth with few, if any, significant additions to their range of products.

These contrasting approaches are reflected in the ways organisations allocate their disposable funds, non-trading income and loans to the development of new products. For example, whereas companies in the new electronic industries may typically allocate 15% to this purpose, the figure for manufacturers of drinks and foodstuffs is around 3%.

The suppliers of consumer goods to the mass market, however, spend considerably more on achieving a high level of production efficiency and assign high priority to distribution, sales, marketing and advertising. Table 1 summarises approaches by *traditional* and *innovative* companies.

FUNCTION	TRADITIONAL COMPANY	INNOVATIVE COMPANY
Corporate Board	Emphasis on financial control	Innovation-oriented ---- future perceived as uncertain
Organisation	Impersonal, hierarchical, status-dependent	Dual structure ---- vertical and horizontal
Marketing	Reactive---- stability based on attractiveness of product. Closed marketing strategy	Constructively creates an unstable environment
R & D	Defensive, evolutionary	Aggressive, innovative
Production	Efficiency, rationalisation and long runs	Openness to change

Table 1 Some characteristics of traditional and innovative companies

and although success and reputation in the ***Oxford Instruments Group***, as an example, was initially based on innovation in cryogenics and superconducting magnets, further prominence and growth has been achieved through gaining technical leadership in medical instruments and electronic components for specialised applications.

An important policy was the pivotal role attributed to in-house research, which is complemented by maintaining:

- very close contact with developments carried out by the users of products
- links with related centres of scientific excellence, including universities.

Another distinguishing feature of the innovative company is that a high proportion of its turnover is attributed to the marketing of relatively few high-cost products. Innovation is aimed at achieving high rewards, and this entails high research cost and capital expenditure. Moreover, the risk factor in high technology is usually great; however, the continued growth of this particular company demonstrates that uncertainty can be addressed by the recruitment and retention of highly qualified and motivated staff.

The case of the traditional company

By contrast the '***metal rivets and caps***' production is an example of a traditional environment. Although the number of employees is larger in comparison with the innovative companies, the majority are craftsmen and technicians with the general absence of qualified scientists.

One reason for lack of innovation can be attributed to their reliance on the production of one or two basic products, the design of which depend mainly on craft skills, experience and ability to respond quickly to the needs of customers.

Another distinguishing feature of traditional companies is the nature of the manufacturing process, which is geared to mass-produce low-cost products. The continuity of these companies does not seem to depend on radical product innovations based on advanced technology, but rather on:

- their ability to maintain competitive prices
- openness and readiness to evolve inexpensive product-modification to meet changing needs
- non-innovative efficient manufacturing
- emphasis on non-price factors such as service, distribution and selling.

A further contrasting factor between the traditional and innovative production cultures is that traditional companies rely on continuous '***incremental***' improvement of products/processes to meet slowly changing market needs, or uninterrupted assimilation of evolving science and technology targeted for sustaining or expanding exiting markets. While innovation primarily involves the conceiving of a new idea, often an invention, together with its successful traverse towards a new material, process, product or system. More essentially, it implies a discontinuity and a need for a radical change in the way the organisation should be managed.

This sharp division between the traditional and innovative companies seems to be contracting in the late 1990s as many traditional companies are faced with the option to either '***innovate or liquidate***', due mainly to increased competition from S. E. Asia in both efficiency and price.

Nevertheless, the comparative study of the eight industrial clusters seems to indicate that the main contrasting features between the traditional and innovative company can be summarised by the following:

- the scale of revenue and capital expenditure on research
- the risk associated with new product development

In real terms the total R&D expenditure in the OECD countries rose sharply from $85 billion in 1978 to over $500 billion in 1995, that is ***$1.4 billion per day*** with over two million people employed in the three regions.

It is quite apparent that the US share is dominant, varying between 42% in 1978 and around 48% in 1989; however, Japan and Western Europe started to assume an increasing share in R&D spending with Japan peaking at 22% (i.e. 50% that of the US) and Europe at 25% of the total. The relatively low figures for Japan and Europe can be attributed to a decline in the share of the public sector to 40% in the former and 20% in the latter.

