EIRMA. Annual Conference 1982

R&D as an Investment

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R&D INVESTMENTS AND BUSINESS CYCLES

Developing the Corporate Strategy

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1) Introduction

Industrial research managers are convince to be of part a rational management system.

Certainly EIRMA contributed to build that image of rationality by analysing different topics of research management such as: methods for evaluating R&D projects; the allocation of R&D resources, etc. (see Table 1)

Table 1. ***Selected EIRMA Working groups***

Nr. 3 - The Use of Computers in R&D
Nr. 6 - Methods for the Evaluation of R&D Projects
Nr. 3 - Information Requirements for R&D
Nr. 12 - The Allocation of Research Resources
Nr. 17 - Licensing
Nr. 21 - System and Methods for Planning R&D in Industry
Nr. 26 - Management of Product Development Projects

If one looks closely at the list of EIRMA Working Groups, titles are found (see Table. 2) that indicate a more global approach: the societal dimension in R&D strategy, how much R&D, etc.

Table 2. ***Selected EIRMA Working groups***

Nr. 7 - Relations between Industry and Universities
Nr. 9 - Cooperative International Research
Nr. 10 - Technological Forecasting and Long Range Planning
Nr. 13 - R&D for Industry of the Future
Nr. 14 - Creativity and Motivation in Industrial R&D
Nr. 15 - Industry - Government Relations
Nr. 19 - The Societal Dimension in R&D Strategy
Nr. 22 - The Changing Interface between Research and Marketing
Nr. 23 - R&D in an Energy and Raw Materials Conscious Era
Nr. 27 - The Role of Industrial R&D in the Innovation Process
Nr. 28 - How much R&D.

The theme of this Conference is somewhat ambiguous in the sense that it might convey the idea of a further step in the rational analysis of the research subsystem - classifying research as one of the explicit variables in the production function along with capital equipment - or on the contrary, that of an integral view of research [1].

Following the first suggestion the analytical approach, it will mean going along with the rational "reductionist" view of the management: i.e. management that is able to "reduce" the decision problem to that of selecting which research projects to support on the basis of the expected return on the investment of resources in each project.

I suspect that this rational approach of project-by-project selection comes to surface in the company management systems when times are difficult and resources scarce. To behave rationally it might seem for the research management the best way to assure that the competition from shorter term-product development and capita] investment-projects do not kill the research activity.

Unfortunately, as we will try to show, the more the company or the economy system is in difficulty, the less a reductionist rational approach to management, in general and particularly so in research, is the best approach.

We know that we live in a dynamic social-economic world, and being !t a very complex system, it oscillates. This fact might have not been evident in our last history.
The period from the end of the second world war to the early seventies was in fact one of expansion.
lf we assume that management perform the role of an instrumentation and control systems, it is possible - notwithstanding the time delays between detecting the signals from instrumentations and operating the actuators - to maintain the system in dynamic equilibrium (homeorhesis) when the input variables increase uniformly. When the external variables suddenly change, then the delayed response of the instrumentation and control system, will produce an oscillatory behaviour.

I indulge an this naive metaphor to stress the point that a man-made instrumentation and control system behaves rationally it takes the signals, it elaborates them predicting future states of the system, and, according to some optimisation rule, it produce feedback actions. To design a control system that avoid large oscillations in case of large input changes, it is a difficult art.

One should be able to design the “logic” of the control so that it changes behaviour, during fast transients, from a rational to an “irrational” or, better, a different level of rationality. As a matter of fact, adaptive control systems that have an internal learning system capable to recognize patterns are developed.

This need to change behaviour is recognized also in the economic system: when large economic changes characterize the prevailing mode, then Schumpeterian economists emerge to emphasize the role of the entrepreneur, capable to deal with high uncertain-

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[1] This ambiguity is not typically only of the theme of "R&D as an investment" but can be extended to the entire management of innovation’s system. See for instance the book by N.M. Kay - The innovation firm. A behaviour theory of Corporate R&D - The McMillan Press, London, 1979.

In general one can consider two extreme approaches
- the reductionist approach
- the holistic approach.

The "reductionist" approach "reduce" a complex system, by the power of the analysis to its basic components: the single R&D projects in the case of the complex R&D system.
In the "holistic" approach it is recognized that the system has its own global behaviour, with synergistic effects so that it is not possible to manage the system by reducing the problem to that of the analysis of the system's component.

ties, with respect to the classical economy concept of the rational operator as a profit-maximizer.

2) <u>Rational Decision Making On R&D Investment</u>

Uncertainties are intrinsic to the economic system but it is the more so the more one moves back from market, to production, to development, to research. Even in the case that the general economic situation is predictable and the company is following a steady growth course of development, it is difficult for the company management to behave rationally with respect to research projects, especially when dealing with radical research projects. In other words, to look at research projects for their profitability - as with capital investment projects - and decide in a well balanced strategic plan, how much of the available resources should be allocated to research projects on the basis of the expected contribution to long term company growth.

