DIFFERENTIAL BEHAVIOUR AND INNOVATION IN THE PORTUGUESE CAPITAL GOODS SECTOR

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ABSTRACT

The paper reports the results of an empirical study of a sample of Portuguese producers of equipment goods. The information collected for this study was based on case studies of nineteen firms. The unit of analysis was the firm. The information was obtained during personal interviews with the owner/manager of the firm or with a Director, following a semi-structured questionnaire. It was based on SAPPHO-type matched pair methodology. The sample consisted of two groups: the “innovative group” and the "average group". It is a procedure equivalent to the experimental group (innovative) and the control group (average) methodology adopted in the social sciences. The firms were matched according to a set of criteria. The objective was to see if common behavioural patterns within the groups and different behavioural patterns between the groups could be discerned that in turn could point out regularities. The inquiry looked at several functions of the firm.

After analysis it come out that there were indeed differences between the two groups of firms and that the variables which showed more variability between the two groups could be grouped according to five broad categories, namely: tangibles (variables related to tangible assets of the firm), intangibles (variables related to intangible assets of the firm), management (variables related to management styles of the firm), external stimuli (variables related to external contingencies) and external sources of knowledge (variables related to external sources of knowledge).

Explanations for the differences in each broad category are given based on concepts such as demand-pull and technology-push theories, firm’s absorptive capacity, public and tacit knowledge, appropriability, human capital and social networks. Relying and building on short but hopefully elucidative descriptions of the case studies, the paper tries to explain the variation in innovation capacity making use of the chain-linked model of innovation. It builds on this model and, based on an extension of it, and inspired on evolutionary theories of technical change, it proposes a conceptual framework that contributes to explain the empirical findings.

INTRODUCTION

This study is concerned with the behavioural causes of innovative performance at the firm level. The quest for the determinants of innovation at the micro level has received increased attention in the social and economic sciences. The interest on the issue follows from the realisation that the efficiency

of inputs to scientific and technological activities, as measured by the correlation between R&D expenditures and GDP growth rates, enjoyed significant discrepancies across a whole series of countries. Japanese technological performance recently reinvigorated this debate and provoked a frenzied search for the explanations of this phenomenon, not only at the macro level (e.g. Freeman 1987) but also at the micro level (e.g. Womack 1990).

The first instances of this quest may be traced back to Marx who saw the continuous stream of technical innovations directly related to the selfish pursuit of rent-seeking activities by the capitalist pole of the dual-class society by him portrayed. The invention of new machines and tools that increased the level of mechanisation of the production process and which decreased the individual or collective power of the operators and hence allowed for the appropriation of labour surplus by capital, were the main goal behind the innovation process. The relentless pursuit of ever larger profits earned by the capitalist at the expense of the worker, the exploratory attitude of the entrepreneur and its disregard for his employees and fellow man, were implicitly the behavioural attributes that characterised a technologically successful entrepreneur. Earlier, Adam Smith also hinted at a similar kind of motive when he analysed the economies gained by increased specialisation, but the hints stop short of that and no significant attempts were made to distinguish between the features of innovative firms.

The orthodox neo-classical school of economics dismissed the subject all-together. Firms were viewed as homogeneous, perfectly informed, rationally acting black boxes, whose only admissible difference was a short lagging period necessary to adjust themselves to the price signals of the market. Knowledge, science and technology were assumed to be non-excludable, non-rivalrous public goods, exogeneously determined and at the disposal of all firms and with no extra costs attached. Even the notion of profit is not useful in the neo-classical context as an explanation of why firms innovate, given the constrains imposed by the assumptions underlying marginal analysis, and some authors go even further when assessing this theoretical framework: '...Indeed, under the standard assumptions [of the neo-classical theory] it is difficult to find reasons why firms exist at all...' (Reinert 1995: 27).

However, to be fair, the neo-classical economic tradition has made significant contributions over the last decades to the understanding of technological progress and its interactions with market mechanisms. Technical change was identified as a main determinant of economic growth (Solow 1956) and technological knowledge was incorporated in the aggregate production function as an endogenous production factor. Differences in factor-price ratios are pointed to as a main endogenous determinant of bias in the choice of technique, and the notion of induced innovation is introduced. Schmookler (1966) ignited the famous debate opposing the demand-pull and the technology-push hypothesis of technological change, by emphasising that demand factors could explain to a large extent the rate and direction of technological change. His study was partly a response to the argument advanced by earlier studies of Schumpeter that inventors-entrepreneurs were the main force behind technical change and growth. The notion of learning by doing and its economic implications was first introduced within a neo-classical context (Arrow 1962). The existence of increasing returns to scale in

the aggregate production function is explained in terms of externalities derived from the development of technical knowledge.

However, since these studies were conducted within the same basic assumptions of the orthodox neo-classical school, namely the notion of equilibrium, the rational behaviour of firms and the assumption of perfect information, their explanatory contribution is more at the macro-economic level than at the level of the firm, and its contribution was stronger to market theories than to the theory of the firm. The theoretical framework could not satisfactorily explain why some firms are more innovative than others and why there seems to exist, at any time, and given the same environment, a population distribution pattern that includes both firms using advanced production techniques and firms using older techniques.

Contributions to resolve this lack of theoretical support of empirical facts came initially from the management and organisation literature, which identified differences in the inner workings of the firms and then tried to identify the factors behind those differences. One group of studies (Marris 1966) highlights the importance of managerial motivation and discusses it in terms of sociological and psychological traits, such as status, power, space for personal creativity and remuneration (which is a more classic perspective). Another theoretical line comes from the work of Penrose (1980), suggesting that the firm is a bundle of physical and human resources and its evolution is fundamentally determined by its managerial capabilities.

Other approaches focus on the structural characteristics of the firm. The transaction-costs approach (Williamson 1981), which was inspired by Coase's (1937) account of the firm as a governance structure, deals with the costs associated with performing certain types of economic activities and their influence on the structure and size of the firm. He argues that certain inherent characteristics of some economic exchanges, namely those connected to imperfect markets, uncertainty, and opportunistic behaviour, make it more economical for the firm if those transactions are internalised inside the hierarchical structure rather than making them in the market. The behavioural perspective of Cyert and March (1963) emphasises the conflicts that arise from the fact that the firm pursues different goals at the same time, associated with production, inventory, market, sales and profit. For instance, higher sales may imply lower profits, higher production may imply higher inventory costs. The firm is then seen as the (unpredictable) outcome of complex internal negotiations and compromises that try to achieve a degree of consistency between diverse goals.

Explicit technological considerations are more visible in the organisational models of Woodward (1965), and Mintzberg (1984). They combine several salient features of earlier approaches into an integrated framework, and then propose a taxonomy of organisations. Woodward's approach is more technologically determined while Mintzberg's is the outcome of complex interactions between internal factors as well as external ones. In both models, the organisational structures of firms are closely connected with technological factors such as the degree of technical complexity or the characteristics of the production technology. However, they link innovative performance with organisational traits in a causal direction that seems to indicate that technology determines the type of organisational structure rather than the other way around.

A different theoretical perspective on the issue of different patterns of firm behaviour and their technological implications comes from the evolutionary theories of economic and technical change, which integrates insights from the management, organisation and economic literature. Their main source of inspiration is the work of Schumpeter (1947), which challenged the neo-classical tradition assumptions of equilibrium and perfect information. The concepts of disequilibrium and imperfect knowledge appropriability are at the core of the Schumpeterian analysis. The neo-Schumpeterian or evolutionary theories assume that the choice and actions of the firms are severely constrained by imperfect information. Their behaviour cannot be assumed as rational but rather as "boundedly" rational, i.e., limited by the kind and level of information that the economic agents possess at any given moment. Therefore, achieving a satisficing but not necessarily optimal condition is the norm, rather than achieving a maximised optimal situation.

Evolutionary theories are stranded in a psychological basis, inasmuch as they emphasise the learning processes involved in the economic process, and they are less amenable to formalization. The behaviour of firms is dependent and shaped by the: '…the learning history of agents, their pre-existing knowledge and, most likely, also their value systems and their prejudices...' (Dosi 1994: 159).

Their analogies with biological systems entail the definitions of four concrete building blocks (Dosi 1994): 1) a fundamental unit of selection (genes), which could be technologies, policies, behavioural patterns or cultural traits; 2) a mechanism linking the genotype level with the entities (phenotypes), and these could include technological systems, firms, agencies or the mind; 3) mechanisms and criteria of selection, involving a long list of possibilities such as, for instance, financial market assessments of firms' strengths, characteristics of their products, their prices, etc.; and 4) mechanisms that generate variations (in the phenotypes through the genotypes), which is the dimension that is directly linked to the presumption of rational behaviour.