Corporate response

Surveying the performance of thirty leading companies within the OECD for the same period shows some interesting results. These are some of the large corporations in electronics and electrical engineering in the US, Japan, and the EU, and include:

- US => General Electric, Hewlett Packard, and IBM
- Japan => Hitachi, Matsushita, Sony, and Toshiba
- EU => Ericson, Philips, Siemens, Alsthorm.

These companies represent not only some of the largest industrial complexes in the world, but an industrial force of overwhelming proportions and magnitude. Their total sales in the mid-1990s exceeded $600 billion, with estimated profits of around $27 billion.

The following is an assessment of the R&D, profits and sales performance of these thirty industrial giants within the OECD, allowing a one year lag between increased expenditure on R&D and profit. When the cumulative totals of profits and R&D expenditure are considered for the period 1978-1995, the latter exceeds the former by about 20% (Fig. 3). The US group was the most successful in keeping up profits with investment in R&D; the profit intensity (i.e. profit as a percentage of R&D expenditure) is about 97%. However, the correlation is at its weakest when companies within the European Union are considered, where profit intensity was only 37%.

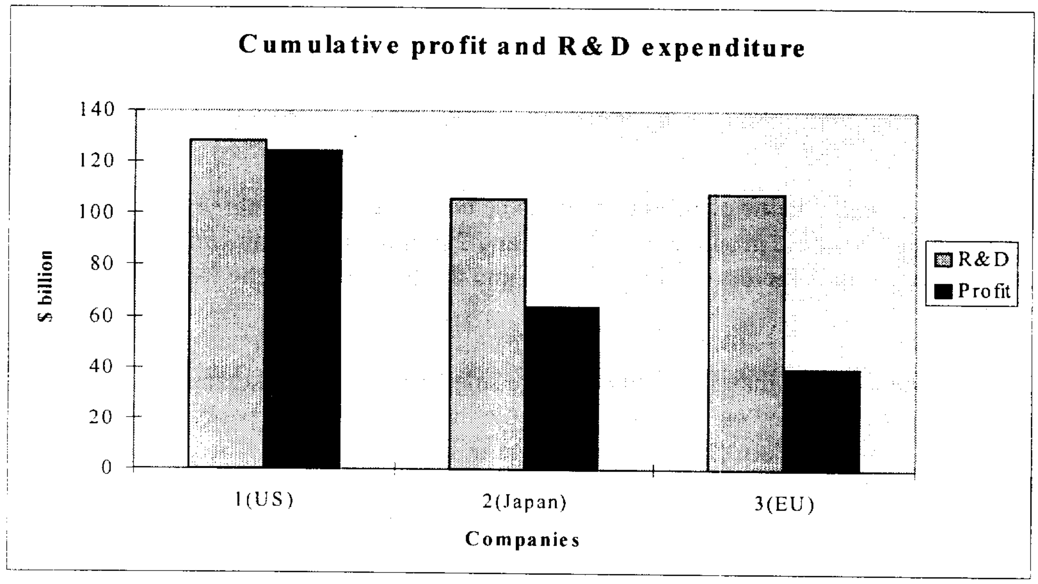

Fig. 3 Regional cumulative profit and R&D expenditure (1978 - 1995)

ANALYSIS AND CONCLUSION

This weak correlation between R&D expenditure, sales and profits seems to contradict the conventional orthodoxy that spending more on R&D should have an immediate and multiple positive impact on the organisation's finance and overall wealth creation.

All the thirty organisations considered are large corporations with wide and diversified production profiles and a considerable proportion of the profit is extracted from marketing

well-established, highly competitive and in many instances monopolistic brand names. These brand names have become progressively more valuable in the OECD countries during the 1980s and '90s as they are designed for world-wide sale with non-costly minor modifications for local export markets. Naturally, this would have wider implications for R&D as new product innovations do not necessarily lead to increase in sales and, therefore, profits.