As a matter of fact, it seems that the game of project-by-project resource allocation in research is seldom played at the different echelons of the company management hierarchy.

The top management, might be satisfied with having delegated to the research management level this rational behaving approach.

We do not enter here into a detailed discussion to what an extent this actually happen.

In any case, top management with all its strategic staff support has a direct responsibility with respect to research, i.e. that of deciding the total amount of resources that are devoted to research and development.

Even limiting the present discussion to this apparently simpler issue of the resource allocation to R&D, one can still question to which extent this decision could be taken rationally, if it is not possible, at least at the level where the decision is taken, to analyse the return of R&D considered as an investment.

The holistic approach reintroduces a certain degree of rationality by assuming that the different echelons of an hierarchical management system decide on the basis of the <u>patterns</u> of information and signals that <u>emerge from the system</u> at their corresponding level.

Typically, at the top of the company one pattern that emerge is that of the research intensity (measured f.i. by the ratio of R&D expenditure to company sales) characteristic, at a certain moment of time, of the industry in which the company operate.

R&D as an investment is therefore a less analytical project-by-project concept and a more synthetic one.

The capability of that high level rational behaviour, based an synthesis perception, is more evident when the patterns are stable and the management have learned to grasp them along the course of company history.

But when environment suddenly change, the cid patterns are no more valid for decision taking, and the new ones are not yet emerging. Talking of R&D as an investment, and therefore relaying on some kind of rational management behaviour in time of large business change is therefore an hopeless exercise?

It is increasingly necessary, in that case, to understand the general mechanism that underlay the research- production interaction or, more in general, the innovation process.

By understanding the basic mechanism one might be able to predict the emergence of future patterns, and how to learn not only reading its own system history but also that of different industry systems.

This is the reason why we will first of ail here summarize the ideas on the interpretative models of the innovation process.

3) A Model For The Innovation Process

A company is a system that process information, materials, energy and financial resources to fabricate and sell products.

It can be classified as an "open" (or "adaptive" or "process type") system. The basic characteristics of open systems are that they exchange resources with the environment and they grow, as if responding to finality, towards increasing complexity and organization which is depending from constraints, system history and environments.

Innovation, and technological innovation in particular, is the process that characterize the company system evolution. The concept can be generalised to embrace an industrial sector, or the entire economic activity.

The company system can be divided into different subsystems and the innovation process in corresponding phases research, development, pre-industrialization, market testing, product manufacture and sales.

The subsystems can be structurally separated or not. Each such subsystems can be considered as "open" one respect to the other in the sense that they exchange resources.

Competing companies do not directly exchange materials, energy and resources among them. So, they can be considered as "closed" one to the other, but "open" with respect to the environment.

A special case is that of different companies working in the innovation process in a chain: the raw material suppliers, the component manufactures, the final product assembler. Since they interact through the environment (customer-client relationship) we will consider also them to be "closed" systems one with respect to the others.

We will see later why we insisted in these detailed remarks.

Going back to the innovation process in a company as an open system, it is possible to borrow from the system of living organisms, characterized by the natural evolution process an interpretative model that fit the characteristics of the innovation process.

The process is divided in two basic sub-processes
- generation of innovation proposals or inventions
- environmental selection of the proposed innovation.

It is not so clear where to put a dividing line among the company subsystems even if as a rule of thumb one could classify research and development more on the generation of invention side of the process.

A complex network of information and feedbacks is underlying the entire process. The generation sub-process is a highly unpredictable process (the chance) while the selection process assure the fitness of the innovation to the needs (the necessity). [2]

When talking of environmental selection, we should distinguish between an internal, to the company, selection process and an external one. The internal selection have to decide f.i. that the innovation is compatible with the company resources (existing manufactur-

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[2] Reference is made to the title of the well known book of Monod "The chance and the necessity".
For the application of the analogy of the natural evolution to the industrial innovation process, see the work of R.R. Nelson, S.G. Winter: "In search of a Useful Theory of Innovation", in Research Policy, 6, 1977, pp. 36-76.