The link between the technological performance of a firm, which is the main concern of this paper, and its organisational and behavioural characteristics is achieved in the evolutionary literature through the notion of routines. Nelson (1982) identifies three sets of routines: 1) standard operational routines, related to the way firms produce under certain constrains, namely their capital stock and their knowledge content; 2) routines that determine the investment behaviour of the firm; and 3) routines that define the process of search for doing better things.

Working, explicitly or not, within this framework of analysis, there have been several contributions to the understanding of the link between innovative performance and behavioural patterns of firms. Miles and Snow (1978) classify firms under the heads of "defenders", "prospectors", and "reactors". Freeman (1982) also proposes a taxonomy based on archetypes of strategy and classifies them under the groupings of "aggressive", "defensive", "imitator", "traditional" and "opportunistic".

A series of empirical studies tried to identify the factors that led to success or failure in innovation, in a specific product, of which the most well known are probably the Project SAPPHO (Rothwell 1974) and the M.I.T. study (Utterback 1975). Rothwell (1977) makes a review of the results of seven of the more important studies and finds a considerable degree of agreement between them. The success factors identified are linked to good communications and effective collaboration, high

levels of corporate commitment, planning and management techniques (with emphasis on cost control), quality of management, personal policy and management style (emphasis on education and training), marketing and user needs, and after sales and user education. Apparently, the two sets of factors more strongly correlated to success are related to communications and collaboration, and marketing and understanding of user needs. Thus, the findings seem to revive the demand-pull/technology-push debate, bending in favour of the demand-pull hypothesis. The author also argues that the innovation process is a complex one and all factors must be taken into account, but advances little in the way of explaining the interactions between them. Mowery and Rosenberg (1979) criticise the conclusion by arguing that there was a built-in bias on the studies (the criticisms addressed the fact that citing user needs ex post facto could be considered a tautology, that the concept "user needs" was loosely defined and it lacked the precision of the concept of demand, and that the technology-push factors were not conveniently represented in the studies). They concluded that not only supply and demand factors are important factors but they must be coupled to ensure success. These studies contributed to the advancement of our understanding of the process in several ways. They represent a significant challenge to establish theories, they pinpointed some apparently recurrent behavioural factors in successful innovation, and they brought to the surface the systemic features of the process. They also stimulated further research at sectoral level. For instance, Pavitt (1994) builds on his earlier sectoral innovation taxonomy of industrial sectors (Pavitt 1984) and suggests a technology-based classification of key characteristics of innovative firms.

This paper adopts a somewhat different approach. While most of the earlier studies concerned with success and failure concentrated their attention on particular innovations at a particular point in the life of the firm, the approach here is based on the difference between the global perception of the firm as, all things considered, being more innovative than the average. It can be argued that the study of only a single innovation, at a particular point in the life of the firm, does not tell much about the firm as a whole and about the way it got where it is. As such, one can say that they are considerably influenced by a static perspective. They also do not have much to say about the way in which the several factors interact with each other.

Maidique and Zirger (1985) suggest that a more useful unit of analysis is the product family, rather than the single new product. They argue that organisations learn from their mistakes ("learning by failing" as they put it) and that a failure often may lead to a posterior success. They suggest a new (family) product model, which has the attractive feature of being explicitly more dynamic, based on cyclical failures and successes of individual products, each success feeding on a previous failure and each success, in turn, eventually leading to a failure (due to excess confidence bred by the success).

Georghiou (1986) argues that the innovation process can only be correctly understood if the conditions and set-up at the time of launching an innovation and its posterior progress and diffusion are looked at simultaneously. The author argues that a successful innovative firm is not solely classified by the successful market introduction of an innovation and the initial perceived innovative level. The subsequent actions of the firm are as vital to its success as it is the introduction of the innovation. Therefore the firm has to engage '...itself to a sequence of post-innovative improvements which are a necessary condition for it to retain and expand its market share' (Georghiou 1986: 3). He

further argues that technological innovation is an outcome of interactions between technological opportunities and market needs which itself evolve over time.

Here, somewhat in line with the latter arguments, instead of looking at a particular product or family of products we look at the global performance of the firm, and we try to identify characteristics that are common to innovative firms and characteristics that are common to less innovative or non-innovative firms. First, these characteristics are identified, and then an effort is made to identify the way in which these factors contributed to the present situation of the firm, as well as the way in which those factors interacted so that they eventually led to superior performances. Throughout the paper the reader will notice a strong flavour of the influence of evolutionary theories of technical and economical change. This is true, inasmuch as use is made of the conceptual framework provided by the analogies with the biological sciences. In particular we associate the notion of genes or genotypes with the identified characteristics of the firm and we associate the phenotype with the global performance characteristics of the firm (reduced to only two kinds, the innovative firms and the average firms). The main thrust of the paper will be in the analysis of the mechanisms linking the genotypic level with the phenotypic level and in the analysis of the mechanism generating variation in the genotypes. We do not consider so much the third conceptual block (mentioned above), which is the selection mechanism and the selection dynamics, since less emphasis is given to the environmental variables, and the main concern of the paper is to try to explain differential behaviour assuming the same external constrains. Implicitly, the degree of innovativeness is considered the best measure of fitness, but, as was mentioned earlier, empirical evidence suggests that this is not always (or indeed, even remotely) true, and some remarks on the issue will be made.

THE METHODOLOGY

The reason for choosing the capital goods sector is that we assume that this sector has a crucial role to play in terms of the innovative performance of the whole manufacturing industry, acting as a fundamental point of diffusion of technological capabilities throughout the society, and more particularly in terms of its indigenous capacity to innovate. Thus, studying what happens or happened within this sector may eventually bring about more understanding to the innovative performance of Portuguese industry, than say, looking at another sector whose perceived technological characteristics may rend it less useful for that purpose. Thus, while the study concentrates on just one sector it hopes that one can extrapolate its conclusions to other sectors as well.

The information collected for this study was based on case studies of nineteen firms. The information was obtained during personal interviews with the owner/manager of the firm or with a Director, following a semi-structured questionnaire. It was based on a comparative methodology between two groups matched by a set of criteria, inspired on (but not strictly following) the SAPPHO matched pair methodology. It consisted of two groups: the “innovative group” and the “non-innovative group” or "average group". It is equivalent to the experimental group (innovative) and the control group (average) methodology adopted in the social sciences. The objective, as stated, was to see if common

behavioural patterns within the groups and different behavioural patterns between the groups could be discerned that in turn could point out regularities.

The joint criteria for matching the two groups, on an individual basis, were the size of the firm and the similarity of the product lines. Ideally, matched firms would be in the same size class and competing with each other, but later this was found to be a more difficult task than anticipated, due to the small size of the industrial structure and due to the niche strategies pursued by most of the firms, and consequently there were difficulties in finding firms operating in the same product line. For some of the firms it was not possible to find a perfect match by type of product, although there were other firms operating in the same product line. The reason underlying this is that the allocation of each firm to each group is based on its relative performance to its pair, and those firms were performing at similar levels (according to our criteria of product improvement, quality or newness). In those cases, a firm operating in a product line whose technology had close affinities with the technology of the product manufactured by the firm in the "innovative group" was chosen. Eventually, the largest firm, whose main product line was in electricity power stations, was left as a stand-alone case because it was not possible to find another firm operating on the same product line. The only alternative was a subsidiary of a multi-national firm, but its activities on Portuguese soil were mainly as a commercial and manufacturing outpost so that conclusions based on behavioural comparison related to innovative performance between the two firms were bound to be fallacious, if they were only to be made based on the activities of the firms in Portuguese territory. It was decided not to discard this case because otherwise the sample would lose its representativeness vis-à-vis the whole population regarding the size dimension.

The rationale for selecting the case studies was essentially based on the characteristics of the products manufactured by the firms, which included the following: new features, quality and performance and new products (sector-wide or world-wide). The criteria were used to compare and select, within the national population of firms, a sample containing the “innovative group” (a group of firms whose innovative performance is, according to the criteria, better than the rest or above the average of the national population) and an “average group” (a group of firms whose innovative performance is, according to the criteria, equal to or below average of the national population). These criteria were confronted with the following sources of information and the subsequent organisation of that information determined the selection of the “innovative group”. The sources of information for selecting the “innovative group” were: reports in newspapers or industry journals, award winning enterprises, opinion of the professional association of the sector, opinion of individuals (industrialists) knowledgeable of the sector and information on expenses in R&D or human resources devoted to R&D as provided by national statistics. It turned out that there were quite a few firms that were common to two or more sources of information, so that the selection of the innovative group was based on the intersection of the information from all the sources, after arbitrarily choosing between firms that were in the same product line, and after assurance was taken that a broad range of class sizes was included (the smallest firm had sixteen employees and the largest twenty five hundred).

Table 1. The product lines and the size (number of employees) of the firms in the sample.