This, however, does not imply that these products do not undergo development; on the contrary they witness on-going modifications, but such changes are incremental and not necessarily costly. A relevant example is the car industry; in 1994 GM (General Motors) launched the Vectra in Europe which proved to be popular. Since its introduction the basic overall design, structure and shape has hardly changed; however, according to GM over 2000 changes were introduced up to 1999. Most of these changes were on improving passengers safety and comfort, engine efficiency and electronic management, fuel economy, etc.

Most of the R&D budget is oriented towards speculative and strategic research the nature of which is to consolidate the organisation's position, give it a leading edge in the global market and maintain its competitiveness in the medium and long term. However, the situation is different when considering small and highly specialised companies where R&D is the mainspring of their functioning and the rapid and effective commercialisation of its results is the main source of profit and growth. Typical examples are biotechnology, genetic engineering, scientific and medical instrumentation.

The observed closer correlation between R&D expenditure and profits in the case of the US companies could be attributed not only to the efficient commercialisation of research, but more importantly to the special position these large organisations, the majority of which are trans-nationals, hold in the global market:

- they are backed and supported by the state with generous incentives and allocations for research
- they enjoy the control of a wide geographical area including North America and the North American Free Trade Association (NAFTA) region
- they have benefited from the retreat of trade barriers elsewhere through a multiplicity of measures, including acquisition, mergers, affiliates and subsidiaries
- they have been aided by the effective utilisation of the World Trade Organisation (WTO) as a vehicle for international trade liberalisation.

As indicated in the introduction, R&D is one of a chain of integrated, linked and interdependent events and activities that make up the innovation process. Evidence from the experience of the OECD seems to suggest that in the majority of cases failure or delay in the commercialisation of a research project could be attributed to the post-research stages of the innovation process and their effective management, in particular the development and product design phases where lateness would have extremely expensive consequences. As an example, in the Euro Tunnel Project which links the UK with mainland Europe, of the $7 billion overspent on the tunnel construction, 44% represented unplanned engineering costs. The other 56% was attributed to the financial consequences of delay.

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Basically, the tunnel was built before the problem of manufacturing the trains was understood. Had this knowledge been available, some of the 44% and much of the 56% would have been saved.

Moreover, although the tunnel and its market have an almost indefinite 'lifetime', many electronic products are obsolete within a short time, and the consequences of delays in development and design can be very serious indeed.

Yet another example on the importance of a holistic management approach to the innovation process could be found in the UK's advanced gas-cooled nuclear reactor (AGR) programme. The nuclear power research programme throughout the 1960's and 1970's was both advanced and well funded by the public sector; however, not enough focus was placed on the concurrent development of the AGR technology. This has resulted in endless design changes and consequent costly and lengthy delays.

A major facet of the end of the 1990s and the challenge for the new millennium is heightened global competition, where market shares are being frequently acquired through pricing mechanism. Consequently, in order to remain profitable more emphasis in production is placed on higher operational efficiencies: this is being achieved by, amongst other measures:

- improvements to existing products
- process optimisation
- focusing on improving technology management
- downsizing and re-engineering.

However, this does not negate the value of investing in R&D. On the contrary, survival in the market place depends on this asset, the core of which is knowledge, its creation, ownership, appropriate management and utilisation which are pivotal for a successful and sustainable development and growth. Moreover, the importance of an integrated approach to the management of knowledge and its ultimate commercialisation is now recognised as the main determining factor in the success of the innovation process. In this context, and in the face of heightened competition in the global market, more emphasis is being placed on *'concurrent engineering'* whereby the design, tooling and engineering phases evolve in parallel with the R&D.

In conclusion it would be appropriate to quote one of Hewlett Packard's Directors:

> *"The fundamental building material of a modern corporation is knowledge. Using knowledge to make money is the real challenge. This 'knowledge pay-off' occurs when a corporation's most valuable intangible asset - knowledge - is converted into bottom-line value in the form of a concrete, saleable product."*

One way of addressing this anomaly is that R&D-related profits are not the only criteria for measuring corporate performance; substantial sales are regarded by many as the main indicative element for success. Growth of an enterprise is seen as a sign of significant attainment, and is considered as one of the more important measures of achievement.