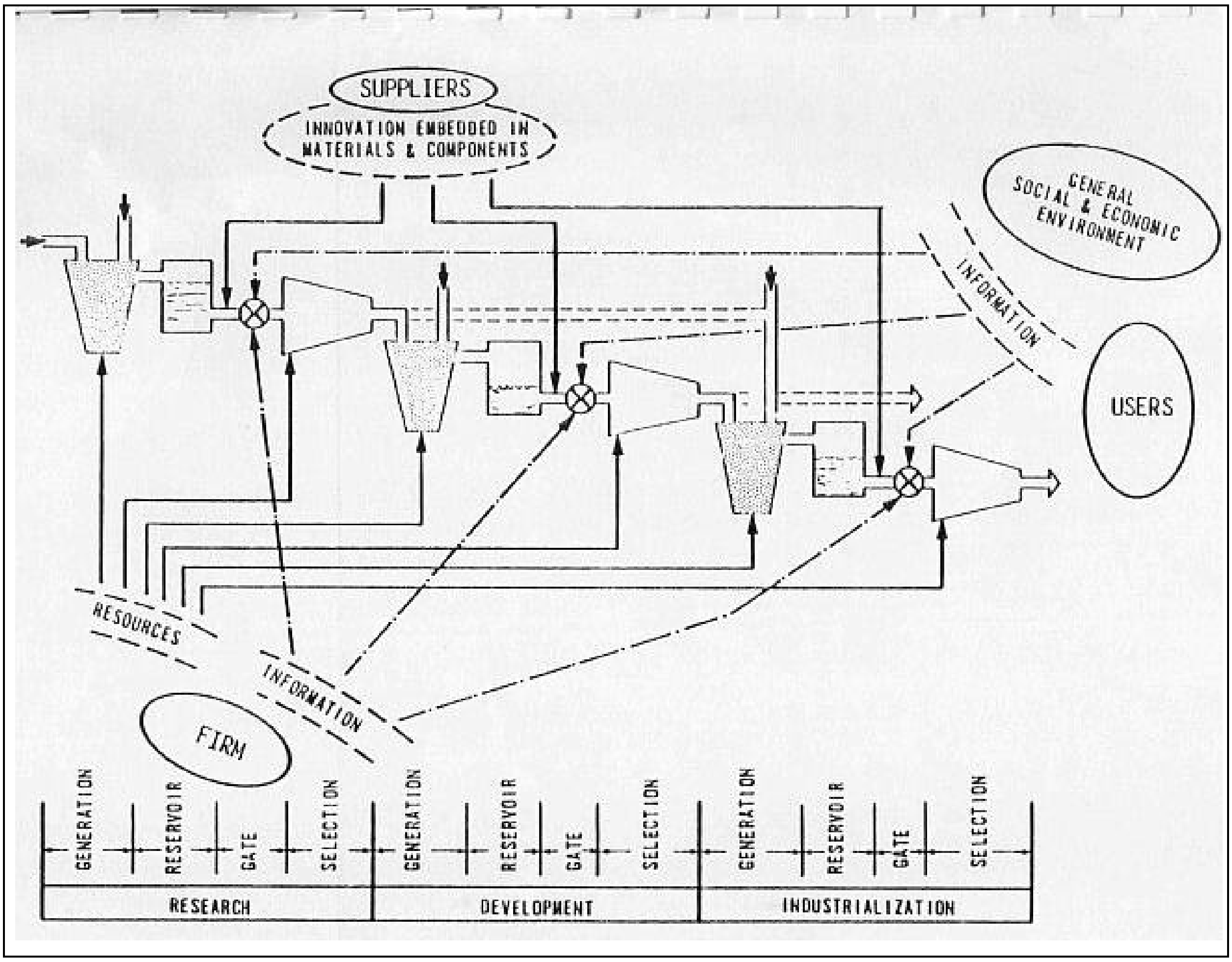
ing facility, or capital for new investments, etc. The external environmental selection operates with different characteristics for the manufacture of consumer goods, with respect to the case of raw material or component manufacturers.

The selection is a process that to start needs a decision f.i. to put a new product on the market. Only in this way selection can do its job to accept or to kill innovation proposal.

We might consider that an “invisible gate” divides the innovation proposal generating sub-process from the selection sub-process. lf the "gate" is “closed”, the innovation proposals “accumulate” untested waiting for better time to come. One common such case is that of the blocking effect due to existing manufacturing facility with regards to innovation that will require new capital investments before the planned obsolescence of the existing ones.

A variation to the above described model (that more closely simulated the real case especially when the research subsystem is structurally separated from the other company subsystems) is that of considering each of the company subsystems (research, development, pre-industrialization, etc.) as interacting open systems. For each such subsystem the same basic model of separating innovation generation from selection wile apply. Remember that, according to Popper, the same basic mechanism apply also to each individual scientist (conjectures and confutations). The projects that have passed the selection (testing and experimentation) process within one subsystem will be imputed, together with other inputs from external environment, to the generation side in the next subsystem (from research to development to .... etc.). A simplified scheme of the model is illustrated in Fig. 1.

Fig. 1 ***A Multistage Generation- Selection Model for the Innovation Process***



The operation of the "selection gate" within each subsystem is depending from a very complex and “incomplete” information system and from the resource allocation’s decision taken within the frame of the global company system.

Each subsystem, being an open system, follows an evolutionary path depending, as already remarked, from constraints and history.

The subsystem can grow and become more complex and organized, or be stationary or die (company reorganization).