	'Average' group			'Innovative' group		
Pair	**Previous products**	**Present products**	**Size**	**Previous products**	**Present products**	**Size**
1	Dumpers	Conveyors, dumpers	60	Conveyors	Conveyors	110
2	Looms	Components for textile machinery, textile machinery, other machinery	23	Looms	Components for textile machinery and textile machinery	40
3	Wood-working machine-tools	Wood-working machine-tools	82	Wood-working machine-tools	Wood-working machine-tools	290
4	Textile machinery	Textile machinery	140	Looms	Hydraulic components, lifting gear, presses, textile machinery	70
5	Agricultural machinery	Lorry bodies, agricultural machinery	30	Agricultural machinery	Agricultural machinery	200
6	Metal working tailor-made machine-tools	Metal working tailor-made machine-tools	19	Metal working tailor -made machine-tools	Metal working tailor-made machine-tools	16
7	Machine-tools for the cork industry	Machine-tools for the cork industry	25	Machine-tools for the cork industry	Machine-tools for the cork industry	19
8	Presses, components	Components, presses	25	Presses, press brakes and guillotine shears	Press brakes, guillotine shears	250
9	Presses, components	Components, presses	49	Moulds, presses, press brakes, guillotine shears, lathes, and other	Press brakes and guillotine shears	103
10				Electric power stations	Electric power stations, electric and electronic machinery, software	2500

Each firm of the "non-innovative" group sample was then selected by randomly picking up a name out of a list of firms that were included in the same product line and confronting it with its pair. This list was provided by the professional association of the sector. The sample is presented in Table 1 indicating the main product lines, previously manufactured as well as presently manufactured, by order of decreasing importance.

ANALYSIS OF THE RESULTS

The information gathered through the interviews was submitted to statistical analytical procedures. Due to the limitations inherent to the sample, specifically its small size and its non-randomness, the analysis was confined to the application of descriptive analysis, to see whether differences in the distribution of the responses of the two groups could be identified and were statistically meaningful. The raw information was coded in nominal or ordinal categories, although for some variables the initial information was at the arithmetic level (continuous). However due to sampling restrictions, it was transformed into a lower level of measurement. In the end the statistical analysis identified differences in the distributions. Table 2 shows the results, representing the variables that showed visible differences between the two groups of firms.

Table 2. Identified relevant variables.

Category	Variable
Tangibles	Existence of automated equipment Predominance of old production machinery Improvements in production machinery
Intangibles	Use of CAD Use of CAM Quality Control laboratory Existence of graduate personnel Graduate intensity Type of training Separate R&D department
Management	Main source of funds for investment Receiver of subsidies Type of strategy Approach to product conception
External stimuli	Existence of exports Export intensity Importance of external competition Type of domestic customer Competition based on quality and performance
External sources of knowledge	Impact of technical fairs on future innovations Search activities and suppliers Search activities and universities

The variables are categorised according to the nature of the factor involved. A set of variables is related to differences in the type of capital stock between the two groups of firms. They are

categorised under the term "tangibles". The second set of variables is related to what is now commonly referred to as "intangibles" and the category in which they are included is named accordingly. They include the role of software, the level of education, the type of training and the existence of separate R&D departments and quality control laboratories. The third set of variables is related to management issues, and it reveals behavioural differences in areas linked to procurement of funds for investment, the type of strategy adopted and the approach to product conception. A fourth set of variables deals with what we call external stimulus to innovation and reveal differences on whether the firm had or not an export activity, to what type of domestic customer it was related, the degree of importance attached to external competition, i.e., competition in external markets or with incoming external products, and the degree of importance attached to competition based on quality and performance. Finally, the fifth set unveils some differences on the way external sources of knowledge impact upon the firm's innovation activities.

Annex A gives the complete information on the responses given by each group to each variable in graphical form (from Figure 2 to Figure 21) and also the meaning of each variable on which nomenclature graphics on Annex A are based (Table 6).

Demand factors

The results show obvious similarities with those obtained by the successful/unsuccessful empirical studies briefly reviewed in a preceding section. All the factors categorised under the term "external stimulus" are somewhat equivalent to the "marketing and user needs" factors suggested by those studies. If we consider these variables as proxies for the existence of demand for certain products, or product features, or as proxies for a response to "needs" (whatever the definition of the term) felt by consumers, then the results support the arguments expressed by the demand-pull theorists.

Table 3. Descriptive statistics of the variable “export intensity”.

	N	Minimum	Maximum	Mean	Std. Deviation
Average group	9	0	0.25	0.056	0.0982
Innovative group	10	0.05	0.85	0.35	0.2877

The fact that export behaviour differs significantly amongst the "innovative" and the "average" group (see Table 3 showing the descriptive statistics of the continuous variable “export intensity”), and that the importance attached to external competition is more strongly felt by the former group, can be interpreted as innovative firms being more responsive to user demands, in the sense that we assume external markets are more demanding than the average internal market.

We make this assumption because roughly 90% of the exports are destined to the European Union countries, the United States, Canada and the Asian NICs. If, in principle, the demands from these markets are more commanding and require higher standards than those demanded by the internal average market, and assuming that products whose technological characteristics satisfying the internal average market would not satisfy the external markets, then demand (in its precise meaning involving quantities and prices) does apparently play a role in fostering innovation. The same argument applies for the variable "type of domestic customer", where a significant difference appears between those firms that are only serving regional markets (where demand for low-tech products exists) and those firms that are serving large domestic firms or subsidiaries of multinational-national firms, where demand for technically advanced products exists.

Using the variable "competition based on quality and performance" to claim that demand-pull influences are at work is more problematic because this variable can also be interpreted as a proxy for specific management goals or strategic objectives, not necessarily dictated by external market forces. It is reasonable to admit that competitive pressures would underlie a defensive-type strategic commitment, but one can also admit that this commitment came before any competitive factor had forced it into being. There is the possibility that a conscious and intrinsic consideration of the issue was, at some time, introduced into the firm's routine approach to product conception. If it was the case, then the variable would be better placed in the "management" category. To take account of the ambiguity the variable should be perceived as lying in a limbo between the two categories. The causal direction of this factor is open to doubts. It can either be considered as a consequence of market pressures or as a managerial cause of innovative behaviour.

Education and management style

Another similarity between the results of this study and other studies lies in the variable related to educational level. The results show significant differences between the two groups of firms concerning this variable. The existence of graduate personnel is apparently related to the degree of innovativeness of a firm. The difference is also strong when we consider the variable "graduate intensity" (the ratio of graduate personnel to total employment). Table 4 shows the statistics related to this variable. The mean intensity amongst the “average” group is less than twice the mean intensity amongst the “innovative” group. The minimum value for both groups is zero but there is only one such case in the “innovative” group while there are four such cases in the “average” group. It relates to the importance of having management of high quality and ability, pointed out by other studies, but it also reflects the importance of having personnel with high technical competence.

The importance of management style (openness, horizontal and organic features) is also pointed out in those studies but we found no significant differences between the two groups of firms concerning that. There are two possible reasons. First, the firms in the sample are all relatively small-sized, with one exception, so that the horizontal and organic nature of the relationships arise naturally. Indeed we found that communications between owners, managers, mid-managers, technicians and workers were, in general, very fluid and easy to establish, not constrained by bureaucratic barriers and facilitated by the often small premises on which the firms operated. Very often the interviewees

Table 4. Descriptive statistics of the variable “graduate intensity”.

	N	Minimum	Maximum	Mean	Std. Deviation
Average group	9	0	0.26	0.042	0.0848
Innovative group	10	0	0.31	0.092	0.0901

stressed the team spirit of the firm and even the presence of quasi-familiar modes of group interaction, and the two-way spirit of loyalty that existed between employers and employees. Simões (1995) also refers to “pre-Taylorist” modes of organisation in Portuguese firms and says they are not uncommon. Second, the considerable handicraft nature of the work involved and the type of skilled work force employed implied that the contributions emanating from the bottom were not taken light-heartedly, and that the contribution of the work force in certain aspects of the creation of the product was accorded significant importance. The style of management was, both in the "average" and in the "innovative" group, essentially organic, or, as it was described by one of the interviewees, "rigidly flexible". This homogeneity derives, to a great extent, from the fact that we are dealing with only one sector, possessing specific idiosyncratic features of operational behaviour. Had we considered more sectors, this homogeneity may not have emerged. However, it suggests that the type of management is not, at least, a sufficient condition for innovative success.

If we take a closer look at the response distribution of the "existence of graduate personnel" variable in Annex A, the same conclusion applies regarding the educational level, since there is a considerable proportion of "non-innovative" firms that do possess graduate level personnel. On the other hand, the variable "graduate intensity" (cf. Table 4) suggests that the level of investment in the educational level does seem to play an important role in the determination of the innovative performance of the firm.

