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THE INTEGRATION OF SMALL AND LARGE COMPANIES IN THE INNOVATION PROCESS [1]

Patterns in the innovation process

It is nowadays common to underline the greater innovation proneness of small and medium sized enterprises with respect to large ones. Twenty years ago on the other hand, when the technological gap that separated Europe from the U.S. was one of the main concerns in the debate on technological policy, the hopes for closing the gap focused mainly on large companies. Why such a difference? Is it a question of changing fashion in the debate or does the shift in focus correspond to an historical change?

As a matter of fact, innovation is a complex process. Looking at it, different patterns could be grasped according to the vantage point and to the historical period of observation. One should therefore be very cautious in inferring general statements from particular observations.

To give a better idea of what I mean, I will very cursorily pass in review some of the patterns emerging from the innovation process.

1. Looking at the economy as a whole, it has been recognized that there are «long waves», of technological changes strictly correlated with the Kondratiev cycles.
   We are talking here of large innovation changes with a few «horizontal» new technologies leading the way to economic growth after deep and long depression. To these horizontal technologies (steam power, train, basic chemistry, synthetic materials, telecommunications), other technologies, cluster» around pushing, or being pulled by, economic growth.
2. lf we now take a more sectoral point of view, such as that of a class of product, the pattern that emerges is still of a non-continuous character (wave-like or logistic). The innovation process shows a typical time behaviour, which can be divided into three main phases.
   When a new product emerges, starting an entire new class of product (such as the automobile at the end of the last century), the innovation is mainly «product-oriented». Several different designs of the products are developed and proposed to the market by several small companies which try to develop local markets. The manufacturing process is very inefficient suitable mainly for small-scale production for a market willing to pay high

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CORPORATIONS, RISK CAPITAL AND THE EUROPEAN COMMUNITY AS PARTNERS IN INDUSTRIAL INNOVATION: LAUNCHING HIGH-TECHNOLOGY BUSINESSES IN EUROPE

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prices and accepting low quality due to the novelty of the product. Competition increases with market growth and at the end of the first phase, a leading project emerges among the several competing ones.
The second phase is one of transition, which sees large expansion of the market, consolidation of the technical features of the leading design towards a standard product and a shifting of emphasis towards process-oriented innovation. Few companies survive increasing in size together with the increased scale of production.
The third phase is a phase of maturity, characterized by an innovation process made of small incremental steps, both product and process-oriented, mainly motivated by increasing the efficiency. Integrated with the few large companies, responsible for the final manufacture and sales of the product, a variegated system of large, medium and small size companies developed to supply materials, components, services.

3. lf we take now an even more narrow point of view and look at a product in its mature phase, we can ask: how is technology transmitted from the regions which have taken the lead in developing the new product to other regions? One can trace here, at least under certain conditions, a different pattern, which has been denominated the «international product lifecycle». New markets are first developed by importing the product, then giving manufacturing licences to local companies, and finally by an independent development, which might grow successfully enough to compete in the region where the original technology was first developed.
If a product having reached its mature phase were to continue in a situation characterized by a series of small steps of successive innovations, one would expect that the growing competition of the new producers, in regions having cheaper manpower, would finally take over the entire manufacturing. Unfortunately - for the theory and for the policy makers - the mature state of a product is challenged by «evolutionary» innovative changes that start anew the entire product cycle.

A first conclusion can be reached by these very sketchy remarks on the innovation process. The size of the company does not characterize univocally its innovation ability. A small company in Turin or Detroit in 1900 could play a role in the automotive sector quite different from a small company in the year 1960.

A lot of opportunities were opened for small companies in 1960 in San Francisco Bay, which could be hardly reproduced today whether the company were located in Silicon Valley or in the Milan suburbs. Protectionism can distort the situation, but not for long, as the Argentina cases have shown in several sectors.

The patterns emerging from the innovation process could therefore help the policy makers, provided naive approaches are avoided. But before proceeding in analysing our theme, we should try to understand some more basic characteristics of the innovation process.