The existence of reservoirs of innovation proposal waiting for selection to become operative is a very important feature of the overall innovation process: portfolio of ideas in research; project proposal in development; product prototypes in pre-industrialization; new products in special market niches waiting for large scale market introduction. Full reservoirs are an asset for the company when the opportunity or the need come to open the selection gate.

The complexity of the model increases with size and multi-divisionality of the company and with the increasing need to take lead time - with anticipatory research - with respect to the starting of the market selection phase of the process.

A small company, on the contrary, could be represented, by a simplified version of the model, for example only by the "pre-industrialisation" subsystem.

The Schumpeterian entrepreneur that integrate in himself the change/necessity (opportunity/needs) mechanism for company growth, is a theoretical construct, for from reality in the real case of a large company.

With the aid of the model of Fig. 1 we can better stress now the remarks of the introduction that to "reduce" the complex company innovation management system to a set of well-informed rational behaving managers is also for from reality. Fortunately the system has its own inertial and compensating forces, such as the above mentioned reservoirs. Moreover innovation often follows "natural trajectories" i.e. it is constrained within channels (defined by science itself), in analogy with the necessary path" (chreods) of natural evolution.

By looking at the model of Fig. 1, and thinking of its complex dynamic behaviour, because of feedbacks, time lags, state of reservoirs, and so on, we can first of all understand why it is so relevant and difficult the problem of resource allocation to R&D. For instance, how it will this complex system react in case of sudden environmental changes, such as an economic crisis, or the threat of a competing radical new technology? In the first case, the resources will become scarce and internal competition among the company subsystems to use relatively more of the scarce resources will increase. The decision to change the resource allocations, will have effects an the future of the company because of the induced alteration on the "generation of idea" sub-process. In the second case the top management will start getting emotional about the company capability to counterattack with the same new radical technology. This capability will depend on the state of the reservoirs, especially those closer to the industrialization phase. Opening of the selection valve or deciding on increasing the resource allocation to R&D will have no effect in the short term, if the reservoirs are empty.

In both cases the separation among the subsystems will tend to be less clear, delegation might be waived , the uncertainty care of the technological innovation process will emerge to the top level of the management hierarchy.

Deciding in such a case, only on the basis of the sectoral pattern of "research intensity" (which might have proven to be a good enough indicator in the case of steady business growth) might not be satisfactory. A more complex pattern emerge and have to be grasped.

4) <u>The Innovation Clocks</u>

A more close lock to the general dynamics of the innovation process, interwoven with the business dynamics, might help in the learning of such patterns. [3]

We know that cycles are characteristics features of the microeconomic activity, at industrial sector, or at company level. One such cycle is that of the product-life cycle. For the automobile case, a new model production cycle last typically 10 years, with three major restyling in between and several minor face-lifting changes. A new car model require changing the car assembly production line.

The facilities for mechanical components and engines manufacturing have a much longer useful life, say 20-25 years.

The “internal selection valve” in a company is certainly “modulated” by the said product’s and manufacturing investment’s cyclic changes.

For car restyling, only the design changes that do not require major changes in the assembly line will be accepted. A completely new car model is an occasion for introducing major innovative changes, provided however the mechanical components' and engineer's changes are compatible with the rather inflexible manufacturing transfer lines. It looks like as if there are “innovation hours” governed by innovation clocks.

So, a large innovation opportunity event happen when both the assembling and mechanical transfer lines have to be renewed. We might look at this case as that of an hyper-cycle.

The periodicity of “hyper-cycles” in a typical company should be looked very carefully. But are they? Do company strategy plan well in advance to be sure that the innovation reservoirs are filled up with proposals ready to be introduced in the new models or new capital equipment plants, when the internal innovation clocks require them? Fortunately, during the growth and especially the maturity phases of the business at macro or at micro-economic levels - when only small incremental innovation compatible with the technology mix are acceptable - there is less competition, among the different company subsystems, to use resources. The research subsystem, loosely planned, is in practice delegated for more long term anticipatory activity, and will fill up the reservoirs.

In principio it might therefore seems possible a “rational” corporate strategic research plan based on the observation of the internal technological cycles, for a company that produce for the final user market.

The companies that produce raw materials or subsystems and components for the final assembler, observe, instead, a variety of micro-cycles, those of the different customer *firms*.

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[3] Economists have shown that cycles of different periodicity and intensity characterize the economic activity. Since Schumpeter (or earlier, by Netherlands’s economists) basic innovations have been strictly correlated with the long term economic cycle (the 50-60 years Kondratiev waves). See f.i. the special issues in "Futures", vol. 13, No. 4 and No. 5, 1981, C. Freeman (ed.).: "Technical Innovation and Long Waves in World Economic Development".
After a depression when the economic activity moves into the new growing cycle a cluster of basic innovation (new energy sources, transportation and communication technologies, materials, etc.) characterize the "technological mix" of the new long term economic wave. The winning mix blocks new radical innovation proposals that will afterwards build up in reservoirs, waiting that the new economic wave will reopen the "selection gate".