Planning activities and management techniques

Another point of confluence between this study and other studies is the importance of careful and precise planning activities and the use of management techniques. The variable "type of strategy" is a proxy of the factor. The majority of the firms in the innovative group had some kind of formal planning procedure in place. Half of them planned their activities at the medium-term and long-term level, which involved, one the one hand a detailed one-year or two-year plan (some firms even had a three-year plan) with quantitative objectives regarding costs, investments and sales, and on the other hand a long-term (usually five-year) plan that detailed the overall objectives and strategic orientation of the firm. The other half was split between those who had a medium-term formal quantitative plan and those that did not have a formal plan but did nevertheless have a strong strategic perception of what the firm should do, how to do it, and when do to it. We have labelled this mode the "visionary" type of

strategy whose characteristics could not be mingled with the other type of approach to strategy making, common in many of the "average" group firms. This other approach is rather a non-approach, in the sense that there was no clear visible strategic perspective, and the firms were essentially engaged in the mere day-to-day running of the business apparently not worried about the possible threats that future changes could bring to them. More than that, they didn't seem to be engaged in any kind of prospective exercise to evaluate possible future trends. This type of strategy was labelled "short-term". The results suggest a strong association between the different types of strategy-making and the innovative performance of the firm.

Propensity to risk

The two variables named "main source of funds for investment" and "receiver of subsidies" are associated with risk-taking behaviour. Although the relationship with innovative performance is not strong, particularly in the first variable, it suggests that firms willing to take a real risk by resorting to outside sources of finance, e.g., by borrowing from the banks, are more likely to succeed. As it regards the second variable it should be noted that the subsidies under consideration are not entirely risk free. First, they required previous investment from the firm and did not cover the total investment. Second, due to bureaucratic delays in the payment of subsidies to the firms, these had to borrow more money than intentionally envisioned, so that, in the end, it turned out that the subsidies, in many cases, paid only the interest on the loan. It should also be noted that, in Portugal, borrowing from banks could be a really risky move because the interest rates were very high. In the early 1980s the yearly interest rate could be as high as 30%. Nowadays it has levelled down to a more manageable figure.

Technological determinants

The results of the variable "separate R&D department" show that the commitment of the firm to invest in this kind of resource is significantly linked to innovative performance. This link was also evident in other studies. As we understand it, it is a definite option taken by the firm to act in a certain way and it expresses the importance it attributes to technological development, as opposed to those who regard product development as a low-priority task and choose to base their chances on other options or do not perceive any advantages in doing so.

If this variable is considered as a proxy for technology-push determinants in innovative performance (in the sense that an R&D department embodies the capability to organise resources related to scientific and technological knowledge with a view to achieving advances that can be translated into the development or improvement of products) and that without such an arrangement innovative performance is less likely to be successful, then its significance suggests that technological factors seem to be as important as the factors related to demand indicated by other variables.

This dependence of innovative performance on technological factors should be analysed in conjunction with the significant relationship shown by the variable "graduate intensity" mentioned earlier, if we assume that the increase in graduate intensity is proportional to technical personnel involved in development activities. The argument is also strengthened by the strong association

suggested by other variables. The superior level of production equipment exhibited by the "innovative" group, the importance attached to equipment upgrading, the consideration given to quality issues revealed by the existence of separate quality control laboratories, and the considerable use of CAD and (less often) CAM, all point in the direction that the capability to take advantage of scientific and technological advances in the firm's own field and the capacity to exploit technological opportunities opened up by generic technologies are indeed crucial determinants in innovative performance.

Approach to product conception

The variable "approach to product conception" is a reflection of a particular kind of difference that showed up in the interviews and it is related to the way firms face their task of producing machines. The variable differentiated between two approaches. One the one hand, we have firms claiming that they do not sell machines but rather an operation. In their view there are several ways of performing a given operation and their task is to provide the best possible way of performing that task. In this sense, they see themselves more as service providers than as producers of machines. As a consequence, they spend a considerable time evaluating the environment in which the machine (operation/service) will be integrated and in considering the limitations, possibilities and technical synergy available and the interfaces required. In contrast, we have the firms that see themselves as producers of a specific type of machine in which they are skilled. The machine performs a single type of function and it is up to the customer to integrate it in the overall production process. The general attitude is: "this is what we do; we may make some modifications here and there to accommodate your requirement, but basically that is what the machine does and it can go no further than that". The former kind of attitude seems to be conducive to a much more creative state of mind, and the potential to search for new ways of doing things and to open up new perspectives when dealing with technological bottlenecks is much greater. Not many firms, even in the innovative group, showed this approach and the distribution of responses between the two groups is not particularly sharp. But it is an additional argument and explanation of the importance of the technological determinants of innovative performance.

External sources of knowledge

Some interesting relationships showed up concerning differences between the impacts of external sources of knowledge on innovation activities. One interesting difference is that the impact of universities on scanning activities was greater for the "average" group than for the "innovative" group. In principle, one would expect that innovative firms would be closer to universities than the less innovative groups, and that the innovative firms would take more interest in new knowledge and its potential for new applications than the other firms. This apparent incongruity can be explained with the notions of appropriability. First, the technological knowledge used by the sector is relatively mature, whether it is mechanics, electronics or even optics, and it is not strongly science-based, and consequently much of it is in the public domain. Second, the innovative group have largely embodied that knowledge within their own structure, encapsulated by the graduates and the highly skilled technical personnel they employ. What they search for is not knowledge with a high public content but

rather knowledge with a high tacit content, one with the higher potential to improve their competitiveness. That is not to say that they do not have relationships and co-operation activities with universities, which most have. However, they seem to happen at a rather informal level. Contacts between ex-university colleagues or teachers are common. Co-operation is sought at very specific levels and in very concrete subjects. Very often it is related to solving a particular bottleneck in production processes, when the internal capabilities of the firm fail. Another common area of co-operation is at the level of technical calculus that requires either a deep understanding of a mathematical sub-area or the need to take advantage of specific equipment with powerful computation facilities, e.g., to perform simulations, the kind of equipment that the firm does not have. The average group of firms, on the other hand, because of their often considerable limitations in educational levels, or graduate intensity, and consequently in their knowledge base, often find the contribution of the university very valuable, even if the level of knowledge provided by the university is modest. What is public knowledge for the innovative firms has not, in many cases, been appropriated by the less innovative firms. The knowledge transfer may be in the form of a specific technique to handle a certain type of material, a change in designs of parts to achieve certain movements, or even a simple mathematical calculation of power requirements, all of which can be considered to be in the public domain but which are not mastered by the non-innovative firms due to their low absorptive capacity.

The notion of absorptive capacity and the degree of "public" knowledge appropriated by the firms also explains the interesting relationship between suppliers and scanning activities of the firms. For many of the "average" group firms, an important source of knowledge comes from the suppliers. The suppliers act as intermediaries between their knowledge base and the forefront of technology, bringing to them information on advances in many areas of interest to the firm such as new materials, new tools, new production machinery and even new techniques. Again, much of the information provided by the suppliers was already appropriated by the innovative firms (the supplier works often for these firms) and in many cases it can be considered to be in the public domain.

The mechanism by which knowledge is appropriated by the two groups of firms can be partly explained by the informational networks which they are part of. We noticed in the interviews that the managers of the firms in the innovative group were apparently moving in the same social circles. They knew each other and were very aware of the activities each one was pursuing. They seemed quite intimate with the strategic perspectives and the managerial approach of their peers, and even their historical background and experience. The same happened with the "average" group, but to a lesser extent. Apparently there was a social divide cutting across the two groups of firms, with the consequence that the information flowing to each of them was quite different, thus explaining the degree of public (or tacit) knowledge appropriated by each group. Von Hippel (1988) has described how these kinds of informational network build up and how knowledge is transferred between firms within the networks. The relationship between fairs and innovation seem to indicate that the two groups of firms make part of different social groups. The greater importance attached by the “average” firms to the knowledge obtained in trade fairs is probably an indicator of the lack of alternative ways of obtaining knowledge. The differences related to the variable “receiver of subsidies” may also be an indication of the social divide separating the two groups. The technical capacity to apply for subsidies

and the social contacts and tacit and informal information required for a successful application are ultimately behind the observed variation. Together with the fact that the firms possess different knowledge bases at the start due to different educational levels, such a kind of dynamic would explain the disparities showed by the two groups of firms.

FIRMS AND THEIR HISTORIES

If the set of characteristics that distinguishes one group of firms from another is not coincidence or circumstantial, then one of the main issues to be addressed is how to explain the simultaneity of the identified constituents and how are they related to one another and to the innovative performance of the firm. The considerations exposed in the previous section about the differential pattern of each group gives only a snapshot of the present situation, but they do not give an entire explanation of why firms got where they are. What are the mechanisms underlying these trajectories and what cause firms to diverge in their path? These are the questions to which answers I will now try to contribute.