Basic characteristics of the innovation process

By innovation we mean the creative application of existing knowledge with the aim of changing (modifying or creating anew) products or manufacturing processes. The input to the innovation process is information and the output is the innovated product or process. But the process is not necessarily simple and once-through. If we start from the

output itself, how far back should we go to reach the starting point of the process? It might be a matter of definition. For instance, we might stress, as in classical tragedy, the importance of unit of «time and space». For a small company, with a simple organization, it might be easy to identify the starting point: the information input. For a larger company, it is more difficult to remain within the departments responsible for the final innovation decision: the product design and the manufacturing departments. The idea of applying available knowledge to innovate company products and processes might have started much earlier in R&D departments.

lf the organization is made up of several tiers, such as divisional laboratories and corporate research centres, one might find that all started at central research, then it passed to the division laboratory, then to the design department. There is a common feature to the larger and smaller companies which emerges if we consider the organization as a whole and, staying within its boundaries, we trace as far back in time as we can the starting of the innovation process.

In both cases, the starting of the process is characterized by the use of available (to everybody, including competitors) information.

The ability to transform creatively such information varies from company to company and depends strongly on the dimension of the company. A large company, with large central laboratories, is, at least *in principio,* capable of utilizing scientific information as produced at the source itself of pure research (motivated not by the application but by the advancement of knowledge). A small company with a staff of few people, whose tasks encompass the entire process from research and development to the design (of the product and of the manufacturing process) has not, or very rarely, such a capability. The exception is when a «scientist», having himself developed or contributed to develop the basic scientific knowledge and having envisaged the potentiality of its application, decides to become an entrepreneur himself, setting up a small «science-based» company to pursue the innovation process from the information input to the new product. Route 28 around Boston and the MIT has entered into the legend of innovation literature; to try to reproduce the phenomenon, science parks are flourishing in several countries and provinces.

Leaving aside for the moment these exceptional cases, small companies have to rely on someone else to bridge the gap to up-stream scientific knowledge. In this century, several public applied research organizations have developed, which contribute an important role in this respect. But much more important is the role played by the other companies, which supply materials, machines and instruments to the small companies, because of the information «embedded» in them. It can be noted, in passing, that the commercial trade fairs play a very important role as starting points for the innovation process in small companies. This is due to the special visibility which is given to the embedded technological knowledge - in terms of new material properties, specifications and potentialities of use - of the exhibited products, such as a new machine tool, just to give one example.

It has to be noted also that larger companies make large use of information embedded in the acquired materials, components, machines. The basic difference, therefore, between large and small companies, lies in the ratio between the «soft» and «hard» information input to the internal innovation process and the quality of the soft information used (how much closer it is to the basic scientific knowledge).

As a consequence of starting further up-stream on the knowledge flow that goes from pure research to practical application, the duration of each innovation project in a large company is typically much longer and the effort much greater.

The further away one starts, the larger is the number of ideas or projects started that will fail along the course be stopped for different reasons. A small company instead has a

much higher efficiency, almost close to one, measured in terms of the successfully ended innovation processes, to the started ones.

Should we deduce from these remarks that small is beautiful and condemn the large enterprises as slow innovative pachyderms?

The integration of companies in the manufacturing system

Manufacturing is a complex system: materials, starting from raw materials, flow from one company to another, and within different plants in a company several times, to arrive at the final product. The system is made up of companies of different sizes, from small to very large ones. The size of a specific company might be quite stable or be subject to rapid changes. To be small can be a somewhat permanent state far a company or a transient one. According to the model of new product class cycles, companies start small to launch the new product and the successful ones are bound to grow, while the unsuccessful one will disappear. In the mature phase of a product class cycle, a cross section of all the companies that participate in the production process shows a somewhat stable mix of small, medium and large companies integrated along the process through a suppliers/buyers mechanism.

To be a small or medium-sized company in this case is a kind of stable state. The role of small companies is here quite different from the case in which a new product class is born.