Its internal “innovation clocks” cannot therefore be set to be synchronous to the several different customer “innovation clocks”.

In normal condition, with a multiplicity of suppliers and customers, the process of innovation will be that typical of an “open system” interacting with the general market environment. The transfer of innovation - embedded in materials, components, machine tools - will take place according to a smoothed-out “diffusion process”.

5) <u>Changing The Pace Of Innovation</u>

Exogenous environmental events might change this "normal condition". One such events is that of approaching a major business crisis, such as that following the maturity stage of a long term Kondratiev wave.

One effect of sustained economic crisis will be that to set the several different microeconomic “innovation clocks” to the same time. In fact, in period of market down-turn, the introduction of new models will be delayed as well as investment to renew obsolescent manufacturing pants. In this depression stage, nevertheless, the innovation “selection valves” open because of the need to increase the useful life of the existing models and manufacturing plants. Product designer and manufacturing engineers will be in desperate need for compatible innovation (which do not require high investments) that will assure another stroke of life to the existing basic mix of product and manufacturing technology. The pace of acceptance of innovation proposal that meet the basic requirement of "compatibility" will increase, and the attitude with respect to the risk of the innovation will soften.

An interesting case is that of microelectronics, in the automotive industry, which is diffusing an the vehicles, to improve fuel economy with existing engines, and even more on the manufacturing plant to increase productivity f.i. with the introduction of “intelligent” robots in mechanical assembling.

In this “extended sunset” of existing product and manufacture mix in case of major economic cycle, the production world is learning to use new invading technologies that will be the base for the next economic wave technology mix.

It is this an interesting occasion not only for internal R&D but also for the intermediate supplier companies to push the innovation embedded in product components and manufacturing equipments.

After the “extended sunset” there will be an “accelerated dawn” of technological changes anticipating the renewal of products and manufacturing plant that have passed across the economic crisis.

From the above remarks, one of the emerging patterns that companies have to look at for R&D strategy is concerned with not so much technological changes but more general economic changes.

Other factors, exogenous to technology, that will change the pace of innovation clocks, are those concerned with social objectives such as environmental protection for densely diffused products, or with more general society strategy such as that of reducing the dependence on oil and scarce materials.

The technological paths (“chreods”) to meet the related objectives are usually well known, such as aerodynamic drag and weight reduction in a vehicle. The difficulties are related to the tentative to increase the pace of innovation, especially taking into consideration the fact that the innovation trajectory has to pass through several systems “closed” one to the other, such as the chain from raw materials, to components, to final products.

There is a push in this case to overcome the intrinsic slowness of the process by "opening" the systems. Few examples will show better the issue.

a) Two-phase steel has been developed as a high strength steel following the “natural trajectory” of the innovation generation process at the research level (technology push). The Japanese steel industry had to renovate their manufacturing plant just in phase with the availability of the innovation, and decided to introduce continuous heat treatment of steel plate after lamination to put on the market a product better (surface finishing and strength) than conventional steel but costing almost the same. The automotive industry in Japan well accepted the 2-phase steel put on the market by the steel industry. There was no apparent direct interaction between the two sectors. The innovation clocks happened to be synchronous.
Now, the need to reduce weight in the car is "pulling" for low cost high strength steel. European steel making industry are not prepared to produce it, and high investments are needed to transform existing production plants.
The "selection gate" is opened at the user side and it exerts a pulling force at the supplier side.
The problem is how to accelerate the process of diffusing innovation. The difficulties depends on the fact that the steel industry, to decide to accelerate the new investments, require engagements from the user firms for fixed quantities at a given price. The decision taking-process is "bouncing forth and back" from one industrial sector to the other.

b) Plastic use in car has grown steadily for non structural parts applications, taking advantage of new material progressively put on the market by chemical and automotive industries, though important has been, the usual supplier-user or "application engineering" type. The need to reduce weight is forcing to accelerate the availability of long-fibre reinforced plastics. This to be possible might require joint R&D strategy between the material producer and the user, at a stage where the new materials are still being developed in laboratory or pilot plants. The "research system" of the chemical industry tend no more to be a "closed system", but an “open system" interacting strongly with the automotive "research system".

c) Oil industry developed the refineries according to the market needs. So, in USA more than 50% of the crude oil barrel is transformed into gasoline, while in Europe (where heavy oil is used for thermal plant) it represents about 25%.
lf in the future more and more of the ail has to be used for transportation (in the other fields of use ail being substituted by other energy sources) the decision on the optimal form of the fuel percentage subdivision between gasoline and diesel oil (or the use of "large cut" distillate cannot be taken by the oil industry alone. The acceleration of the market development of the diesel automobile depends from the car industries, the government fiscal policy, etc. Again, closed systems open one to the others.