The argument above could be verified by examining whether R&D has contributed to sales growth. Fig. 4 shows the regional growth in R&D expenditure and the value of sales in 1995 with 1978 as the base year (i.e. 1978=100).

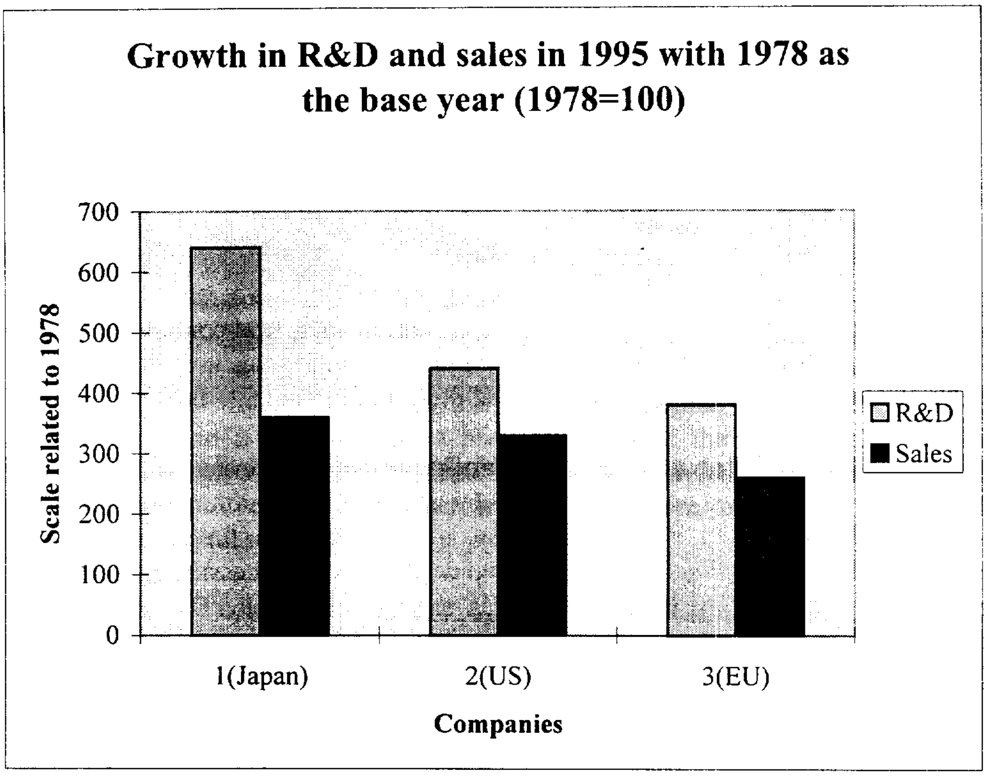


Fig. 4 Regional growth in R&D expenditure and value of sales with 1978 as the base year

The growth in the value of sales appears to be comparable in the three regions, having increased by a factor of 3.6 in the Japanese group, 3.3 in the US and 2.6 in the European Union. On the other hand, R&D expenditure has grown by a factor of four in the US and the EU, while in the Japanese group the growth was by a factor of six.

Even if one assumes that the higher average sales growth of the Japanese companies was caused by primarily higher expenditure on R&D, it is quite apparent that expenditure on R&D had to grow disproportionately to gain a relatively small advantage in sales growth.

For almost all thirty companies investigated in the three regions, the increase in R&D expenditure has exceeded the growth in the value of sales.

The few exceptions are those companies with a wide product base including industrial and household goods, such as Philips, Westinghouse, Hewlett-Packard, Siemens, Mitsubishi and Sony.

- the anticipated benefits from product development
- volume of production and costs of products
- the source of development ideas, whether external or internal
- the importance placed on research, design and development
- the likely sources of threats to growth.

INDUSTRIAL R&D: MANAGEMENT PERFORMANCE IN THE OECD

The post-war national response

The 1960s witnessed an accelerated technological race between companies for growth and market control. Economic boom led to the dismantling of trade barriers between nations, and to the emergence of the ***'global'*** manufacturing conglomerates. The US was the first to respond by increasing its expenditure on R&D between the early 1950s and the late 1960s by a factor of four in real terms.