These complex interaction mechanisms among different companies tied together in the manufacturing process also operate with varying degrees of intensity for the innovative process concerned with manufactured products.

The different innovative abilities of small and large companies described above, complement each other, setting also reciprocal bounds and limits.

Supposing that the share-out of the scope of work in the entire manufacturing process among companies of different sizes corresponds to an optimal, or practically optimal, organization solution, is it possible to find the implicit rationale behind such a share-out?

To make a long story short, let us take a complex product like an automobile. In analysing the product and the thousands of parts which compose it, one can try to find a hierarchical organization of the different parts, dividing them first in subsystems (such as the engine, the body, the drive line), each subsystem in components (such as pistons, carburettor), the components in parts (such as injector, elastic seals), the finished part in the semi-worked materials (such as the engine castings) and so on.

There are different ways to arrange hierarchically the different parts which might lead to a different manufacturing split up and accordingly to different «make or buy» decision. For instance, one can divide the parts into primary and auxiliary (from the point of view of their importance with respect to product performances). We will suggest here that a more natural hierarchy might be found, according to what might be called the duration of the innovation cycle for a specific part or component or subsystem. A car engine new design, is made to last 20-30 years. The optimal scale of manufacture (of the order of one million units/year) and the type of metal processing needed requires such a huge capital investment that a lower replacement time will not be economical. A basic innovation in engines which requires a new manufacturing plant has to wait, in normal conditions, until the old engine model is obsolete before being introduced. The basic part of a car body requires capital investment with an economic life time of the order of 10 years. Interiors of cars are replaced in restyled or face-lifted changes of the model every 3 to 4 years.

The basic change in the component with the longer innovative cycle time, such as an engine, is governed by internal technology-pushed motivation, while short-lived restyling is more motivated by market pulls. A new engine represents quite an innovative change, both in the design and in the manufacturing process taking into account the big change in the general state of scientific knowledge and technologies in the course of the 20-30 years during which the engine to be replaced was being manufactured. Preliminary ideas and design alternatives on a new engine might begin 15-20 years before the date of first commercial unit production. All this points to the fact that a large company, with a multi-tier technical organization, is the only one able to afford the innovative tasks. This was not the case at the beginning of the history of automobile development. There are still single inventors or small companies which are nostalgic for those good old times and think that it is still possible for their creativity to participate in the innovation process. Newspapers often give space to the cries of these lonely inventors who point to the obtuseness of the large company, which does not understand the merit of their invention. Unfortunately, inventions have to wait, in practical life, until the time is ripe.

Smaller companies instead are better fitted to contribute to the innovation of parts which have a shorter innovation cycle, because they are more prompt to interpret market changes and because the information input needed to innovate is usually available, embedded in materials and machinery which are not very different from those used two or three years previously. There is no special need to go up to the new scientific discovery to perform the innovation job.

The example of the automobile production system is typical of several other cases. where small and medium enterprises operate in the intermediate phase of the entire process. At one extreme, there are large companies which manufacture raw and semi-worked materials, at the other extreme, the large company responsible far the overall design, manufacturing of basic components, final assembling and sale of the product.

It might be interesting to consider another typical case, where the small and medium company is responsible far the final end of the production process and far the sale to the end-user. This might be the case, far instance, of small household products. In general, such a produce is characterized by a short model’s life with product changes strongly market oriented.

In observing these cases, we are struck by the quick market response ability of small and medium companies, their ingenuity and inventiveness. A larger company in the same field will show a less prompt and efficient behaviour.

Comparing products made after several subsequent product model life-cycles, we might be amazed how this system of small-medium enterprises, with reduced ability to dialogue directly with basic science, has been effective in transferring new basic knowledge into the product (new materials, new manufacturing technologies). The apparent paradox is solved by considering the role of the, usually large or highly technologically specialized, companies that supply materials and machine tools.