d) Innovation in traffic control is be4ng introduced through the use of microprocessor. The traffic control system sense the vehicles and, combining with statistical information on traffic flow, operates the cross-lights. This can be considered as a "subsystem" innovation, the "traffic control" being a subsystem of the traffic system.
If the traffic control subsystem could interact with the "vehicle subsystem" to know, e.g., for each vehicle the destination, an "innovative state" of the entire "traffic-system" could be conceived, much more efficient than the today "subsystem" innovative traffic control technology. Unfortunately, the decision to modify the "vehicle subsystem" cannot be taken by the "decision makers" of the traffic control subsystem alone.
Furthermore R&D programs to prove the effectiveness of the "system" innovation are much more complex, and “selection" could operate only if very costly testing of experimental prototype systems could be done "in the field". It is act only a problem of availability of resources but also of participation of systems external to R&D to the decision taking.

The examples and the discussion above show that, in general, in periods of rapidly changing exogenous variables the subdivision of the innovation process into a chain of well separated sub-processes tend to be upset, within a company or even between companies. The basic innovation model of Fig. 1 is still valid with its two sub-processes, the generation of innovation followed by selection.

The different subsystems (research, development, pre-industrialization) tend, however, to restructure themselves, such as trying to form a "transient state" of cooperative research among different companies.

On one hand, that make all the business of company strategy with respect to R&D investment much more difficult. On the other hand it seems possible to take advantage of some ordering effects produced by the external changes, such as the synchronizing of micro-economic innovation clocks.

6) The Changing Quality Of Innovation

From the proposed innovation model it is apparent that the intensity of the flow of innovation varies, being tuned to the rhythm of product changes and capital investments at the company level and of business cycles at the macro-economic level, even when the input of resources to the innovation process is constant.

Referring to the effect of long term economic changes we have also noted that the quality of innovation also varies, with radical innovation tending to cluster around the economic wave upturn.

Also at the company level innovation has sudden bursts. The product model’s changing and the manufacturing plant renewal are occasion for using the internally stored innovation proposals as well as the embedded innovation in materials and equipments. This notwithstanding, when averaged over time, the innovative rate of change might be constant.

But what happen to the quality of innovation? Does it varies with characteristic patterns that could be grasped to help the R&D allocation decision taking?

The studies of product and process innovation have shown that such general pattern exists for the quality of innovation's changes with time [4]. Typically, three phases could be reckoned.

Starting with a basically new product, innovation is in a state of flux, changing very frequently, motivated more by the product’s change than by the manufacturing process. The influence of the user is very important in this phase. Competition is very high and several companies try the market with different designs. From the state of flux a leader design eventually emerges, market grow and innovations tend to arise more from internal technological push than from market pulp. Innovation oriented to manufacturing process' change increase, while the production scale increases.

To this transition phase, a state of maturity follows, where innovation is very specific, mostly process oriented, cumulating small incremental steps. This state of specific innovation can go over several product cycles each characterized by new models substituting the old ones. The sum of the pieces of incremental innovation might be very high, measured over several product-life cycles, even if it would be difficult to trace the single most significant steps.

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[4] We refer to the model developed by Utterback and Abernathy, as illustrated in the book:
W.A. Abernathy, The Productivity Dilemma. Road Block to Innovation in the Automobile Industry, The J. Hopkins University Press, Baltimore, 1978.

New technologies developed by companies already with a strong market hold, or by new companies, "suddenly" appear to perturb the state of specific innovation’s changes.

The mature product is "rejuvenated" or an entire new product, with new functions and performances, substitutes it.

Take the automobile industries. In the USA they have already passed through two such basic new product cycles. The first, starting at the beginning of this century, had in the Ford model T the leader design, and lasted until the twenties. The G.M. closed body Chevrolet represented the new technology leader design. It is now subject of discussion whether or not in our days the automobile industries is changing to a third basic new technological cycle. This phenomenological behaviour of the innovation process can be related to the model of Fig. 1: the state of the selection gates depends on the phase of the product-process cycle.

But how can we recognize that a new product cycle is coming?

Is there any particular pattern that characterize the emergence of radically new products? While it is difficult to generalize, in certain case - like for instance that of DC.3 which started the modern civilian airplane based an propellers - a successful new product is characterized by the convergence of several different innovation already in existence and having been tested, often with scarce success separately. Again, referring to the model of Fig. 1, the state of the innovation reservoirs, waiting for selection, is of importance.

In the G. M. Chevrolet car of the 1920's, converged together with the closed body innovation also the V-8 engine, and the synchronized transmission gear, among others. The state of flux of today automobile technology is characterized by many technological alternatives in the propulsion system, in the material in the auxiliary systems. Moreover every car designer knows very well that the convergence of new solutions for materials and components in a new <u>optimal match</u> is necessary, for a successful new design, to satisfy the several contrasting design requirements.