To that purpose maybe it will be useful to take a glance at the history of some of the firms that were studied. Take, for instance, the pair 5 on Table 1, both producers of agricultural machinery. This pair is quite useful because their product lines are very similar and their fates seem to be inextricably linked. Both firms started from humbling beginnings at the first half of the century, as one-man firms. The founders were blacksmiths forging basic manual agricultural tools such as shovels, axes, spades, rakes, etc. Both developed into family-owned firms by the 1930s. They started manufacturing somewhat more complicated products such as ploughs and trailers adopting other techniques, e.g., foundries, casting and soldiering, and subsequent introduction of machine-tools took place. By the 1950s the "innovative" firm reached an industrial stage, with production being fairly based on machines and greater division of labour, and not so much on handicraft methods. This stage is reached in 1960 by the "average" firm. By this time the main products were simple and special purpose trailers, ploughs and a closely connected family of products, such as cultivators, drills and disk-harrows, all designed to be coupled to tractors (which were diffusing at a higher rate than before).

During that time, the sons of the founders had achieved different educational levels. Those of the innovative firm were educated at professional technical schools, while those of the average firm only went trough basic school and learned their professional skills on the job. It is interesting to conjecture why it happen like this. Both families had similar backgrounds and enjoyed considerable success in their activities. Both were located relatively near to large cities and educational facilities. If sociological or geographical considerations are not enough, then the explanation for it can only be found at the psychological level. In this context of explaining innovation differentials, the event can only be considered as a random outcome of a complex and inscrutable process of the mind. It will have considerable consequences on the trajectories of each firm due to its "expanding" or cumulative features. This event can be considered as a point of divergence that will drive the two firms in different directions, as the impact of the occurrence will effect on the future of the firms.

These repercussions will not be felt immediately. In the early 1970s both firms engage in ambitious expansion projects and they both diversify into new product lines. However, the

characteristics of the products begin to show up considerable differences. The new mechanical techniques learned in the technical schools, the theoretical context on which they were taught, as well as the ancillary disciplines related to production management and accounting practices start to express themselves in the form of more reliable products, better applications of pneumatic devices, and more cost reduction savings later invested. The educational lag deepens even further. The third generation of the innovative firm is educated at university level, while the third generation of the average firm is educated at vocational technical level, the level at which the previous generation of the innovative firm was educated. The social networks on which the firms are now immersed are very apart. The implications for cumulative learning and the expansion of the knowledge base are increasingly important.

Those implications become visibly clear when the innovative firm starts to hire engineers, in the early 1980s, and re-structures its organisation to include a department concerned only with design and development. Its products are subject to increasing refinements, namely at the level of new materials, improved finishing, broader applications and sophistication of hydraulic components and controls, and new designs in mechanical parts to improve coupling with the power source, and the ease and reliability of operation. Planning procedures multiply reaching every type of activity of the firm, from the operations level to the investment level. Continuous training becomes a routine activity and is applied at every level.

By now the products are widely superior to those manufactured by the other firm and the range of products is broader. Sales grow and are now affecting directly the sales of the other firm, which were sinking for some time.

Other important events also took place. It adopts an aggressive marketing policy, definitely abandoning its regional tradition towards a national dimension. It builds an ever growing network of representative agents, which not only sell their products but also provide technical assistance, with personnel trained by the firm. It starts to export in the mid 1980s, first to Africa then, very soon, to France, a market that proved to be more regular and consistent than Africa. They now export around 30% of their production of which 80% is destined to France, Spain and Germany. They also have engaged themselves in sub-contracting activities with French and German firms. They have agents in all those countries. Recently they built two factories in African countries and are now trying to build one in France. They have also been involved in several co-operation agreements with universities, both at the training level, and at the development level (in an application of optic devices to planners). In the early 1990s it embarks on a huge investment that covered building of new plants, acquisition of new automated production machinery including a robot, application of informatics at the level of administration, accounting, production costs control, stock management and CAD.

In the meantime the other firm acted quite differently. During the 1970s the firm also expanded and diversified into somewhat more sophisticated products, such as frontal loading cranes to adapt to tractors and other functionally differentiated machinery to be coupled to tractors (the other firm was also active in most of these product lines). However, these products demanded a design expertise that was gradually surpassing the skills embodied in the personnel of the firm. Knowledge of mathematical and geometrical principles, and techniques necessary to design articulated components and parts,

were either out of reach of the present knowledge base of the firm or were becoming more and more costly to learn (generally involving numerous trial and error experiments not guided by a solid theoretical background). However, the firm did not manage to circumvent that obstacle by hiring skilled engineers, for instance, or by resorting to external technical advisors, even though they were aware of the developments going on in the innovative firm. The lack of action may have been caused by lack of funds, or inability to see beyond their present circumstances relying excessively on their own capacities, or insufficient risk taking attitudes. Whatever the case, the firm went on a downwards spiralling course. No new acquisitions of machinery nor improvements on the existing stock were made. The machinery they now possess is twenty-five years old and virtually unchanged. No attempts were made to expand beyond their regional level of actuation. Sales relied on market arrangements with sales outlets who were increasingly reluctant to buy their products. Many were now agents for the other firm. Sales sunk by the mid-1980s, at which time the firm decided to concentrate on manufacturing and repairing lorry bodies, relying on the knowledge and the machinery they acquired when manufacturing agricultural trailers. Note that the capacity required to build lorry bodies is lower than that required to build trailers, since the later often incorporated additional devices and machinery to serve explicit functions (pumps, motors, pressure gauges, etc.). In this sense, the firm followed an unlearning path because it ceased to apply on a repetitive basis the skills and knowledge it once applied.

The above comparison is an extreme one, where on the one hand we have one firm steadily building in a cumulative its capacities and achieving considerable success, and on the other hand we have a firm that is strikingly characterised by the incapacity to move ahead from where it stands, and actually moving backwards, because it ceased to exercise all its skills.

But the story could have turned in another way, had the average firm chosen at least to act in specific areas that could mitigate the limitations of their knowledge base. It could, for instance, have improved its capital stock, enabling the production of better quality products, even if that implied divesting in their range of products. The same applies for training activities. It seems, however, that their main problem was at the level of construing a coherent course of action and their incapacity to react to changing circumstances.

The histories of the firms in pair 2 illustrates how firms face several alternatives to improve their chances of success, even if there are intrinsic limitations in the knowledge base. Both firms manufactured mechanical looms, but by the mid 1960s competition from abroad seriously challenged their chances of survival. The educational level in both firms was at the secondary technical level. The innovative firm decided to abandon the production of looms because, after several attempts to upgrade its product, it concluded that it was not in the position or willing to take further risky investments in development activities. After a long search for alternatives it identified a family of products on which it perceived enough demand opportunities that coupled with firm specific knowledge and cost advantages would render its production feasible and lucrative. The product niche on which it grounded herself was in complementary machinery for the textile industry (lifting and transport gear). It also continued to manufacture components for looms. At first, the same mechanical skills used in the construction of looms were applied to the new product lines, then it gradually added hydraulic and

other electric means of control. Over the years there was a persistent concern with the upgrading of the product and with the production machinery to fulfil quality requirements and cost constrains. It has also maintained uninterrupted efforts to keep abreast of new developments in the sector, by participating in international fairs, other important events, and in maintaining contacts with production engineers in customer firms. Most of its clients are large textile firms and it exports components to Swiss textile firms.

The firm in the average group persisted in the manufacturing of mechanical looms, although demand was shrinking daily. It didn't attempt to improve its educational level and knowledge base, nor its attempts to improve its products, based always on a mechanical paradigm, bear any results. Search activities were scarce and the firm didn't find a viable alternative. It began to rely more and more on component production and repair of old machines still in operation on local textile firms. Eventually it began to accept and look for any opportunity to manufacture components, even if not directly related to the textile sector. Occasionally it finds a local customer that still wants a machine (not looms) based on mechanical operation, well within its technical capabilities and knowledge base that has remained virtually unchanged. No resources were spent in training the work force, and no investments in new machinery or improvements in existing machinery were made. It now seeks desperately a market niche on which to survive but its efforts in scanning and search activities are weak and restricted.

The example above shows that the combination of a limited number of factors may result in significant improvements in the prospects of the firm. In spite of modest educational levels and knowledge capacities, differences in investment in production machinery, search activities and a clear visionary strategic perspective gave its fruits, and the point at which these decisions were made mark defining divergence points on the history of the firms.