These companies fulfil a strong technology-push role in their market efforts to diffuse the new materials, the new machines derived by their internal innovation process. Embedded in such new materials and machinery is the new knowledge derived by pure scientific research which the large companies are able to cope with. The suppliers-buyers links assure, also in this case, a satisfactory innovation process from basic to applied research to the final innovation change in the product.

An interesting recent study by the OECD (L'innovation dans les petites et moyennes entreprises, 1982) effectively stresses the need to take into consideration the variety of cases in the manufacturing processes, to understand the role of small and medium-sized companies which varies from case to case. The OECD study lists five different types of industrial sectors ,

1. the sectors where the small and medium-sized enterprises are predominant, where practically no large companies are present
2. the sectors where there is a division of work among larger and smaller companies;
3. the sectors where small companies compete with larger ones;
4. the sectors in a fluid state of technology under large growth, far high performance products,
5. the embryonic industries.

We refer you back to the OECD study for a more detailed discussions. The two cases that we outlined above correspond roughly to case 2) and 1) respectively.

The innovation process during difficult times

Here we will expand the analysis, on the two types of sectors illustrated above, to underline conditions, where the system of interrelations among companies along the manufacturing process might enter into difficulties. Let us start with the case of sectors characterized by large companies responsible for the final end of the production process.

In a stable or growing market situation, the system of relationships of the supplier/customer type assures a stable condition in the innovation process. The large company, responsible for the innovation in the final product, relies on itself and on its suppliers' ability to innovate for the incremental innovative steps in both product and manufacturing technologies. Changes in the specification of acquired parts are the responsibility of the final product designer, who relies on the suppliers' ability to use, innovatively available information to improve material processing and detailed design features of the supplied part. There is an intense osmosis, on a formal or informal basis, of technological know-how and a continuous dialogue with proposal of innovative changes both ways between the supplier/customer partners, made possible by their long-standing relationship and the somewhat stable pace of technological changes.

This situation is valid for mature products in conditions of innovation made up of a series of cumulated small steps. But what happens when the market enters into a period of fluctuations, uncertainties, large innovative changes from competitors?

These new factors are transmitted through the production system from the customers to the suppliers with delay times, which induce fluctuations that might destroy the system of relationships. The pace of innovation is no longer stable. The company responsible for the final product might fear not to be able to innovate the product quickies enough and in sufficient quantity to withstand competition, which in the meantime might accept larger technological risks or might decide earlier changes in the product plan, anticipating the marketing of new models. The ability to accelerate the pace of the innovation plan depends only partly upon the innovative «ideas» developed and stored in-house. What about the suppliers, especially the medium and small ones, which, because of their dimension, cannot follow alterative innovative path to store ideas for difficult times '?

Let us now consider the case of sectors characterized by large companies supplying materials and components to small and medium companies which operate at the final end of the production process. It might happen that the suppliers, say, because of tight money, concentrate their technological innovative, technology-pushing role on their more established customers, reducing the innovative effort in new uncertain areas. The reverse might also be true where they have a vital need to increase the market for their materials. The small buying company might ask, in an attempt to accelerate innovative changes in their proudest, the supplying company for more assistance and innovative

ideas than usual, which the supplier is unable to provide. As a consequence, the flow of innovative proposals and transfer of ideas shows sluggish behaviour, with pauses and accelerations, disturbing the pace of effective innovation.

In general, during difficult times, the production system is asked to put more resources into innovative changes than the system is able to sustain. Provided it is not «destructive», the passage through such a critical period produces beneficial results, because it has induced a higher attention to the importance of the innovation and more resources are devoted to it and a faster pace is reached.

Strengthening the innovation process across the industrial] system

From the above considerations, it is evident that devising public policies to support the innovation process is not a simple matter. A policy, which emphasizes in this respect small and medium-sized companies, risks being ineffective and may confuse ends and means.

The ends should be that of strengthening the innovation process which, as we have seen, is a complex one, where small and larger companies are interwoven. To choose the means, one should first of all understand, thoroughly and this varies according to time and sector, where the real problems are and where actions can be effective. What we know of the innovation process today should be of help in the analysis.