Another sign to be looked at, is related to the diffusion of “horizontal” new technologies, that might produce synergetic effect at "system" level integrating innovated subsystem and components. Microelectronics might have such synergistic effect in several mechanical] products. Synergistic effects might also be the results of new design and experimentation techniques, that might change an empirically based industry into a science based industry. The "chreods", or necessary path, of innovation become in such a case much more well defined, and the pace and efficiency of innovation could increase, and consequently the pay-back time for the resources dedicated to the innovation process.

<u>7) Developing The R&D Corporate Strategy</u>

We have reached now the point, in the discussion where it is possible to turn to our basic theme of how to develop a R&D strategy of resource allocation.

We have suggested in the introduction that, while discarding the reductionist rational approach, a “higher level” rationality, based on the holistic view of the company, could guide management decision taking.

The remarks on the complexity and oscillatory behaviour of the innovation process seems to lead to discard even this hypothesis, in condition of large exogenous changes. Fortunately, even if business at micro economic level is typically cycling, the inertia of the entire innovation processing system is such that imputed resources to R&D show a much reduced degree of variability. Anchoring ourselves to this inertia, we should proceed in illustrating in a very qualitative way the problem of resource allocation in R&D. [5]

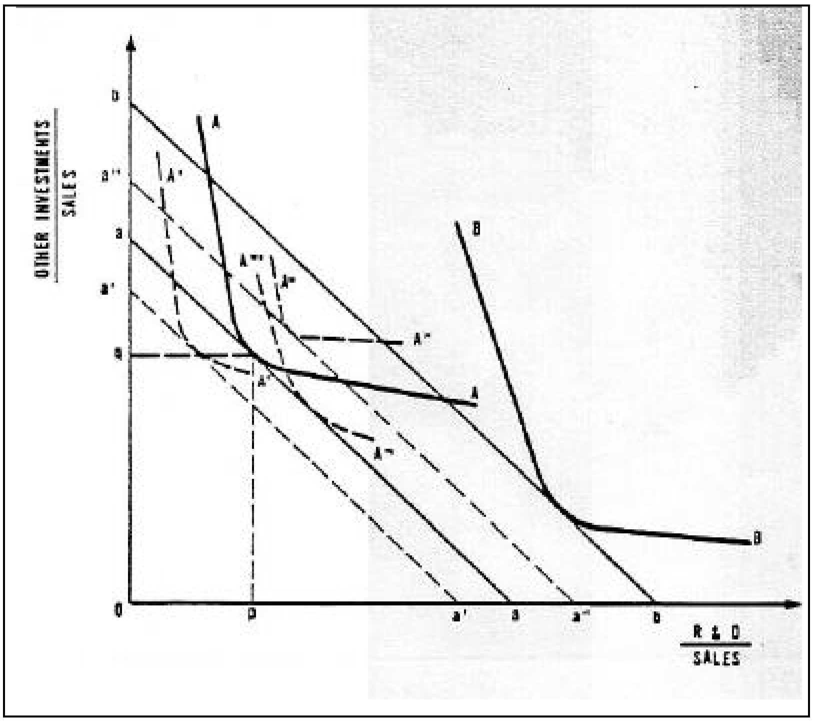
As already mentioned a simple pattern typical of a given industrial sector is that of the R&D yearly spending intensity (R&D expenditure to sales).

Let us consider the total company expenditures or “investments” which are concerned with the general problem of assuring the company growth, such as: R&D, capital investment, publicity, personnel training, etc.

First of all we are faced with the problem of finding the optimal subdivision among R&D and all other investments. To understand the "optimisation" problem let us for a moment imagine that the total resources available are unlimited: not necessarily then, an increase in the absolute spending on R&D or on the other investments will produce an increased growth, average on the years, for the company. For instance, the capability to profit from R&D and capital investments, the so-called "technological opportunity" varies from company to company, from an industrial sector to another. Increasing R&D expenditure, beyond certain limits, will therefore result in wasting money.

The situation can be best pictorially synthesized, as in Fig. 2.

Fig. 2 ***Optimal Resource Allocation between R&D and other Investments***



Using as one coordinate the R&D intensity and as the other coordinate the sum of all the other investments/intensities, one can imagine to plot curves of iso-opportunity, i.e. the locus of points that conceptually will produce the same opportunity to grow for a company varying the absolute amount of investments and the relative allocation between R&D and other expenditures.
Curve A-A might be characteristics of a given industrial sector and B-B of another.

[5] Reference is made to the book of N.M. Kay. See note (1).

The optimisation problem correspond to that - giving a fixed amount of total investment intensity, say a - of how to best subdivide such total amount between the two investments. The solution is the tangent point of the straight line a-a to the curve A-A, of coordinates (p, q), being p + q = a.