By the mid-1960s there was ten times as much R&D in the US as in any other country in the world.

This sent shock waves throughout the rest of the industrialised world, and gradually in the 1960s, '70s, '80s, and '90s other countries and companies started to invest seriously in R&D, primarily within their own internal R&D infrastructure. Corporate industrial research laboratories and public sector research facilities became pivotal in the innovation process.

Fig. 2 shows the percentage expenditure on R&D for the period 1978 to 1995 in the US, Japan and the European Union (EU).

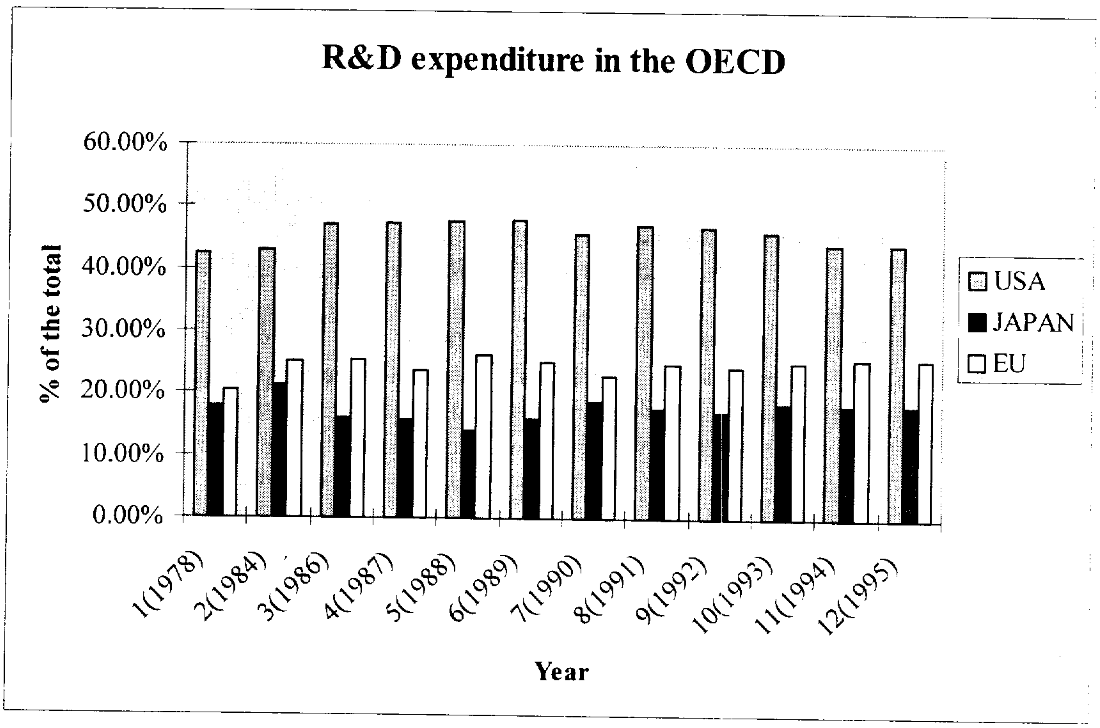


Fig. 2 Expenditure on R&D in the OECD

A traditional company operates in a relatively stable environment, declines change and adopts a reactive attitude to market requirements. The operations associated with relatively unchanging products are concerned with attaining the highest possible efficiency, and this is achieved by giving attention to automation, rationalisation and other production engineering procedures. When R&D or design is carried out it is, normally, evolutionary and defensive in character.

The company organisation tends to be impersonal, hierarchical and status-dependent. The Boards of traditional companies place emphasis on financial control and corporate plans which may be based on the use of extrapolated historic trends of financial statistics.