To underline this point, let us take few examples, without seeking completeness.

1. First of all, let us consider the case of the starting phase of a new product class. We have seen that small companies play a very important role here. But a new product is born in several different places, more or less at the same time, with a host of small companies trying their venture in the new field. A direct public intervention to support specifically selected entrepreneurs might be difficult because of the necessary multiplication of parallel interventions, most of which will later fail. A policy to favour the development of a new product class should therefore improve the conditions for attracting several entrepreneurs in the new business. Imitation is a very important factor to this effect. But sometimes imitation is ill-placed because information is incomplete and delayed; or, the general local conditions are different and so on. Helping the information to circulate, evaluating local conditions as to the possibilities of a successful development, whether it is not too late to start a local business: this might be much more effective than specific financial support to single entrepreneurs. Large companies, looking for diversification into new areas, could have a role to play in carrying out effective situation evaluations, in helping to pursue information, as well as in providing more venture capital to small entrepreneurs.
2. For the case of small and medium-sized companies integrated as suppliers to larger companies in the production system - for mass-produced complex products - first of all one should analyse product class to see if any is in a state of innovative turbulence.
   If not, the suppliers/buyers liaison, as explained above, is usually sufficient to assure also a good integration of the innovation process. In the contrary case, if is a matter for concern and specific actions should be taken to help the innovative ability to cope with the increased pace needed and the more difficult interfacing among the different partners in the production process.
   The wrong thing to do in the latter case is to isolate out from the system the small and medium enterprises and define a policy aimed at them alone. Support should be given where there are the human and technical resources to develop innovation solution in an accelerated time-frame.
   To be more clear, paradoxically, the means to be adopted to reach the ends are

those of supporting innovative projects within the larger enterprises in the system, as a service conducted in favour of the smaller enterprises, possibly in joint-ventures among them.
Generally speaking, the policy should be aimed at improving the interaction among the different enterprises, which might deteriorate during difficult times.
I suggest that there are very important industrial sectors in Europe, such as the so-called white domestic appliances and the automotive sectors, which fall into these categories and there is here the opportunity to take advantage of the critical period to help the sectors to develop into a new organizational state on a truly European basis.
When the crisis is overcome, a public policy should favour the ability for the entire production system to develop in advance alternative innovative ideas to be stored, for prompt use during crisis, when it might be too late to develop them.

3. Where small and medium-sized companies are responsible for the end-product, the best policy to favour innovation is to help the larger up-stream company, which supply materials and tools, to develop a better promotional activity to their clients, with cheap and prompt services, with applied engineering projects. This will be especially effective in difficult times, when cost-cutting reaches also the materials application laboratories, the new product development departments, and so on.

4. A particularly relevant case (as pointed out also in the OECD study) is that of medium-sized companies operating in the so called «generic» techniques, such as heat exchangers, controllers, special electric motors, hydraulic valves, and so on. The generic techniques play a very important role in the diffusion of new basic technologies (such as new materials, microelectronics, etc ...) in products and manufacturing processes. To give an example, numerically-controlled machine tools will be unable to take advantage of innovation opportunities related to large-scale integrated microelectronics, unless microchips are integrated in the- design of the controllers supplied by the companies specialized in such generic techniques. Lack of ability to incorporate quickly the new basic technologies will have the effect of blocking customers' innovative ability.
Here again, a policy to help accelerate the pace of innovation might find limits in the human and technical resources available in the medium-sized companies responsible for the manufacturing of the generic technique components: larger client companies should be included in the picture to devise a better policy which should, among others, support joint R&D programmes, aimed at developing prototypes of components integrating new basic technologies.

These suggestions are not meant to be exhaustive but rather provocative. I am aware of the fact that my own experience, almost entirely with a large company, puts a bias on my vision of the world.

This notwithstanding, I strongly suggest that there are no simple solutions, no «small is beautiful, panacea for innovation policies.