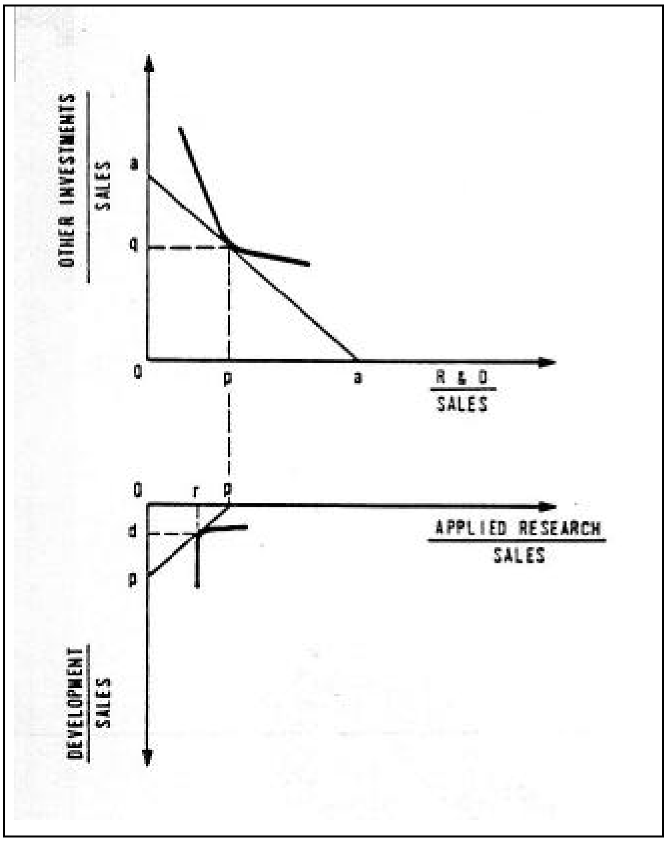
A first target for a corporate R&D strategy is therefore to "grasp" the pattern of iso-opportunity for their company at a given time. From the discussion on the innovation process we should expect that such pattern varies with time and company history: f.i. a company operating under licence in a national market (curve A’-A’) will have not only smaller total resources available, say a, but the optimal allocation will see a lower value for R&D intensity. The growing of the company with increasing profitability and total resources available, say a”, might mean a shifting to another iso-opportunity curve (A"-A"), but without changing the relative allocation between R&D and non R&D investments.

Changing of technology, such as towards more flexible manufacturing, will tend to increase the product oriented innovation opportunity therefore changing the iso-opportunity pattern (curve A"'-A"') towards a relatively higher R&D intensity.

All the above remarks are very qualitative and serve only to the purpose of defining the heuristics of the R&D allocation problem at corporate level.

One could proceed a step forward, and, supposing to have defined the optimal R &D intensity value, say p, to ask how to optimally subdivide !t between, e.g., applied research and development or between R&D oriented to product innovation with respect to R&D oriented to process innovation. For a given company, at a given time of its history, different research iso-opportunity patterns apply. One can pictorially describe the optimisation problem as in Fig. 3.

Fig. 3 ***Optimal Allocation of the R&D Resources between Applied Research and Development***



The variability of the iso-opportunity curves in the Research-Development plan is much more sensitive to : the typical business product cycle, the exogenous variables such as macro-economical cycles, the invading new technologies, etc.

Though very qualitative, as an heuristic tool, we suggest that it might be useful to discuss the R&D Corporate strategy along those lines with the help of the innovation process model of Fig. 1. For instance, when the "selection valve" opens in accordance to the various innovation clocks, it will help management to make explicit the needed temporarily shift towards more development type activities at corporate research centres, even if they usually are designed to play a major role on long term research.

8) Concluding Remarks

We have made a long tour, going back even to discussing the generalities of the innovation process to collect a very meagre harvest on our general theme of how to develop better corporate strategy towards R&D investments.

The intention, at least the conscious one, is not to convey a pessimistic view on the problem, but rather to show that the job is much less reducible to a standard "project selection" approach that one might think of.

The unavoidable complexity of the industrial system with the technological innovation process interwoven with the others economical and social change processes, cannot be mastered simply by recurring to more and more complex analytical tools.

Analytical tools certainly helps, but they are no substitute for the interactive growing of the management and the firm together considered as a “learning system”.

The understanding of the general patterns, which is the points on which we insisted in this paper, developing a feeling of history and of the wholeness of the system, might be more important than the aids of analytical tools. And this seems to be the more so, the more we are in a transient period of the entire economy and social system.

There is no simple recipe to be suggested. Certainly it helps not to accept as for granted that the innovation pattern of the specific business we are in, could not rapidity change. The understanding of the general model for the innovation process will help in this respect. It will help especially in the capability to understand the significance of early signs of changing of the said pattern.