On the other hand, the innovative company accepts that the future is likely to be uncertain and the process of corporate planning must itself generate new insights and be dynamic. One aim of the marketing function will be to '***disturb***' the stable environment in order to create new opportunities. Industrial operations will thus need to be designed with a view to the possibility of introducing new production methods. Research, design and development will be important activities and will be aggressive and innovative rather than reactive. The organisation pattern is likely to be dualistic in structure, a vertical one based on a specialised function and a horizontal one concerned with co-ordinating independent activities.

During the recession of the 1970s and 1980s many international companies in the industrialised world adopted innovative policies after decades of lucrative markets and traditional approaches to production. The classical strategy of achieving growth by marketing well-established products more effectively in international markets invariably attracted fierce competition, which consequently led to losses in turnover and profits.

PRODUCTION, TECHNOLOGY AND THE INNOVATION RESPONSE

A case study of the performance of eight manufacturing industries in the UK illustrates the diverse nature and degree of the innovation process. These industries included:

- Food preparation
- Metal rivets and caps
- Industrial glass
- Fluid-level control and switching
- Electronic products for monitoring and control
- Components for automobiles and process industries
- Industrial engines
- High precession instrumentation.

The case of the innovative company

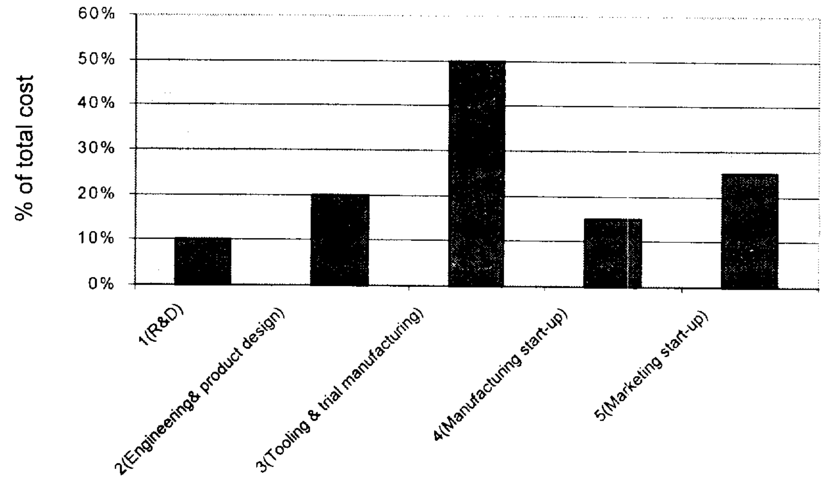
The study concludes that the highly innovative company demonstrates many features that are not shared by traditional companies.

The most evident difference lies in the use of advanced research which is carried out by scientists and technologists. For example, in the companies producing '***high precession instrumentation***', typically:

- around 25% of employees are graduates
- 10% are holders of high degrees (i.e. M.Sc. and Ph.D.).

This reflects the main purpose of the organisation, which is to achieve and maintain international excellence while operating at the frontiers of technology. Research in this environment is multidisciplinary

Fig. 1 Typical cost breakdown of product innovation



Hence, in budgeting for innovation the entire cost, not only, R&D should be projected. Moreover, within the R&D component itself the development stages will account for a much greater proportion of this expenditure than scientific research, which thus becomes a relatively small part of the total innovation cost.

In the manufacturing industry this wide spectrum of activities can be, typically, divided into three main linked and integrated phases or levels:

- applied research
- mission-specific research
- product development and design.

Applied research

Such projects are mainly concerned with ***technological transformation***, i.e. the techno-economic feasibility of new concepts which are considered potentially critical to future product differentiation in the marketplace. That is to say, these projects invariably relate to a range of products.

Moreover, they are usually involved with extending and broadening the current boundaries of existing technologies rather than the development of totally new or novel ones such as jet propulsion, the micro chip and computers.

When the new concepts are techno-economically feasible then they could generate a number of applied research projects. For example, the synthesis of non-conducting heat material may lead to further research on a new range of fire-resistant appliances.

Mission-specific research

These projects utilise the know-how and technical competence gained at the previous level to meet the requirements and specifications of a potential new ***product range***. Such requirements would typically include functional, performance and cost targets.