The last example, provided by pair 1, depicts a situation where several factors are already in place, specifically high educational levels, upgraded production machinery and a rather well defined strategy, but where divergence between the two firms occurs at the level of R&D and risk attitudes. Both firms produce conveyors or conveyor systems for handling intermediate stages of the production process. The average firm relies on the technological knowledge of the owner/managers, who have been together since the inception of the firm, thirty years ago, and who are in charge of every aspect of the product cycle, from conception and design to production. There are no clear boundaries between departments, and none of them is exclusively concerned with development. They produce good but relatively non-demanding products. They only build conveyor systems to transport unitary solid components. The integration between mechanics, electronics and software is reached at a relatively simple level, were the path is essentially linear and the bifurcation's decisions involve simple algorithms. On the other hand, the innovative firm has an R&D department and it pours many resources in development work, and in hiring new engineers for R&D activities. The products are of better quality and reliability, and they build systems that are not only able to deal with unitary solid components but also with continuous non-solid components. It produces also complex, integrated large systems that the other firm is unable to do, due to lack of personnel and its lower capacity to integrate complementary technologies such as software and electronics. The innovative firm exports

40% of its production to France and England while the other firm serves the domestic market. It seems apparent that the firms diverged due to the way they took advantage of their knowledge base and how cumulative effects building on their technical know-how enhanced the performance of one firm against the other. In this case, the relevant factors are related to risk attitude and the greater strategic importance attributed to R&D activities.

DIVERGENCE PROCESSES

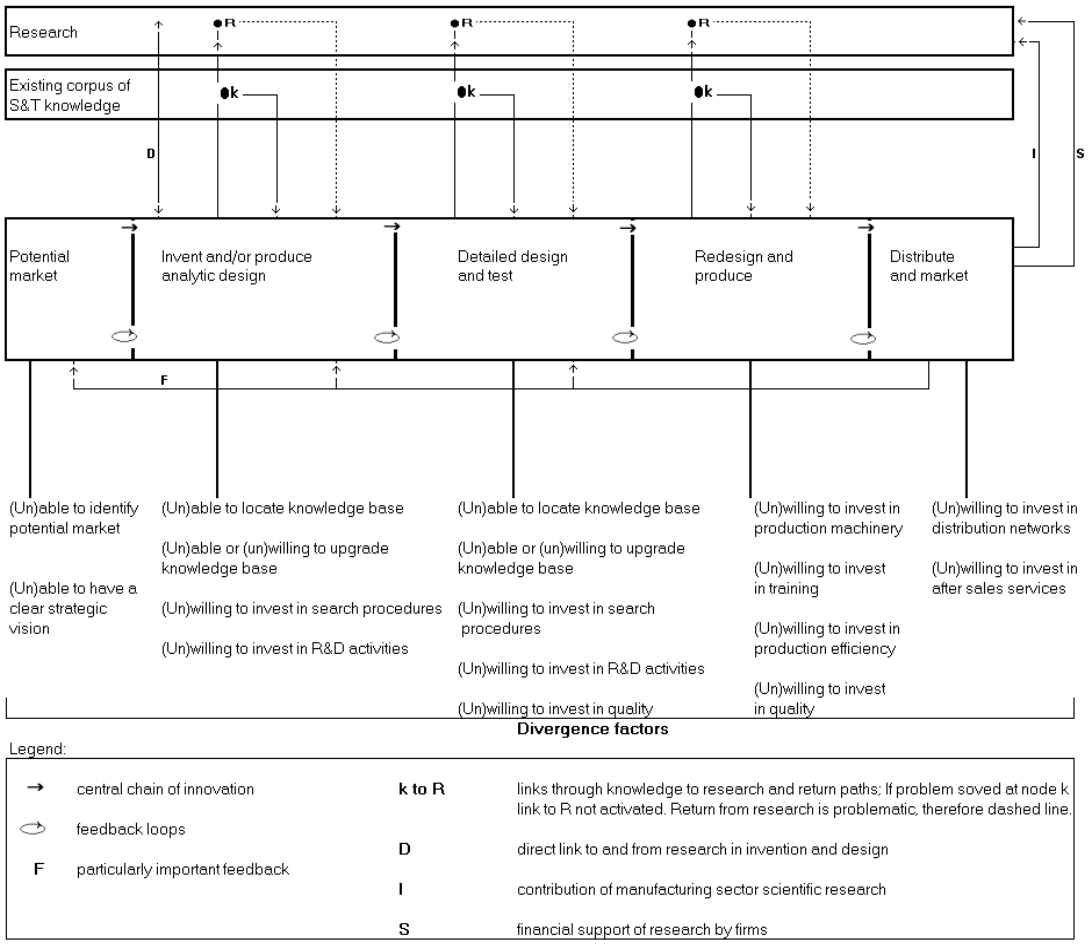
The considerations given so far suggest that as firms proceed along their path they encounter specific moments whereby a decision has to be made that will affect the future of the firm and it has to be made based on the existing strengths and limitations of the firm. The outcome of that decision process can either reinforce and improve the perceived strengths of the firm or it can set it even further apart from leading firms in comparable sectors of activity. Those moments were referred to as divergence points and some examples were given of certain decisions and the possible consequences on the global performance of the firm. By way of generalising it is useful to relate these crucial points to the process of innovation, and for that purpose we use the Kline and Rosenberg's (1986) chain-linked model of the innovation process. The model includes a series of stages that define the innovation process at the level of the firm. At each stage we propose a series of factors that may push on the firm to a divergent path of low innovative performance, or conversely, towards greater innovative performance (Figure 1).

At each stage there are factors that may be more important than others. They are not sequential, in the sense that a previous decision leading to a low performance path does not necessarily mean a subsequent decision favouring another low performance path. Since there are several possible combinations of factors, there are also several possible divergent paths and consequently several performance positions possible for a give population of firms at any time.

This process of divergence, dependent on the behavioural attitudes of the firms, their choices and actions, can be represented by resorting to a biological analogy. Consider each definition of a particular variable in Table 2 as a gene and consider that the firm acts in a Lamarckian space, i.e., it can acquire features that make it better fitted to the environment on which it is immersed. Then there are several possible combinations of that genes and each combination will define a certain type of firm, or in other words and using the biological analogy, a phenotype. In the same way that a combination of human genes determines the global characteristics of a human being, so does the combination of variables define a firm innovative performance. Each gene or factor has its own function to fulfil and the factor related to management has the special and important task of co-ordinating all the others. We may liken it to the DNA, the fundamental source of information and guidance for all the firm. The model is based on the premise that the more new genes replace the old ones, the more likely that its performance will be enhanced.

Figure 1. Innovation stages and divergence processes.

Source:



Adapted from Line and Rosenberg (1986).

The probabilities of innovative success are dependent on the managerial resources of the firm. Independently of these, the reasons why probabilities of better performance increase with new genes are based on the following assumptions: 1) the more factors are added, the higher is the probability that cumulative effects will lead to increased performance, and 2) the more factors are added the higher is the probability to increase the absorptive capacity of the firm and consequently increase the probabilities of adoption of new factors. Table 5 depicts several possible factor combinations and the deduced performance characteristics of the firm.

Table 5. Combinations of factors and deduced configurations.

	Factor combination	Deduced configuration
Firm type 1	All factors present	Excellent products Market leaders at domestic level Very active in external markets Tendency to grow
Firm type 2	No factors present or low grade factors (only internal training, short-term strategy)	Obsolete products Serving only declining firms at local level Likely to disappear in a short time
Firm type 3	automated equipment Improvements in machinery Visionary strategy Information network reasonable	Reasonable good products with no demanding technological concepts involved Likely to be component supplier in precision engineered products Serving essentially large firms but also a host of varied firms Potential to be in external markets as a component supplier but eventual decline (if no other factors added)
Firm type 4	High education level External training Low R&D intensity Automated equipment Improvements in machinery Good information network	Good products with some level of demanding technology Manufacturer of sub-systems Serving large firms Possible sub-contracted firm supplying sub-systems to leading external firms Potential to growth but at a slow rate

For instance, firm types 1 and 2 represent the two extremes. Firm type 2 is characterised by a combination of low-quality factors or the absence of many of them, determining a technologically laggard firm, operating only on local markets and on the verge of extinction. Firm type 1 represents the "ideal firm" that has acquired all the high-quality factors. Its innovative performance is high and it operates in international markets. In between, there are a number of possible factor combinations from which the global innovative characteristics of the firm, the products that it manufactures and the markets on which it operates can eventually be deduced.

SELECTION CRITERIA

When working within an evolutionary framework of analysis it is fundamental to consider the mechanisms and criteria of selection. Above we said that we simplified the matter by assuming that innovative performance was the measure of fitness and that the selection criteria were based on that. In reality, the matter is not so simple. Firms with varying degrees of achievement co-exist, which calls for the identification of other selection mechanisms. On the other hand, firms with similar levels of innovative performance, are selected according to other criteria. Selection based on innovative

performance seems to be the case in the example provided by pair 5 (although other factors were also important) where the firms were operating in the same environment. In other cases, the environment itself is not homogeneous, but multifaceted, and the selection criteria are also multifaceted. In our study of the capital-goods sector we found that firms face an environment that is composed of firms with varying degrees of innovative performance or behaviour, thus characterised by the existence of several demand curves. The multidimensional nature of the environment implies that the criteria of selection and the variables on which the firms ultimately will be selected are also multi-dimensional. That fact partly explains the variability of performance and behaviour in the population of firms. To survive, a firm does not have necessarily to adopt all factors favourable to innovative performance. It will selectively adopt those that will make it better suited to the particular sub-environment on which it lives. For instance, the average firm in pair 7 manufactures extremely simple machine-tools for the cork industry and it is able do so because it finds that its products are in demand from a multitude of small firms processing cork (making cork stoppers). The selection criterion is not based on advanced technology products. One wonders if it eventually tried or if it was able to upgrade their products, and presumably charge higher prices, it would not then be confronted with a very different and probably unfavourable demand curve from that sub-environment. On the other hand, its innovative pair operates in another section of the environment comprised by large firms. The machine-tools produced by these firms are mechanically much more sophisticated and of greater reliability and quality and incorporate electronic and optical devices. These firms do not compete for the same clients and the survival or growth of one of them does not affect the survival or growth of the other, as long as the environment remains split, and as long as each firm does not invade the domain of the other.

Both the innovative firms in pairs 8 and 9 share a similar story. One started around late 1930s producing moulds for the glass industry. The other was founded in the mid 1950s, as a machine repair shop and manufacturing small machines. The former abandoned the manufacture of moulds when the glass industry incorporated their manufacture into their factories, and it then started to produce machine tools. The production was diversified (presses, shears, press brakes, lathes, etc.) but there was a non coincidental relation with their former activity (making moulds with presses). Competition during the 1960s led them to specialise in two products. The other firm adopted a specialised strategy earlier in its lifetime and they have been consistently in the same product line since the 1960s. Both firms show a quite clear vision of their goals and their strategy. Both began to export during the late 1960s, because the internal market was not enough to provide a basis for expansion, initially to Africa and then to Europe. Now they export 80% of their production, of which approximately 30% to Europe, 30% to the United States and Canada, 15% to Asia and the rest for other countries. The diversification of markets was adopted to prevent an excessive reliance on one country alone (a problem that was felt earlier, before they began to export, and later during recession periods). They both produce, on a serial basis, a core machine body to which they then add electronic controls, CNC controls or other peripherals according to the requisites of the customers. They also produce tailor made products and offer a series of options that can be added to the basic machine, including coupling systems to robotized flexible manufacturing systems. The selection criteria for these firms have been based on the interplay between technology, performance, quality and price. The technology of the products is

average/above average, not state of the art, but their quality, efficiency and reliability are excellent in the range at which they operate, and the price is competitive compared with other producers of similar equipment in the countries to which they export. This mix of qualities has proven to be quite successful.

CONCLUSION

This paper started with a brief review of the literature concerned with the determinants of innovation at the level of the firm, outlying the evolving theoretical views that have underpinned our comprehension of the subject. Contributions to the understanding of the phenomena have came from several disciplines, notably from the economic, organisation and management literature. More recently the subject received attention from scholars in the field of industrial innovation.

We have identified in our empirical study of the Portuguese capital goods sector a number of variables that were significantly associated with the innovative performance of the firm. Some of those factors are quite similar with those identified by other studies (such as variables linked to management techniques and the impact of demand conditions) and they have been used to draw conclusions about the influences of external demand factors, as well as the influence of internal behavioural factors on the innovative performance of firms. Other variables were more specific to this study, such as the impact of external sources of knowledge or the approach to product conception.

After having identified and compared those variables, we took a closer look at the particular trajectories of some firms and pinpointed the importance of some factors on the development of that process and on the way they have influenced the evolution of the firm.

Based on that analysis it was then suggested that differences in innovative performance could be explained in terms of the particular competencies that the entities acquired along their way and how they incorporated them within the existing structure of the firm. Failure to acquire specific competencies at specific points or insufficient reinforcement of existing capacities could jeopardise subsequent performance characteristics of the firm, due to the interactions between the several factors. We suggested, based on an organic, evolutionary perspective, that the presence or absence of specific factors would be reflected in different ways on the firm as a whole. Finally we explored some of the relations between the performance of the firm and the environmental selection criteria it faces.

ANNEX

Table 6. Identified relevant variables and their definition.

Category	Variable	Definition
Tangibles	Existence of automated equipment	Values: 1=yes ; 0=no
	Predominance of old production machinery	Values: 1=yes (50% or more of manual machine); 0=no (less than 50% of manual machines)
	Improvements in production machinery	Values: 1=yes ; 0=no
Intangibles	Use of CAD	Values: 1=yes ; 0=no
	Use of CAM	Values: 1=yes ; 0=no
	Quality Control laboratory	Values: 1=yes ; 0=no
	Existence of graduate personnel	Values: 1=yes ; 0=no
	Graduate intensity	Continuous variable: graduate personnel/total employment
	Type of training	Values: 2=training plan; 1=external courses; 0=only internal training
	Separate R&D department	Values: 1=yes ; 0=no
Management	Main source of funds for investment	Values: 1=loans (more than 50% of investment) 0=own funds
	Receiver of subsidies	Values: 1=yes ; 0=no
	Type of strategy	Values: 3=long-term and medium-term formal planning; 2=medium-term formal planning; 1=visionary; 0=short-term
	Approach to product conception	Values: 1=integrated approach; 0=individual machine
External stimuli	Existence of exports	Values: 1=yes ; 0=no
	Export intensity	Continuous variable: percentage of production exported
	Importance of external competition	Values: 5=crucial; 4=very significant; 3=moderately significant; 2=slightly significant; 1=insignificant
	Type of domestic customer	Values: 2=large innovative firms 1=any domestic firm 0=regional firms
	Competition based on quality and performance	Values: 5=crucial; 4=very significant;3=moderately significant; 2=slightly significant; 1=insignificant
External sources of knowledge	Impact of fairs on future innovations	Values: 5=crucial; 4=very significant; 3=moderately significant 2=slightly significant; 1=insignificant
	Impact on scrutiny by suppliers	Values: 5=crucial; 4=very significant; 3=moderately significant; 2=slightly significant; 1=insignificant
	Impact on scrutiny by universities	Values: 5=crucial; 4=very significant; 3=moderately significant; 2=slightly significant; 1=insignificant

GRAPHICS OF THE IDENTIFIED RELEVANT VARIABLES

Tangibles category

Figure 2. Existence of automated equipment.

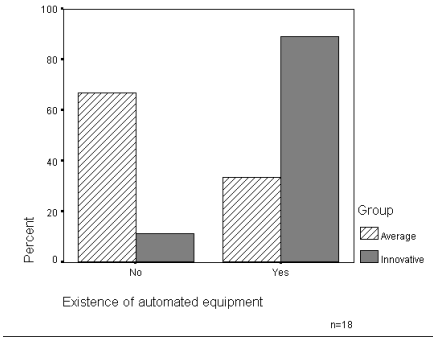


Figure 3. Predominance of old machines.

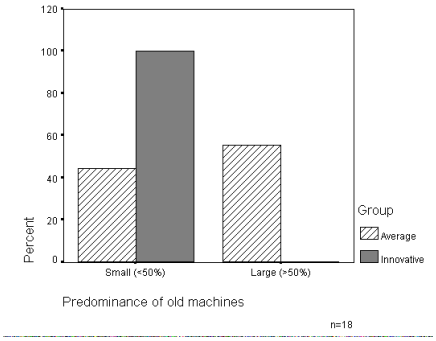
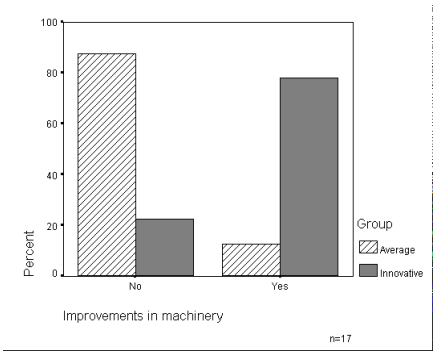


Figure 4. Improvements in production machinery.



Intangibles category

Figure 5. Use of CAD.

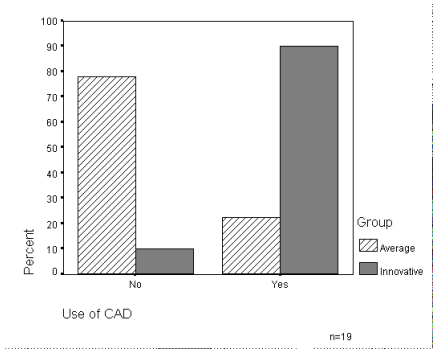


Figure 6. Use of CAM.

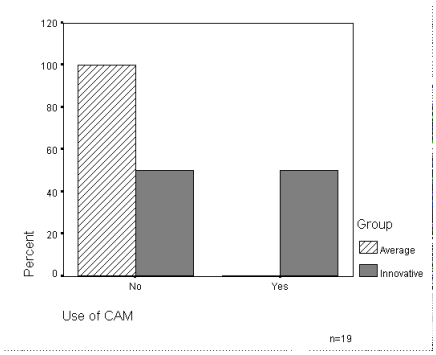


Figure 7. Internal quality control laboratory.

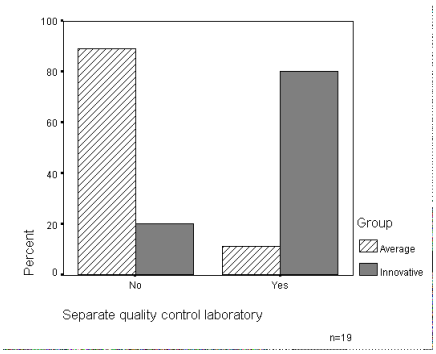


Figure 8. Existence of graduate personnel.

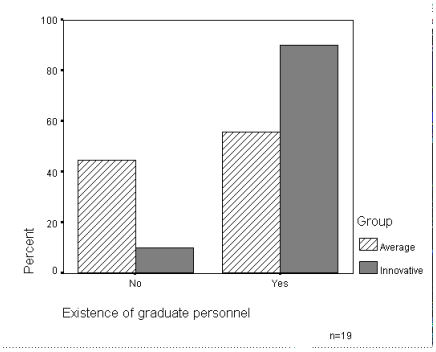


Figure 9. Type of training.

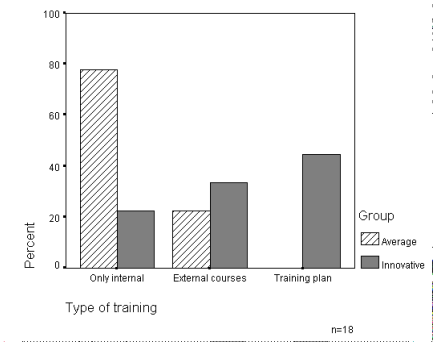
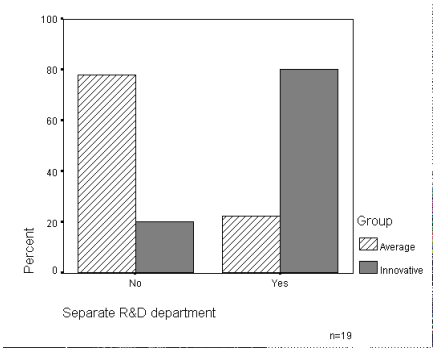


Figure 10. Separate R&D department.



Management category

Figure 11. Main source of funds for investment.

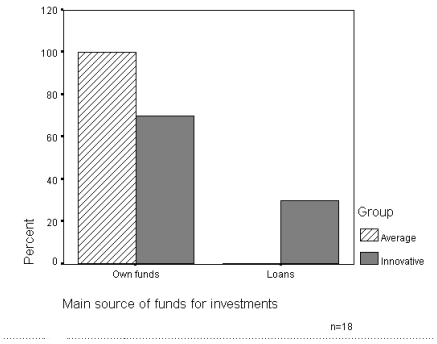


Figure 12. Receiver of subsidies.

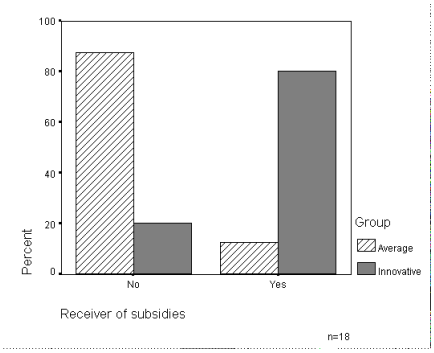


Figure 13. Type of strategy.

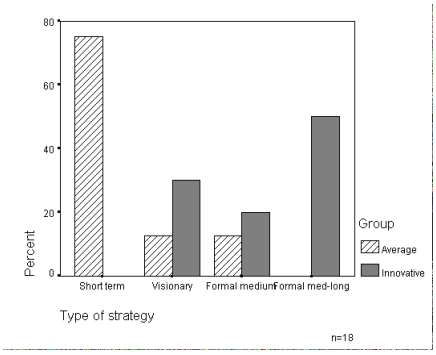
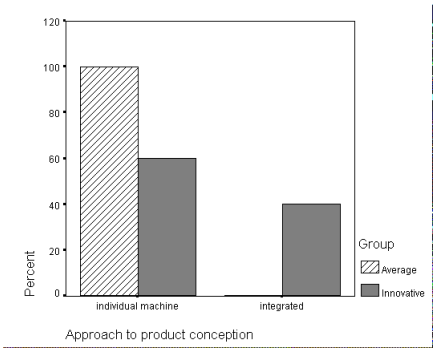


Figure 14. Approach to product conception.



External stimuli category

Figure 15. Existence of exports.

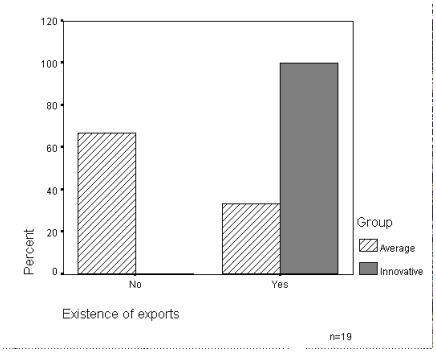


Figure 16. Importance of external competition.

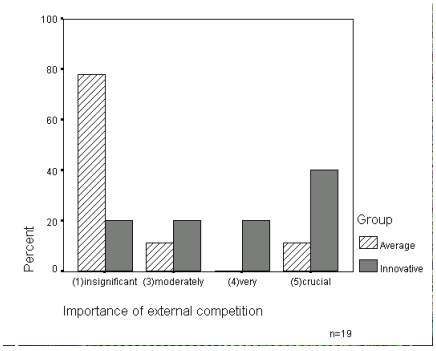


Figure 17. Type of domestic customer.

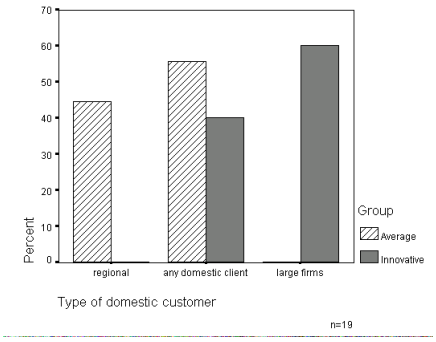
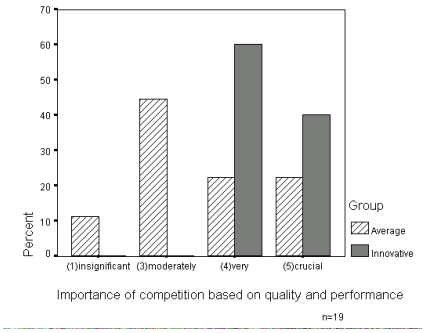


Figure 18. Competition based on quality and performance.



External sources of knowledge category

Figure 19. Impact of fairs on future innovations.

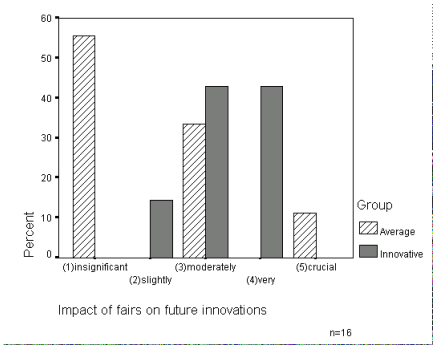


Figure 20. Impact of suppliers on scrutiny activities.

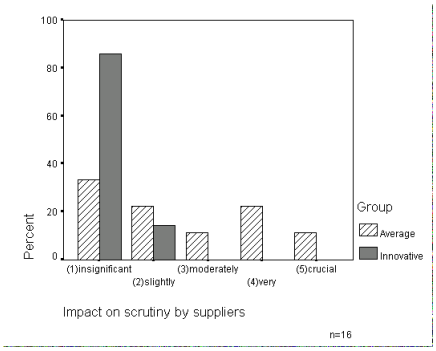
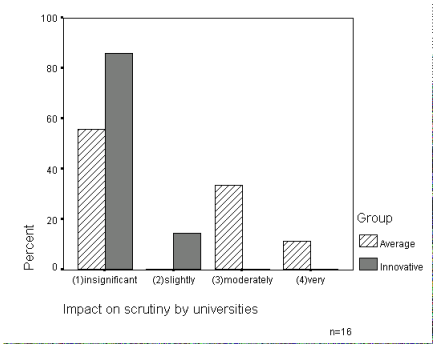


Figure 21. Impact of universities on scrutiny activities.



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